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Identifying Barriers to and Opportunities for Telehealth Implementation Amidst the COVID-19 Pandemic by Using a Human Factors Approach: A Leap Into the Future of Health Care Delivery? (e24860)
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Background: Rising criticism about the risks associated with the use of mobile health apps necessitates a critical perspective to assess the use of these apps. A cost-benefit approach involving several moderating factors can be used to detect technology effects and individual-level push and pull factors related to health attitudes, lifestyle, and health management behaviors.

Objective: We introduce a cost-benefit perspective to examine how health attitudes related to mobile health apps and health situational factors (health crises, health changes, and hospitalization) affect the likelihood of adopting lifestyle and health management behaviors among app users.

Methods: The analysis is based on individuals' reported use of mobile health apps. The sample included 1495 US adults aged over 18 years who were contacted by landline or cellphone. A total of 50.96% (762/1495) of the participants were women. A set of logistic regression models was used to predict lifestyle and health management behaviors among users considering variations in the extent of use, health attitudes, health situation, and socioeconomic characteristics.

Results: The findings indicate that the proposed models were reasonably adequate. In all, 88.76% (1327/1495) of the cases were correctly classified regarding lifestyle behaviors, but only 71.97% (1076/1495) of the cases were correctly classified regarding health management behaviors. Although a large percentage of individuals changed their attitudes following the use of mobile health apps, only a small proportion adopted health management behaviors. The use of mobile health apps affected up to 67.95% (1016/1495) of the users for consultation and 71.97% (1076/1495) of the users for decision making. The model was effective for 88.76% (1327/1495) of the cases regarding lifestyle behaviors but only 71.97% (1076/1495) regarding health management behaviors. The moderating effect of regular use of mobile health apps significantly affects lifestyle (Wald=61.795; B=2.099; P<.005) but not health management behaviors (Wald=12.532; B=0.513; P=.01). These results collectively indicate that the use of mobile health apps for health management is partially effective.

Conclusions: The use of mobile health apps is a main route to instigate the process of health empowerment and shape health attitudes. However, an accurate assessment of the effectiveness of mobile health apps necessitates distinguishing between lifestyle and health management behaviors and adopting a cost-benefit approach because individuals facing health concerns, such as a chronic disease, health emergency, health crisis, or health change, consider their affordances and situational effects. These moderators generate a push and pull framework in the decision-making process that balances the costs and benefits of use.

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KEYWORDS
mobile health apps; health empowerment; health management behaviors; costs-benefits; mobile phone
**Introduction**

**Background**

Finding new ways to support and care for various groups of people living at home has become a challenge for health care providers [1], brought about by the growth of the aging population as well as the shortage of hospital beds [1,2]. This challenge has been partly addressed by the introduction of technology-based tools and services [2] and has led many countries to apply information technology to telemedicine care services [3]. Among these tools, mobile health apps provide general support in the areas of medical education [4], preventative health care [5], health monitoring [6], and illness management [7]. More than 100,000 mobile health apps are available on smartphones [4]. Approximately 3 to 4 billion smartphone and tablet users use mobile health apps to download and update health fitness programs, contact health care professionals, and monitor health conditions, and most users access at least one health-related app [8].

Indeed, mobile health apps play a major role in self-management and care at home. Few existing studies have explored the variations in using mobile phones for health-related issues while on the go, and some studies have begun to report user feedback on specific apps [1], mostly showing that these technological advances [2] have enabled better health care services to be provided to the public [9]. Not surprisingly, mobile health apps attract the attention of institutional health care providers [8,10] for various purposes, such as improving treatment, diagnosing early symptoms, providing faster responses, accessing medical data and decision support systems, increasing digital health literacy, and accentuating support on social platforms [11].

Many studies have assessed the feasibility, functionality, clinical utility, benefits, and risks of mobile health apps [12-16]. Evidence indicates that mobile health apps are effective in providing feedback and improving goal setting and self-monitoring in eating disorders [17], alcohol use disorders [18], and attempts to stop smoking [19]. They are also used to encourage physical activity [20] and provide psychotherapy [15]. The demand for home care services has grown over the last decades [9,21] to support individuals and diverse groups [2], including the aging and chronically ill people [11], to better manage their health at home [4]. However, some of these studies have also indicated that the focus on specific groups led to a missed opportunity to address how users facing health-related emergencies put off further use of mobile health apps [21-25].

First, technology skills vary [26], as do the purposes and extent of technology use [27,28]. Second, health management behaviors involve different levels of uncertainty and vulnerability [28] or perceived threats [29,30]. Third, health attitudes do not necessarily coincide with health management behaviors [31], as issues of functionality may not necessarily lead to lifestyle and health management behaviors [32]. Finally, sociodemographic variations are important when considering both the use of mobile health apps and health management behaviors [33,34]. This is why we need to distinguish between lifestyle health management behaviors, such as increasing daily vitamin intake and engaging in a physical fitness program, and more complex health care management behaviors, such as those related to the management of serious health concerns [12,35] considering the different needs and affordances of individuals.

In this study, we address these concerns. We consider the possibility that even though mobile apps are highly accessible and exert a general beneficial effect on health attitudes and empowerment, their potential to encourage health management behaviors is limited due to the limited consideration of individual health situations and affordances. We examine how variations in the use of mobile health apps enhance or restrain the adoption of lifestyle and health management behaviors among individuals experiencing health concerns [9,11,34] and health crises.

The shift from *mechanical to informational* medicine [36] has placed a growing responsibility on individuals regarding health concerns [37] and urged them to increase their own health awareness through access to web-based health information [38] and health services [39]. Mobile health apps increase health awareness and instigate health management behaviors by causing individuals to adhere to new health routines and improve existing ones [40]. Three major theoretical directions enable an integrative approach: (1) technology-human interaction models, (2) health empowerment (HE) and health belief model (HBM), and (3) the social diversification hypothesis (SDH) [33].

**Technology-Human Interaction Models**

The technology acceptance model (TAM) [41] focuses on factors associated with the use of internet communication technology (ICT). TAM assumes that variations in the acceptance of computerized technology reflect a set of facilitating conditions, including expected effort, performance, and social influence [42,43]. TAM suggests that individuals will adopt technology when its perceived usefulness and perceived ease of use are high, and ICT use is likely to shape a new set of attitudes regarding technology’s potential to contribute to health purposes [44,45]. The perceived *functionality* of mobile health apps will increase the level of use of the mobile health apps and the need to update such apps [46]. Health adoption models test these assumptions.

**The HE and HBM Perspective**

The HE perspective introduced the notion of health efficacy and the right to express health aspirations, thus enabling individuals to develop critical awareness about their existing health conditions [47-49]. The HE model complements assumptions from communications and computer-mediated models and provides specific hypotheses about the effect of individual health-related conditions on health changes. Individuals who learn and internalize aspects of health and disease develop health-related consciousness are more likely to express health-related aspirations and expectations, and these individuals develop the confidence to adhere to a more focused approach to health concerns, making them more willing to use mobile health apps [50]. Moreover, a rational consumer choice approach will motivate individuals to seek even more information and compare multiple sources of information before making health decisions [49].
HBM applies the concepts of self-efficacy and HE. Initially, HBM suggested that beliefs and attitudes moderate the impact of technology on health management behaviors among individuals concerned with health issues [51]. Later, HBM focused on the perceived benefits or barriers stemming from taking action to prevent diseases or disorders [28]. The relative weight of benefits versus barriers affects the likelihood of taking preventive action. When barriers are perceived to be high, individuals are less likely to engage in healthy lifestyle behaviors [52]. HBM was applied to predict helmet use [53], improve driving [27], improve adherence to treatment [28], and improve communication about health concerns [44]. Both HE and HBM suggest that individuals will be more willing to play an active role in preventing, treating, and following up on health issues for themselves and others [49,54]. Hence, we hypothesize the following:

- **H1**: Greater use of mobile health apps will increase the likelihood of a change in approach when addressing a health concern.
- **H2**: Greater use of mobile health apps will increase the likelihood of making a decision to address a health concern.
- **H3**: Greater use of mobile health apps will increase the likelihood of asking a health provider new questions or seeking a second opinion from another doctor.

Nonetheless, neither the HE nor the HBM model provides the necessary assumptions to tap into factors associated with choices and behaviors when individuals face a set of health-related situations.

### The SDH Perspective

SDH addresses the possible outcomes of inequalities in the use of ICT devices on additional aspects of life, such as health [55]. ICT devices serve as a major vehicle for overcoming environmental barriers, both geographic and temporal. Nevertheless, their use is often affected by the (1) costs involved in the acquisition and use of ICT and mobile devices [56]; (2) technology skills necessary to use such devices [57]; (3) individuals’ beliefs, attitudes, goals, and plans; and (4) differences in their socioeconomic background [58]. These socioeconomic characteristics, including age, gender, ethnic background, education, and income, are proxies for the potential to (1) use and (2) apply technology devices [33,55]. Similarly, recent studies indicate that aging individuals are less likely and women are more likely to use and capitalize on technology to adopt lifestyle and health management behaviors [34]. Hence, we hypothesize the following:

- **H4**: Greater use of mobile health apps will increase the likelihood of adopting lifestyle health management behaviors after controlling for variations in socioeconomic factors and health attitudes.
- **H5**: Greater use of mobile health apps will increase the likelihood of adopting health management behaviors after controlling for variations in socioeconomic factors and health attitudes.

Mobile health apps may inspire individuals to reshape their health attitudes. Nonetheless, individuals may also critically evaluate the functionality of mobile health apps and dismiss the use of mobile health app guidelines and programs [49,54]. A perceived threat that might otherwise motivate individuals to adopt lifestyle health management behaviors [30,44] may cause individuals to restrain from the use and influence of mobile health apps [59].

### Health Behaviors: The Concept of Affordances

Overall, the HE and HBM models [60], and to some extent SDH [33], assume that rational health management behaviors emerge when individuals develop empowering attitudes regarding a health concern. However, these assumptions are based on shaky ground. First, individuals may not necessarily behave rationally, especially when many additional factors come into play. Second, individuals are more likely to capitalize on virtual health information regarding lifestyle but not on health management [59]. To clarify these points, we addressed the role of affordances [61] in health management behaviors.

The concept of affordance captures the beneficial or injurious aspect of objects and is relative in terms of how well objects fit an individual situation. The strength of affordances lies in the individual’s perceptions regarding the need to weigh one’s action possibilities [62]. The term affordances denotes the need to address everyday objects together with their features and functions. Individuals using a device are seldom preoccupied with its objective qualities because these objective features and functions do not necessarily fit users’ needs. A lack of fit shapes individuals’ perceived affordances and generates the need to assess the costs and benefits of using apps. As a result, individuals use a push and pull framework in their decision-making process before acting on the content of the ICT medium [34]. A set of personal situations may encourage or discourage individuals from developing favorable health attitudes and adopting health management behaviors. Hence, we hypothesize the following:

- **H6**: Greater use of mobile health apps will increase the likelihood of lifestyle behaviors after controlling for variations in mobile health app use and health attitudes.
- **H7**: Greater use of mobile health apps will increase the likelihood of health management behaviors after controlling for variations in mobile health app use and health attitudes.

Technology devices such as mobile health apps are reported to fall short of their intended purposes [63-65] because, in practical terms, individuals assess their situation and apply a push and pull decision-making process [66].

### The Push and Pull Perspective: A Situational Approach to Health Behavior

The push-pull perspective analyzes the migration decisions [66]. It highlights the need to identify the best destination option during migration while considering a set of factors that may threaten the outcome of the migration. Favorable conditions push individuals in a specific direction toward a specific location, whereas less favorable conditions pull them away. By applying the push-pull perspective in health, we can assume that individuals’ health management behaviors depend on the way they relate to their specific health situation, especially when it involves a perceived threat or risk [15,44]. In the process, users will consider adopting mobile health apps according to
their specific situation regarding a health concern, especially when it manifests in a medical emergency or an unexpected health change. This situational health context will ultimately shape their perceived affordances regarding the use of mobile health apps and affect their health management behaviors [62,67,68]. Individuals may then consider their affordances in terms of the potential of mobile health apps to support their needs in light of their situation. When these affordances are costly, individuals may not be willing to use mobile health apps, especially individuals diagnosed with a chronic condition [39]. Hence, we hypothesize the following:

- H8: Use of mobile health apps will increase the likelihood of lifestyle behaviors after controlling for situational effects.
- H9: Use of mobile health apps will increase the likelihood of health management behaviors after controlling for situational effects.

Objectives
This study aimed to investigate the variations in health attitudes and behaviors of individuals using mobile health apps. We conducted an analysis of smartphone users to explore the extent to which the use of mobile health apps enhances or restrains the adoption of health management behaviors among individuals experiencing different situational health concerns. We address their existing experiences of using health-related smartphone apps and their health management behaviors following the currently available or future apps. We sought to determine the extent of use and behaviors relevant to lifestyle and health management. We also considered that a set of moderating push and pull factors, including the diagnosis of medical health and the occurrence of a health emergency crisis, may lead to disinclination to use the apps.

Methods
Sample
This study draws on a secondary analysis of the data released by Princeton [69]. The sample was taken from a national tracking survey of 8323 individuals aged over 18 years and contacted by landline or cellphone. The analysis is based on individuals’ reported use of mobile health apps (N=1495). The sample comprised 50.96% (762/1495) women; 60.6% (921/1354) were married or cohabitating, 41.33% (618/1495) were parents of children living at home, 29.69% (444/1495) had less than a college degree, and 24.15% (361/1495) earned less than US $30,000. A total of 79.66% (1191/1495) of the sample reported using a single health app, and 20.06% (300/1495) of the sample reported using more than one app (Multimedia Appendix 1).

Dependent Variables
Health Behaviors
Health behaviors manifest in two different ways: (1) lifestyle behavior: do you currently keep track of your own weight, diet, or exercise routine? (1=yes) and (2) health management behavior: do you happen to track your own blood pressure, blood sugar, sleep patterns, headaches, or any other indicator? (1=yes).

Health Attitudes
The use of mobile health apps influenced the following: (1) approach: has this health indicator changed your overall approach to maintaining your health or the health of someone you help take care of? (1=yes), (2) decision making: has tracking this health indicator affected a decision about how to treat an illness or condition? (1=yes), and (3) consulting: has the use of mobile health apps led you to ask a doctor new questions or to seek a second opinion from another doctor (1=yes).

Independent Variables
The independent variables refer to the use of mobile health apps: (1) number of apps used: what kind of health apps do you currently have on your phone? Respondents replied to the question 10 times for 10 uses. We used the first 4 counts reporting 4 different types of health concerns. The range is from only one use to four uses, (2) updates (1=yes), and (3) update frequency (1=every day).

Control Variables
Socioeconomic Characteristics
An important role to the use of apps for health purposes is the role assigned to socioeconomic variations. There are 5 key variables, which have been described below.

Age
Age is a proxy for technology skills and the likelihood of chronic illness (18-85 years). Studies have shown that older individuals perform more poorly than young people in using internet browsers, finding search engines, and navigating the internet [57]. Older people often experience more difficulties using technology than younger people [33], which may affect both use and outcomes among older age groups [70,71]. Moreover, health usually deteriorates with age [72], so age may be an important motivation for seeking health-related information and engaging in health-related discussions [73].

Gender
Consistent findings indicate that women use the internet for health purposes more than men do [33,34], reflecting their social function of family caregivers [33] and health managers [74]. Men were also found to have lower odds of using health sites and web-based consultations [75] (1=male).

Marital Status
Married or cohabitating individuals are reported to be more likely to use web-based health services [59] and consult web-based rankings or reviews [75] (1=yes).

Education
Education increases the likelihood of health literacy and the ability to understand medical information, including drug prescriptions, the etiology of diseases, and risks. Better cognitive skills, attributed to highly educated individuals, lead to a better evaluation of health information [59]. Therefore, more educated individuals may want to use technology for health-related concerns more than less educated individuals (ranging from 1=no formal education to 10=PhD).
**Income**

How much did you earn last year? Studies on inequalities in the use of web-based health information have found differences between groups based on their socioeconomic status. The likelihood of searching for web-based health information was inversely associated with income (ranging from 1=less than US $10,000 to 6=less than US $150,000).

**Situational Effects**

Individuals’ health management includes several specific conditions that may affect the use of apps for health purposes: (1) chronic disease: previous studies have shown that those who report having a chronic illness are more likely to seek medical information and participate in online health-related forums [40,67]; (2) health crisis: in the last 12 months, have you personally faced a serious medical emergency or crisis (1=yes); (3) health emergency: in the last 12 months, have you personally gone to the emergency room or have been hospitalized unexpectedly (1=yes); and (4) health change: in the last 12 months, have you personally experienced any significant change in your physical health, such as gaining or losing a lot of weight, becoming pregnant, or quitting smoking (1=yes).

**Strategy Analysis**

To examine the effect of technology use on (1) health attitudes and (2) health management behaviors, we implemented the following steps.

First, we provide a general description of the distribution of the sample across the study variables (Multimedia Appendix 1).

Second, we tap into an overall estimation of the impact of the model’s independent and control variables on the dependent variable (health attitudes following the use of mobile health apps) using the classification tables of a logistic regression procedure. We estimate the correctly classified cases, which cover both successful and failed cases. We present the results separately for the effects of mobile health app use on health attitudes (Table 1) and on lifestyle and health management behaviors (Table 2).

Table 1. Logistic regression summary models predicting the number of correctly classified cases for the model that predicts the influence of mobile health apps on health attitudes.

<table>
<thead>
<tr>
<th>Observed effects</th>
<th>Participants</th>
<th>Number of correctly predicted cases</th>
<th>Percentage of correctly predicted cases</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>False</td>
<td>True</td>
</tr>
<tr>
<td>Influenced health approach</td>
<td></td>
<td>377</td>
<td>294</td>
</tr>
<tr>
<td>False</td>
<td></td>
<td>182</td>
<td>638</td>
</tr>
<tr>
<td>Overall percentage</td>
<td></td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Influenced health decision</td>
<td></td>
<td>844</td>
<td>98</td>
</tr>
<tr>
<td>False</td>
<td></td>
<td>321</td>
<td>228</td>
</tr>
<tr>
<td>Overall fit</td>
<td></td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Influenced consulting</td>
<td></td>
<td>761</td>
<td>145</td>
</tr>
<tr>
<td>False</td>
<td></td>
<td>334</td>
<td>252</td>
</tr>
<tr>
<td>Overall fit</td>
<td></td>
<td>N/A</td>
<td>N/A</td>
</tr>
</tbody>
</table>

*N/A: not applicable.*
Third, we explored the direct impact of mobile health apps’ use on lifestyle and health management behaviors by using logistic regression. To this end, we proceeded systematically. First, we introduced the set of variations in mobile health apps’ use (number of mobile health apps and update frequency). Second, we added the impact of variations in health attitudes following mobile health apps’ use. Subsequently, we inserted socioeconomic effects and situational effects. This hierarchical systematic method enables us to assess the extent to which variables in each set of predictors increase or decrease the likelihood of predicting lifestyles (Table 3) and health management behaviors (Table 4).
### Table 3. Logistic regression coefficients predicting health attitudes following the use of mobile health apps.

<table>
<thead>
<tr>
<th>Variables affecting health attitudes</th>
<th>B</th>
<th>SE</th>
<th>Wald</th>
<th>Significance (P value)</th>
<th>Explained (B)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Approach regarding a health concern</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Mobile health apps’ use</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of health apps = −1</td>
<td>−0.448&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.112</td>
<td>16.046</td>
<td>&lt;.001</td>
<td>0.639</td>
</tr>
<tr>
<td>Number of health apps = +1</td>
<td>0.247</td>
<td>0.174</td>
<td>2.006</td>
<td>.16</td>
<td>1.280</td>
</tr>
<tr>
<td>Updates frequency</td>
<td>1.40&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.128</td>
<td>120.447</td>
<td>&lt;.001</td>
<td>4.054</td>
</tr>
<tr>
<td><strong>Socioeconomic factors</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sex: 1=male</td>
<td>0.000</td>
<td>0.006</td>
<td>0.004</td>
<td>.95</td>
<td>1.000</td>
</tr>
<tr>
<td>Married or cohabitation</td>
<td>0.772&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.126</td>
<td>37.351</td>
<td>&lt;.001</td>
<td>2.163</td>
</tr>
<tr>
<td>Parenthood</td>
<td>0.034</td>
<td>0.035</td>
<td>0.961</td>
<td>.33</td>
<td>1.035</td>
</tr>
<tr>
<td>Education</td>
<td>0.048</td>
<td>0.152</td>
<td>0.099</td>
<td>.75</td>
<td>1.049</td>
</tr>
<tr>
<td>Income</td>
<td>−0.155&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.037</td>
<td>17.252</td>
<td>&lt;.001</td>
<td>0.857</td>
</tr>
<tr>
<td><strong>Decision regarding a health concern</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td><strong>Mobile health apps’ use</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of health apps = −1</td>
<td>−0.801&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.138</td>
<td>33.804</td>
<td>&lt;.001</td>
<td>0.449</td>
</tr>
<tr>
<td>Number of health apps = +1</td>
<td>0.794&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.170</td>
<td>21.787</td>
<td>&lt;.001</td>
<td>2.212</td>
</tr>
<tr>
<td>Updates frequency</td>
<td>−0.164</td>
<td>0.127</td>
<td>1.664</td>
<td>.197</td>
<td>0.849</td>
</tr>
<tr>
<td><strong>Socioeconomic factors</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sex: 1=male</td>
<td>0.009</td>
<td>0.006</td>
<td>2.420</td>
<td>.12</td>
<td>1.010</td>
</tr>
<tr>
<td>Married or cohabitation</td>
<td>0.417&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.128</td>
<td>10.562</td>
<td>.001</td>
<td>1.518</td>
</tr>
<tr>
<td>Parenthood</td>
<td>0.054</td>
<td>0.036</td>
<td>2.253</td>
<td>.13</td>
<td>1.055</td>
</tr>
<tr>
<td>Education</td>
<td>0.232</td>
<td>0.157</td>
<td>2.184</td>
<td>.14</td>
<td>1.261</td>
</tr>
<tr>
<td>Income</td>
<td>−0.120&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.039</td>
<td>9.749</td>
<td>.002</td>
<td>0.887</td>
</tr>
<tr>
<td><strong>Consulting regarding a health concern</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Mobile health apps’ use</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of health apps = −1</td>
<td>0.197</td>
<td>0.112</td>
<td>3.071</td>
<td>.08</td>
<td>1.217</td>
</tr>
<tr>
<td>Number of health apps = +1</td>
<td>1.749&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.174</td>
<td>100.893</td>
<td>&lt;.001</td>
<td>5.748</td>
</tr>
<tr>
<td>Updates frequency</td>
<td>−0.348&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.125</td>
<td>7.762</td>
<td>.005</td>
<td>0.706</td>
</tr>
<tr>
<td><strong>Socioeconomic factors</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sex: 1=male</td>
<td>−0.008</td>
<td>0.006</td>
<td>1.580</td>
<td>.21</td>
<td>0.992</td>
</tr>
<tr>
<td>Married or cohabitation</td>
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<tr>
<td>Parenthood</td>
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<td>0.035</td>
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<td>.11</td>
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<tr>
<td>Education</td>
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<td>0.156</td>
<td>0.094</td>
<td>.76</td>
<td>0.953</td>
</tr>
<tr>
<td>Income</td>
<td>−0.142&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.038</td>
<td>14.036</td>
<td>&lt;.001</td>
<td>0.867</td>
</tr>
</tbody>
</table>

<sup>a</sup>P<.001.
Table 4. Logistic regression coefficients predicting lifestyle and health management behaviors following the use of mobile health apps.

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Lifestyle behavior</th>
<th>Health management behavior</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>B</td>
<td>Wald (P values)</td>
</tr>
<tr>
<td>Mobile health app use</td>
<td></td>
<td></td>
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<tr>
<td>Number of mobile apps = -1</td>
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<tr>
<td>Number of mobile apps = +1</td>
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<td>0.330</td>
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<tr>
<td>Frequency of updates</td>
<td>2.099a</td>
<td>0.267</td>
</tr>
<tr>
<td>Health attitudes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Approach</td>
<td>1.493a</td>
<td>0.263</td>
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<tr>
<td>Decision</td>
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<tr>
<td>Consulting</td>
<td>2.713a</td>
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<tr>
<td>Socioeconomic effects</td>
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<td></td>
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<tr>
<td>Age</td>
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<td>0.011</td>
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<td>Sex: 1=Male</td>
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<tr>
<td>Married: 1=Yes</td>
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<td>Parent: 1=Yes</td>
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<td>Education</td>
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<tr>
<td>Income</td>
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<tr>
<td>Situational effects</td>
<td></td>
<td></td>
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<tr>
<td>Chronic disease</td>
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<td>Emergency</td>
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<td>Health crisis</td>
<td>-0.751a</td>
<td>0.343</td>
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<tr>
<td>Health change</td>
<td>-0.699a</td>
<td>0.254</td>
</tr>
</tbody>
</table>

aP<.001.

Results

Testing the Overall Fit of a Push and Pull Model in Predicting Health Attitudes and Health Behaviors

First, we tested how well the proposed model enabled us to correctly classify the examined cases. The findings indicate that the proposed models are reasonably adequate and make it possible to classify the examined cases correctly for health attitudes (up to 1076/1495, 71.97%) following the use of apps. The overall percentage of correctly predicted cases indicates that the use of mobile health apps affects up to 67.95% (1016/1495) individuals for consultation and 71.97% (1076/1495) for decision making. The model was effective for 88.76% (1327/1495) of the cases regarding lifestyle behaviors but only for 71.97% (1076/1495) of the cases regarding health management behaviors.

A closer look at the positive outcomes shows that a higher level of involvement in the reaction, which ranged from a mere attitude to a practical behavior, decreased the effectiveness of mobile health apps. Although a large percentage of individuals (1163/1495, 77.79%) changed their attitudes following the use of mobile health apps, only a small proportion (738/1495, 49.36%) used them for health management behaviors and even less (642/1495, 42.94%) sought out a second opinion. Therefore, the results indicate that using mobile health apps is generally less effective in generating higher HE than expected, especially after considering situational effects.

Mobile Health Apps and Health Attitudes

Extent of Use

The findings in Table 3 suggest that an increase in mobile health apps’ use does not have a uniform effect on health-related attitudes. In addition, the number of apps used is likely to have both positive and negative effects. For example, although the use of a limited number of mobile health apps can decrease the likelihood of changing the user’s approach (Wald=16.046; B=-0.448), only the use of more than one app increases the likelihood of taking steps to seek further consultation.
Updates

Similarly, an increase in the frequency of updates can increase the likelihood of changing a user's approach (Wald=120.447; B=1.4), but it can also decrease the likelihood of seeking further consultations from a health provider (Wald=7.762; B=−0.348). Individuals with specific health concerns are more likely to crosscheck information or look for multiple health concerns. These results clearly point to the possibility of distress following the excessive use of mobile health apps in terms of information overload, similar to the technology fatigue syndrome already apparent in the use of email-based communication and the differential effects of digital communication on individuals' well-being [76]. To explore the source of these differences and in line with SDH [33], we next examined socioeconomic effects.

Socioeconomic Effects

The most impressive findings among the socioeconomic effects are the negative effects of income level and marital status. The higher the income, the less likely it is that users will be affected by mobile health apps in terms of approach (Wald=17.252; B=−0.155), decision making (Wald=9.749; B=−0.120), or consulting (Wald=14.036; B=−0.142). The significant effect of higher income as a pull factor on the effect of mobile health apps indicates that income may increase the likelihood of using less technology for both leisure and health concerns. Being in a spousal relationship increases the likelihood of a changed approach (Wald=37.351; B=0.772) to decision making (Wald=10.562; B=0.417), but it has no significant effect on consulting regarding a health concern (Wald=2.381; B=−0.195). The results indicate that individuals in spousal relationships are more likely to address the health concerns of their spouse as well as their own.

Mobile Health Apps’ Use and Situational Effects

To explore the direct impact of technology on (1) lifestyle and (2) health management behaviors, we proceed in a stepwise manner. The stepwise method enables us to explore the extent to which variables in each set of predictors increase or decrease the likelihood of predicting health lifestyle and health management behaviors. First, we introduced variations in mobile health apps’ use—the number of mobile health apps and update frequency. Second, we predicted variations in health attitudes following the use of mobile health apps. Third, we introduced socioeconomic variables, controlling for both mobile health apps’ use and health attitudes.

In the final step, we introduced situational variables to assess the extent to which the use of mobile health apps is beneficial to lifestyle and health management behaviors.

Use of Mobile Health Apps

The findings in Table 4 indicate that the use of mobile health apps (eg, the number of mobile health apps and updating frequency) has a differential effect on health management behaviors. More specifically, using a greater number of mobile health apps significantly decreases the likelihood of lifestyle health management behaviors among users (Wald=21.295; B=−0.863), but it has no significant effect on health management behaviors (Wald=3.154; B=−0.220). However, regular updates increase both lifestyle (Wald=61.795; B=2.099) and health management (Wald=12.532; B=0.513) behaviors.

Health Attitudes

Next, we examined the effects of health attitudes on health management behaviors. An empowering change of approach (Wald=32.110; B=1.493), making a decision (Wald=9.333; B=0.865), and seeking further consultation (Wald=70.820; B=2.713) regarding a health concern following the use of mobile health apps increase the likelihood of lifestyle health management behaviors. Similar effects are evident regarding health management behaviors, with the exception of change in approach. Making a decision (Wald=34.915; B=0.914) and seeking further consultation (Wald=9.796; B=0.481) regarding a health concern following the use of mobile health apps increase the likelihood of health management behaviors.

Socioeconomic Effects

The most prominent findings indicate the mixed effects of socioeconomic variables in predicting lifestyle and health management behaviors. Older adults (Wald=44.445; B=−0.070) and men (Wald=50.567; B=−1.736) were less likely to instigate lifestyle health management behaviors following the use of mobile health apps. Furthermore, educated users were more likely to pursue lifestyle health management behaviors following the use of mobile health apps (Wald=85.811; B=0.641). The combined effect of the use of mobile health apps and socioeconomic factors clearly indicates that mobile health apps have an empowering effect on both lifestyle and health management behaviors among users. Nonetheless, the extent to which these sets of factors remain effective necessitates considering situational effects that can possibly reverse this general trend.

Situational Effects

Overall, the results pointing to the influence of situational effects on lifestyle and health management behaviors are indicative of the significance of such effects on health management behaviors. Situational effects have mixed effects. They can have a negative effect on lifestyle health management behaviors and less on health management behaviors. A chronic disease (Wald=32.221; B=−1.359), a health emergency (Wald=9.367; B=−1.842), a health crisis (Wald=4.795; B=−0.751), and a health change (Wald=7.583; B=−0.699) all decrease the likelihood of adopting lifestyle health management behaviors. Moreover, the effect of situational factors on health management behaviors is not uniform. Chronic disease (Wald=50.472; B=1.007) and health crises (Wald=27.256; B=1.086) increase the likelihood of health management behaviors. In contrast, a health emergency (Wald=13.101; B=−1.012) and a health change (Wald=16.290; B=−0.679) decrease the likelihood of health management behavior.

These results provide the following conclusions. First, it is evident that situational effects create some kind of general perception of risk [15] because they inhibit the effective impact of mobile health apps on lifestyle behaviors, such as weight loss or physical activity. Second, there is apparently a difference
in the way individuals perceive the threat related to their situation. Chronic diseases, but not health crises, often manifest in the form of health management routine [77]. In this case, the use of mobile health apps helps to address the health concerns of individuals who are already aware of their health condition. However, in the case of an emergency or a sudden change in health, mobile health apps may become irrelevant and possibly risky [8].

Discussion

Principal Findings

In this study, we assessed the impact of mobile health apps on health attitudes, lifestyle management behaviors, and health management behaviors. We adopted a cost-benefit approach and applied the push-pull perspective to introduce a set of situational factors including health crises, changes in health condition, and sudden hospitalization. We considered the possibility that situational health factors affecting individual affordances may, in some cases, enhance (push) the adoption of lifestyle and health management behaviors following the use of mobile health apps, whereas in others, they may restrain (pull) this adoption. Overall, the classification model indicates that mobile health apps are only partially effective because a set of situational effects moderates the link between the use of mobile health apps and health management behaviors. In fact, although a large percentage of individuals change their health-related attitudes following the use of mobile apps, a much smaller portion adopts health management behaviors. These findings support most of the proposed hypotheses.

First, technology use clearly affects health attitudes, increasing the likelihood that mobile health apps will change attitudes and causing users to seek out advice about health concerns based on the knowledge acquired through mobile health apps, but it is also possible that the users may go a little overboard and become confused and distressed [76]. Second, although positive attitudes increase the likelihood of developing empowering health attitudes [53], these attitudes may not necessarily prompt users to actually engage in health management behaviors. Indeed, the occurrence of situational effects, such as a sudden change in health, health crises, and hospitalization generate different realities that shape individuals' affordances and define the limits of their own cost-benefit framework that accounts for the push and pull factors and encourages or discourages health management behaviors [8]. As a result, for individuals who experience health-related concerns, tailored programs are less appealing because they have specific needs or even face health risks.

These findings help in assessing similar conclusions in recent studies [6,8,69] and necessitate considering situational effects in an individual's health management behavior in both lifestyle and health management behaviors. Therefore, the prediction of health management behaviors following the use of mobile health apps aiming to increase the likelihood of adopting effective health management behaviors should be assessed within a push and pull framework.

Strengths and Limitations

The use of mobile apps for health purposes represents an important breakthrough in ICT. The availability of mobile health apps affects individuals wishing to enhance their levels of HE and improve their health routine. Individuals use these apps for various health purposes. These include lifestyle behaviors, such as quitting smoking, adhering to physical fitness programs, and accessing health services, and health management behaviors, such as adhering to sugar and blood pressure monitoring, cancer and heart disease management, and psychotherapy support. However, existing studies supporting the beneficial effects of mobile health apps have focused mostly on specific health groups and less on a wide range of individuals with or without health concerns. As a result, there is little evidence of a cross-sectional comparison of the usefulness of mobile health apps. This is especially important considering that health institutions and professionals report that they rely increasingly on the use of mobile health apps to increase health awareness and promote adherence to health management practices.

Conclusions

We conclude that the effect of mobile health apps on health management behaviors should intersect with both the objective qualities of those apps and health situational factors and not just induce empowering health attitudes [61]. Designers of mobile health apps should take into account the effect of possible barriers to effective use of apps. Acknowledging these barriers will assist to develop in-depth insights into how and why health lifestyle and health management behaviors develop following the use of mobile health apps. These insights will in turn assist individuals who depend on the effective use of these apps to address frail health conditions and attain effective home care support.

Conflicts of Interest

None declared.

Multimedia Appendix 1
Distribution of central variables (N=1491).
[PDF File (Adobe PDF File), 244 KB - humanfactors_v8i2e21251_app1.pdf ]

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72. Mano RS. Chronic disease and use of online health information and online health services. JHA 2016 May 04;5(4):55. [doi: 10.5430/jha.v5n4p55]


Abbreviations

- **HBM**: health belief model
- **HE**: health empowerment
- **ICT**: internet communication technology
- **SDH**: social diversification hypothesis
- **TAM**: technology acceptance model

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Augmenting Critical Care Patient Monitoring Using Wearable Technology: Review of Usability and Human Factors

Evismar Andrade\textsuperscript{1,2}, BSc; Leo Quinlan\textsuperscript{2,3}, PhD; Richard Harte\textsuperscript{1,2}, PhD; Dara Byrne\textsuperscript{4,5}, MD; Enda Fallon\textsuperscript{6}, MEngSc; Martina Kelly\textsuperscript{8}, PhD; Siobhan Casey\textsuperscript{7}, MSc; Frank Kirrane\textsuperscript{8}, MSc; Paul O’Connor\textsuperscript{4,5}, PhD; Denis O’Hörá\textsuperscript{9}, PhD; Michael Scully\textsuperscript{10,11}, MD; John Laffey\textsuperscript{10,11}, MD; Patrick Pladys\textsuperscript{12,13}, PhD, MD; Alain Beuché\textsuperscript{12,13}, PhD, MD; Gearoid ÓLaighin\textsuperscript{1,2}, PhD

\textsuperscript{1}Electrical & Electronic Engineering, School of Engineering, National University of Ireland, Galway, Galway, Ireland
\textsuperscript{2}Human Movement Laboratory, CÚRAM Centre for Research in Medical Devices, National University of Ireland, Galway, Galway, Ireland
\textsuperscript{3}Physiology, School of Medicine, National University of Ireland, Galway, Galway, Ireland
\textsuperscript{4}General Practice, School of Medicine, NUI Galway, Galway, Ireland
\textsuperscript{5}Irish Centre for Applied Patient Safety and Simulation (ICAPSS), University Hospital Galway, Galway, Ireland
\textsuperscript{6}Mechanical Engineering, School of Engineering, NUI Galway, Galway, Ireland
\textsuperscript{7}Intensive Care Unit, University Hospital Galway, Galway, Ireland
\textsuperscript{8}Medical Physics and Clinical Engineering, University Hospital Galway, Galway, Ireland
\textsuperscript{9}School of Psychology, NUI Galway, Galway, Ireland
\textsuperscript{10}Anaesthesia, School of Medicine, NUI Galway, Galway, Ireland
\textsuperscript{11}Department of Anaesthesia & Intensive Care Medicine, Galway, Ireland
\textsuperscript{12}Centre Hospitalier Universitaire de Rennes (CHU Rennes), Rennes, France
\textsuperscript{13}Faculté de Médecine de l’Université de Rennes, Rennes, France

Corresponding Author:
Leo Quinlan, PhD
Human Movement Laboratory
CÚRAM Centre for Research in Medical Devices
National University of Ireland, Galway
University Road
Galway
Ireland
Phone: 353 9149 ext 3710
Fax: 353 91 494544
Email: leo.quinlan@nuigalway.ie

Abstract

Background: Continuous monitoring of the vital signs of critical care patients is an essential component of critical care medicine. For this task, clinicians use a patient monitor (PM), which conveys patient vital sign data through a screen and an auditory alarm system. Some limitations with PMs have been identified in the literature, such as the need for visual contact with the PM screen, which could result in reduced focus on the patient in specific scenarios, and the amount of noise generated by the PM alarm system. With the advancement of material science and electronic technology, wearable devices have emerged as a potential solution for these problems. This review presents the findings of several studies that focused on the usability and human factors of wearable devices designed for use in critical care patient monitoring.

Objective: The aim of this study is to review the current state of the art in wearable devices intended for use by clinicians to monitor vital signs of critical care patients in hospital settings, with a focus on the usability and human factors of the devices.

Methods: A comprehensive literature search of relevant databases was conducted, and 20 studies were identified and critically reviewed by the authors.

Results: We identified 3 types of wearable devices: tactile, head-mounted, and smartwatch displays. In most cases, these devices were intended for use by anesthesiologists, but nurses and surgeons were also identified as potentially important users of wearable technology in critical care medicine. Although the studies investigating tactile displays revealed their potential to improve clinical
monitoring, usability problems related to comfort need to be overcome before they can be considered suitable for use in clinical practice. Only a few studies investigated the usability and human factors of tactile displays by conducting user testing involving critical care professionals. The studies of head-mounted displays (HMDs) revealed that these devices could be useful in critical care medicine, particularly from an ergonomics point of view. By reducing the amount of time the user spends averting their gaze from the patient to a separate screen, HMDs enable clinicians to improve their patient focus and reduce the potential of repetitive strain injury.

**Conclusions:** Researchers and designers of new wearable devices for use in critical care medicine should strive to achieve not only enhanced performance but also enhanced user experience for their users, especially in terms of comfort and ease of use. These aspects of wearable displays must be extensively tested with the intended end users in a setting that properly reflects the intended context of use before their adoption can be considered in clinical settings.

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**KEYWORDS**

patient monitor; physiologic monitor; human factors; ergonomics; usability; user experience; wearable; mobile phone; critical care

**Introduction**

**Challenges in Critical Care Patient Monitoring**

Monitoring the vital signs of patients is a crucial task when dealing with critical care patients [1,2]. For this task, critical care clinicians extensively use a patient monitor (PM), which is typically placed close to the patient in the intensive care unit (ICU) or operating room. The essential features of a PM used for critical care patient monitoring were presented by Andrade et al [3]. The PM uses sensors connected to the patient to measure a range of physiological signals (eg, heart rate [HR], blood pressure [BP], and saturation of peripheral oxygen [SpO2]). This information is processed, converted into a human-readable format (eg, digital values and traces), and presented to the clinician through the PM screen. In addition, when the PM detects any sign of abnormality in the patient’s vital signs (eg, elevated HR), it alerts the user of the potential risk to the patient through the auditory alarm system. These interaction mechanisms between the PM and the clinician are presented in Figure 1.

*Figure 1. Patient monitor interaction mechanisms with the clinician. The patient’s physiological state is conveyed to the clinician through their visual and auditory senses. Once the clinician perceives a change in the patient’s state through these sensory signals, their cognition processes make use of this information (in addition to other contextual information) to comprehend the patient’s current state and make projections of their future state. At the end of this process, clinicians can make a decision on what they should do next regarding the patient’s care. AS: actuator signal; EDS: external device signal; IS: interaction signal; PS: physiological signal; SS: sensory signal.*

These interaction processes enable the clinician to be continually informed about the patient’s state. As discussed by Andrade et al [3], the PM is used in a variety of critical care settings (eg, ICUs, high dependency units, and operating theaters). Each of these different settings puts different demands on the PM, and although this device is designed as a generic patient monitoring device, some challenges are associated with using the PM to monitor critical care patients in some specific contexts of use. For example, during an anesthesia procedure, anesthesiologists need to check the patient’s skin pallor, chest movement, and...
other signs, while also continuously being required to check the PM for the patient’s vital signs [4,5]. In this case, the clinician’s visual sense is required for several tasks simultaneously, which increases the likelihood of the clinician missing a critical event. This can be even more problematic when, because of limited space, the PM is not in the anesthesiologist’s direct line of vision [6]. This ergonomic issue not only impacts the anesthesiologist’s physical comfort but can also lead to human error [7].

Another well-documented context-of-use challenge for a PM is the noise generated by PM alarms and the associated alarm fatigue [8,9]. ICU nurses, for example, may be exposed to as many as 700 alarms (from multiple alarming medical devices) per patient per day [10,11]. In addition, depending on the ICU layout, multiple patients might be monitored in the same area, which increases the number of alarms significantly. As the ICU nurse must be notified immediately if the vital signs become abnormal, they must be close enough to the PM to be able to hear an alarm. This cacophony of alarms may disturb their workflow and distract them, especially in situations where they are already under stress or involved in other essential activities related to the patient’s care [12].

In an attempt to improve patient monitoring in critical care, several researchers have developed novel interface designs to augment the PM [3]. In other studies, researchers have attempted to minimize the problem of alarm fatigue with various techniques such as developing better signal filtering algorithms, changing the PM settings, and changing hospital protocols (eg, frequently changing electrocardiogram electrodes, which might otherwise lose contact because of poor adhesiveness) [13]. With the advancement of wearable technology in a range of application areas, researchers have sought to investigate how wearable devices may be used to enhance patient monitoring by overcoming these identified problems and thus potentially improve the experience of the clinicians and, therefore, potentially enhance their performance. Our review focuses on the use of wearable devices to address the identified problems associated with the PM in critical care medicine.

Augmenting Patient Monitoring With Tactile Displays

As illustrated in Figure 1, the PM conveys patient information to clinicians visually and aurally. Tactile displays, on the other hand, are composed of small devices (tactors) that use vibratory sequences to display the patient status to the clinician. Therefore, the goal of tactile displays is to enhance the patient monitoring task by using the clinician’s tactile sense in addition to their visual and audio senses, which are already being used by the PM (Figure 2).

Figure 2. When a tactile display augments a patient monitor, the tactile display receives the patient data from the patient monitor, and this information is conveyed to the clinician using the clinician’s tactile sense through the delivery of vibration sequences. Tactile displays can be attached to different parts of the clinician’s body, such as the wrist, forearm, and waist. AS: actuator signal; EDS: external device signal; IS: interaction signal; PS: physiological signal; SS: sensory signal.

In addition to information coding using the vibration time sequences, designers may also use the intensity of the vibration and the position of the tactors as means to display additional information. For example, the intensity of the vibration can be used to convey the extent of a change in a variable value with a low amplitude change encoded as a low-intensity vibration and a high amplitude change encoded as a high-intensity vibration. The location of the tactors can be used to represent the relative value of a variable (eg, tactors vertically positioned in the arm can be programmed to indicate an increase or decrease in the variable value by activating the tactors in sequence upwards or downwards) and to represent a specific physiological measure (eg, a tactor on the left arm representing SpO₂ and a tactor on the right arm representing HR) [14]. Therefore, designers can use a series of combinations and permutations with tactile parameters to display patient information.

The tactile display uses a processed version of the data presented by the PM screen. For example, it might display whether a
particular physiological signal is increasing, decreasing, or not changing (continuous display), or it can be used to display alarms in a modified way to that delivered aurally by the PM (alarm display). Continuous tactile alarm displays could be used to support the anesthesiologist during anesthesia procedures by informing the anesthesiologist of the patient’s state without having to avert their eyes from the patient multiple times during a procedure. When configured as an alarm display, the vibration pattern delivered by the tactor may indicate a PM alarm status (eg, low risk, high risk, or technical alarm), and the body site of the vibration could indicate which parameter is the subject of the alarm. The anesthesiologist could use this tactile display configuration to be informed only when a variable value becomes abnormal, without having to look at the PM screen to establish which variable is generating the alarm. ICU nurses could also use alarm tactile displays to reduce the number of audio alarms in the ICU. For example, instead of the PM sounding an alarm to everyone in the ICU, alarms would be silently directed to the nurse looking after that particular patient, using a tactile display.

**Augmenting Patient Monitoring With Head-Mounted Displays**

Another approach to solving the problem of anesthesiologists having to divert their visual attention from the patient to the PM screen is the use of head-mounted displays (HMDs). The patient’s vital signs can be displayed directly on the HMD, allowing the anesthesiologist to observe the vital signs regardless of where their gaze is directed. Designers have the option to display the same information presented by the PM screen or provide a subset of that information (eg, only the digital values).

The initial HMDs were bulky prototypes with a wired connection to a computer. However, in 2013, the first smart glass was launched, Google Glass (Google LLC). This device is an optical HMD in the form factor of a pair of eyeglasses. When used for vital sign monitoring, Google Glass has the potential benefit of improved comfort because of its size (13.3 cm×20.3 cm), mass (36 g), and wireless design. The display is positioned on the right side of the right eye. HMDs and smart glasses may also be used to monitor patient alarms from multiple patients in an ICU. For example, ICU nurses could wear smart glasses to display when the vital signs of one of his or her patients become abnormal. As can be seen in Figure 3, in addition to their inherent visual actuator, HMD or smart glasses can also feature tactile and auditory actuators. Audio can be transmitted to the user through bone conduction, and vibration sequences can be conveyed by placing a small tactor on the device. Therefore, designers have the option to combine these 2 additional interactive elements to enhance interaction with the clinician.

**Figure 3.** Interaction mechanism between the head-mounted display and the clinician. AS: actuator signal; EDS: external device signal; IS: interaction signal; PS: physiological signal; SS: sensory signal.

**Augmenting Patient Monitoring With Smartwatches**

Another wearable being explored by researchers for patient monitoring is the smartwatch, connected to the wireless network either directly or through the user’s smartphone or tablet. Most apps developed for smartwatches for health care monitoring focus on its use as a sensor to monitor the wearer’s vital signs or health status [15]. However, given the increasing power of smartwatches, researchers are starting to investigate the feasibility of clinicians wearing smartwatches for patient vital sign or alarm display applications in critical care settings.
As shown in Figure 4, smartwatches can use 3 senses to convey information to the clinician.

Given the described challenges of monitoring critical care patients using PMs and the opportunities for wearable devices to address these challenges, the authors found it timely to investigate the state of the art in wearable devices applied to critical care patient monitoring. This study aims to critically review the literature on wearable devices in critical care medicine in terms of design, performance, and usability and to explore how the participants in the different studies responded to the use of these wearable devices. This review critically analyzes the relevant literature, with a focus on the usability and human factors performance of the prototype devices reviewed.

Figure 4. Interaction mechanism between the smartphone/smartwatch and the clinician. AS: actuator signal; EDS: external device signal; IS: interaction signal; PS: physiological signal; SS: sensory signal.

**Methods**

**Article Selection**

A narrative synthesis approach was used in this scoping review. Although this is not a systematic review, the papers selected for review were identified using PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-analyses) [16]. The search by article title, abstract, and keywords was conducted in 4 relevant databases (Scopus, PubMed, Cochrane Library, and Engineering Village) using the keywords presented inTextbox 1.

Textbox 1. Keywords used in the database search. The keywords are grouped into 4 categories: keywords related to wearable devices, usability and human factors, hospital settings, and vital sign monitoring.

<table>
<thead>
<tr>
<th>Wearable devices (AND)</th>
<th>Usability and human factors (AND)</th>
<th>Hospital settings (AND)</th>
<th>Vital signs monitoring</th>
</tr>
</thead>
<tbody>
<tr>
<td>“wearable” OR “tactile” OR “head-mounted” OR “google glass” OR “smart glasses” OR “smartwatch” OR “smart watch”</td>
<td>“human factor”* OR “usability” OR “ergonomic”* OR “human error” OR “UX” OR “user experience” OR “situation awareness” OR “response time” OR “detection time” OR “performance” OR “accuracy” OR “efficiency” OR “effectiveness” OR “satisfaction”</td>
<td>“hospital” OR “intensive care” OR “ICU” OR “critical care” OR “operating room” OR “emergency department” OR “cardiology” OR “surgery” OR “anesthesia”</td>
<td>“vital sign” OR “heart rate” OR “spo2” OR “blood pressure” OR “respiratory rate” OR “hodynamıc” OR “alarms” OR “monitoring parameter” OR “physiologic”*</td>
</tr>
</tbody>
</table>

https://humanfactors.jmir.org/2021/2/e16491
The literature search included data up to May 2020, with no cutoff on the start date. Articles were further excluded after title, abstract, and full paper analysis by members of the multidisciplinary team (composed of engineers, health scientists, nurses, anesthesiologists, human factors specialists, and medical consultants). To ensure that all the relevant studies were identified, the team reviewed each paper’s references, looking for possible studies that were not captured with our search strategy, and 1 study was identified [3].

Inclusion and Exclusion Criteria

The focus of the review is on the human factors and usability of prototype wearable devices from research laboratories designed to augment PMs to enhance patient monitoring and to overcome PMs’ identified limitations in critical care medicine. On the basis of this focus, the inclusion criteria used in this review were as follows:

1. Studies must be published in English and appear in peer-reviewed academic sources.
2. The prototype display must be a wearable device designed for real-time physiological monitoring or feedback in critical care.
3. The study must include user testing of the prototype display and present the test findings.

Data Analysis

The data analysis involved carefully reviewing each paper to extract the following information and present it in a summarized form in the paper:

1. Display modality: for example, tactile, auditory, and visual
2. Intended user: for example, nurse, surgeon, and anesthesiologist
3. Intended use: • Single or multiple patient monitoring • Continuous vital sign monitoring or alarm condition alert
4. Study design adopted to evaluate the display: • The participant’s clinical expertise • The environment in which the device was evaluated • Simulated or real clinical procedure used • Control device adopted • Outcome measures used • Usability and clinical performance evaluated • Within-subject or between-subject design

Results

Overview

A breakdown of the article search using the PRISMA guidelines can be seen in Figure 5.

In the identification phase of the review, the search of the databases, using the chosen keywords described in Textbox 1, provided a total of 841 records. In the screening phase, duplicate records were removed, resulting in 684 remaining records. These were reviewed by title and abstract. We identified that 634 studies clearly did not meet the inclusion criteria and were therefore discarded. In the eligibility phase, the full text of the remaining 52 studies was examined in more detail, and a further 32 studies were excluded for not meeting the inclusion criteria. The 20 remaining studies were included in this review. In reporting on these studies, a standardized method of reporting on the terminology and performance variables was created, as different studies used different names for the same parameters and other names for the same technology or techniques, which could create confusion for the reader. Therefore, a mapping between the new standardized naming convention and the other names was created and is presented in Multimedia Appendix 1. The studies included were grouped into 3 categories, depending on the type of wearable device involved. A total of 10 studies investigated the use of tactile displays, 10 studies investigated the use of HMD or smart glasses, and 1 study investigated the use of smartwatches.
Figure 5. PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-analyses) guidelines flow diagram depicting how many records were identified, screened, assessed, and included in the review.

Tactile Displays
A total of 10 studies investigated the use of tactile displays as patient monitoring devices for critical care. The first investigation of tactile displays for anesthesia monitoring was conducted by Ng et al [17]. Ng et al [17] developed a tactile display prototype composed of 2 vibrating motors located on the forearm (Figure 6). These vibration motors generated 6 different alarms, provided by 6 different vibration patterns, corresponding to a +10%, +20%, +30%, −10%, −20%, and −30% change in the variable of interest. The tactile display was compared with an auditory display, which provided 6 different alarms, provided by 6 different auditory patterns, depending on the variable change level and direction.
A total of 10 engineering students with no anesthesia training were asked to test the tactile display, an auditory display, and a combination of these 2 displays. The interaction signal (IS) detection by the participants was statistically significantly better when using the tactile display or a combination of the tactile display and auditory display than when using the auditory display alone. Six participants commented on the auditory display’s poor ability to attract attention, which explains the faster IS detection for the tactile display. On the other hand, regarding usability, 9 participants reported some discomfort with the wearables, citing arm numbness, resulting from the tightness of the elastic strips; itchiness caused by the vinyl sheet connecting the vibrating motors; and a restriction of arm motion from the nonwireless tactile prototype. Two years later, Ng et al [18] evaluated a new vibrotactile display on the forearm, a vibrotactile display on the wrist, and an electro-tactile display on the forearm. The vibrotactile display on the forearm and the vibrotactile display on the wrist used direct current motors to generate vibrations at the forearm (tactors), and the electro-tactile display on the forearm used a low voltage (9 V) nerve stimulator in the forearm skin to convey information (Figure 7). The study aimed to identify which mechanism was more suitable for a tactile display (electro-tactile or vibrotactile) and the preferred location on the body for it to be located (wrist or forearm). It was found that the mechanical vibration was superior to the electrical stimulation in terms of learnability and IS identification. Participants (26 individuals with no medical training) experienced discomfort when using the electro-tactile display prototype and found it more challenging to identify patterns with this display; more than 80% of participants preferred the vibration instead of electrical stimulation. No significant differences were found between the 2 vibrotactile displays. Ng et al [17,18] introduced the concept of vibrotactile displays for patient monitoring and reported that vibrotactile displays were superior in terms of comfort to electro-tactile displays. All later studies involving tactile displays used vibration instead of electrical stimulation. However, it is important to note that, ultimately, novel devices should be tested by the intended end users (experienced anesthesiologists) rather than nonclinicians, as was the case with these studies.
The display by Ng et al [19] worked in a similar manner to the previously discussed devices, but it was designed to be worn around the waist by anesthesiologists during an anesthesia procedure. It could monitor up to 4 variables simultaneously (Figure 8), with each tactor capable of generating 4 different vibration patterns. Therefore, a total of 16 different vibration patterns could be decoded by the clinician with this display. A total of 15 participants (certified specialist anesthesiologists and anesthesia residents) were asked to wear the tactile belt prototype and identify the IS being conveyed. The authors found that the IS identification was approximately 97% in low workload conditions and 93% in high workload conditions. The percentage of failed IS detection was 2% in low workload conditions and 17% in high workload conditions. Participants were reported to be satisfied with the user interface, but some participants expressed a preference for reducing the amount of information displayed. Although the study by Ng et al [19] demonstrated that potential end users could decode the information conveyed by the waist-worn tactile display, it is not possible to determine if these results indicate an improvement in patient monitoring, as this novel display was not tested against a PM.

The tactile device presented in Figure 8 was tested again in 2012 by Dosani et al [20]. This time, the tactile display was used to monitor pediatric patients undergoing general anesthesia. A total of 17 anesthesiologists (with a minimum of 3 years of experience with patient care) were asked to wear the tactile belt during anesthesia procedures. Once the patient’s physiological state was considered stable by the anesthesiologist, he or she turned on the tactile display, which then started receiving real-time vital sign data wirelessly from the PM. Every time that the belt vibrated, the anesthesiologist echoed their understanding of the tactile message into a computer. The device was evaluated in terms of IS detection, IS identification, and user satisfaction. In total, 530 alerts were delivered during the study, with 81.0% of them being decoded by the
anesthesiologists (IS detection), and participants accurately identified 89.5% of the alerts (IS identification). In the study by Ng et al [19], as there was no control group in this study, it was not possible to determine if improved patient monitoring occurred. However, by testing this novel display with the desired end users during real patient monitoring, the authors acquired valuable usability information. Most participants indicated that they were comfortable wearing the tactile belt, whereas 6 participants reported that they would not be able to wear the tactile belt for a full workday. Clinicians reported that the mental process of decoding of messages became easier, with less mental effort, the longer the device was used, highlighting the importance of extended exposure to devices before testing. Barralon et al [21] compared 2 tactile display prototypes: a tactile belt to be used around the waist and a dorsal tactile display with an array of tactors located along the spine (Figure 9). The tactile belt and dorsal tactile display could monitor 6 physiological variables. Each tactile represented a specific variable with 4 possible alerts to represent the direction of change of the variable (increasing or decreasing), and the magnitude of change in the variable was categorized as level 1 or level 2. This resulted in 24 different alerts (6×2×2) that could be conveyed using the devices. Using 28 participants with no medical background, it was found that dorsal tactile display was easier to learn than tactile belt. It took longer to display the message with dorsal tactile display alerts (mean of 4.3 seconds) than with tactile belt alerts (mean 1.3 seconds). Participants using the tactile belt had a shorter response time than those using the dorsal tactile display. When measured from the end of the IS, however, the response time was shorter when participants used dorsal tactile display than that when they used tactile belt. This reflects the impact of the IS duration on response time. However, no statistically significant difference was found regarding IS identification of both devices. As these novel displays were not compared against a PM with clinicians, further studies to assess the usability of tactile belt and dorsal tactile display in clinical settings with the intended users would be desirable.
Figure 9. Tactile displays by Barralon et al [21]. Tactile belt worn around waist and dorsal tactile display positioned along the back. The tactile belt was designed to monitor 6 variables, each represented by a tactor with 4 possible vibration patterns. For the dorsal tactile display, each variable was represented by the tactors forming its initial letter. For each letter, the sequential locations were activated for 300 milliseconds, followed by a 700-milliseconds pause and a sequence of vibrations to indicate the level and direction of change (permission to use the image obtained through RightsLink).

<table>
<thead>
<tr>
<th>Tactile belt vibration pattern</th>
<th>Dorsal tactile display alphanumeric letters</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Increase: levels 1 and 2</strong></td>
<td>Blood pressure (B)</td>
</tr>
<tr>
<td>1</td>
<td><img src="image1" alt="Pattern 1" /></td>
</tr>
<tr>
<td>Time (s) 0, 0.5, 1, 1.5, 2</td>
<td><img src="image4" alt="Pattern 4" /></td>
</tr>
<tr>
<td><strong>Decrease: levels 1 and 2</strong></td>
<td>Oxygen saturation (O)</td>
</tr>
<tr>
<td>1</td>
<td><img src="image7" alt="Pattern 7" /></td>
</tr>
<tr>
<td>Time (s) 0, 0.5, 1, 1.5, 2</td>
<td><img src="image10" alt="Pattern 10" /></td>
</tr>
</tbody>
</table>

Dorsal tactile display vibration patterns to indicate the direction of variable change (increase or decrease) and the intensity of change (level 1 or 2). The time is represented in seconds.

<table>
<thead>
<tr>
<th>Increasing level 1</th>
<th>Increasing level 2</th>
<th>Decreasing level 1</th>
<th>Decreasing level 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 3 3 3 3 3 3 3 3</td>
<td>1.4 1.4 1.4 1.4 1.4</td>
<td>3 3 3 3 3 3 3 3 3</td>
<td>2.5 2.5 2.5 2.5 2.5</td>
</tr>
</tbody>
</table>

Ferris and Sarter [22] developed a tactile display to monitor 3 variables. As shown in Figure 10, the apparatus had 3 different display modes: alarm display, continuous display, and hybrid display. The alarm display worked in a similar manner to the tactile displays previously discussed. The continuous and hybrid displays were 2 new concepts for tactile displays, which had not been tested before. The differences between these 3 display modes are detailed in Figure 10 (image created based on the concepts presented in the paper and in Ferris’ PhD dissertation [23]).
Figure 10. Tactile display by Ferris and Sarter [22]. The vest could be configured in 3 different modes: alarm, continuous, and hybrid display (image created based on the concepts presented in the paper and Ferris’ PhD dissertation).

<table>
<thead>
<tr>
<th>Tactile display design</th>
<th>Vibration pattern for the alarm display</th>
</tr>
</thead>
<tbody>
<tr>
<td>ETCO₂</td>
<td>As an alarm display, the tactile display presented vibrations at the appropriate location when a variable exceeded the acceptable range, and the vibration pattern was used to indicate whether the low or high threshold value had been exceeded. The tactors vibrated according to the following pattern.</td>
</tr>
<tr>
<td>MAP</td>
<td><img src="image" alt="Vibration Pattern" /></td>
</tr>
<tr>
<td>TV</td>
<td>Time (s) 0, 0.5, 1</td>
</tr>
<tr>
<td>Tactors mapped to the physical location of corresponding variable for ETCO₂ (chest) TV (spine). MAP tactors were placed along the left upper arm.</td>
<td></td>
</tr>
<tr>
<td>Vibrations pattern for the continuous display and Hybrid display</td>
<td></td>
</tr>
<tr>
<td>As a <strong>continuous display</strong>, it continually informed user on current levels of 3 variables using natural mapping. During “normal” conditions for the MAP and ETCO₂, the tactors at the center would vibrate every 3 seconds using the pattern.</td>
<td></td>
</tr>
<tr>
<td><img src="image" alt="Vibration Pattern" /></td>
<td></td>
</tr>
<tr>
<td>When either of 2 variables became abnormal (increased or decreased level 1), the vibration would occur immediately above or below the center tactor. When the abnormality reached level 2, the vibration would occur on the top or bottom tactors of these axes. The intensity of the vibration would also change according to its values.</td>
<td></td>
</tr>
<tr>
<td>For TV, vibrations began at the bottom tactors for each lung and continued upward to the other tactors, representing “filling” of the 2 lungs. As the fill pattern traveled upward, vibrations increased in intensity to represent sensation of pressure. Duration of the vibration pattern varied according to the patient’s respiratory rate.</td>
<td></td>
</tr>
<tr>
<td>The <strong>hybrid display</strong> followed the same presentation rules as the continuous display, with some adjustments to incorporate characteristics of the alarm display. For example, whenever variable levels became abnormal, the characteristic vibration pattern for that variable was replaced with the vibration pattern from the alarm display.</td>
<td></td>
</tr>
</tbody>
</table>

In this study, 16 anesthesiologists were asked to (1) complete each scenario (containing at least 50 tasks each) as quickly as possible and (2) maintain the monitored variables within acceptable levels. The authors found that the **event detection time**, **event correction time**, and **multitasking performance** were statistically significantly improved when using the tactile displays compared with the PM. For instance, the mean event detection time was 56.4 seconds with the PM, 28.1 seconds with the alarm display, 26.8 seconds with the continuous display, and only 14 seconds with the hybrid display. No statistically significant differences were found for task completion time between displays. Despite the hybrid display’s better performance, participants felt that the alarm display and the PM display supported multitasking performance better. The authors suggest that this may be because of the display’s novelty and that participants would be inclined to choose interfaces they were familiar with over new ones. In addition, the participants considered the continuous and hybrid display uncomfortable, which can invariably generate concerns. These factors are all part of the balance of forces acting on the clinicians when deciding if they should augment the PM with a wearable display for critical care monitoring or continue using a PM only. This concept is presented in a diagram (Figure 11) adapted from “The Science of How Customers Buy Anything” by Maurya [24].
Figure 11. Balance of forces acting on the decision making of the clinicians when deciding if they should augment the patient monitor (PM) with a wearable display for critical care or continue only using the PM. Diagram adapted from the concept presented in “The Science of How Customers Buy Anything,” by Maurya [24].

This feedback reinforces the importance of incorporating more extended familiarization with the wearable display before testing (especially when the wearable display has a large number of new concepts to be learned) and making the wearable as comfortable as possible.

McLanders et al [25] investigated the use of tactile displays to continuously convey information from a pulse oximeter. In the study by McLanders et al [25], HR was continuously displayed as very high, high, normal, low, or very low, and the SpO2 was displayed as normal, low, or very low. As in the study by Ferris and Sarter [22], this reflected an attempt to communicate absolute values for the variables instead of communicating alarms only. As hospitals in the United Kingdom and Australia have adopted a bare below the elbows infection control policy since 2011, the authors determined that it was inappropriate to wear the tactile on the forearm and placed it on the upper arm instead. As shown in Figure 12, the tactile display could be used in 2 modes: separated and integrated. In the separated display, the HR alert was displayed first, followed by the SpO2 alert. In the integrated display, both variables were displayed using a single alert.

Figure 12. An elasticized tactile display sleeve on the upper arm with 3 tactors (A, B, and C) monitoring heart rate (HR) and saturation of peripheral oxygen (SpO2). This display could be used in 2 display modes: separate and integrated. In the separated display, the HR signal came first, followed by the SpO2 alert. In the integrated display, both alerts were displayed with a single alert (a model of the concept presented in the paper). H: heart rate; H: high; L: low; N: normal; VH: very high; VL: very low.
In a between-subjects study, 30 participants with no medical background were asked to test the prototype and to identify 5 ranges of HR and 3 levels of SpO\textsubscript{2} in random sequences generated by a computer. Results showed no significant differences regarding alert identification, with participants recognizing over 90% of the changes in HR and SpO\textsubscript{2} in both modes. There was a significant effect of display mode on the response time, with participants responding faster in the integrated mode. Regarding comfort, participants were moderately positive, with a mean score of 6.8 out of 9 on the comfort scale. The authors suggest that the use of wireless tactors may have contributed to the comfort of the devices, as they require less adhesive tape to secure the tactile display in place.

Cobus and Heuten [26] developed and tested a tactile display with the ICU nurse as the intended user. Unlike previous studies, the prototype used by Cobus and Heuten [26] was designed as an alarm system to inform the nurse of a possible risk to the patient, irrespective of which vital sign triggered the alarm, and was intended to reduce auditory alarm fatigue for nurses and patients by displaying the alarms silently. For this reason, only 3 vibration patterns were required to indicate 3 levels of urgency (eg, low, medium, and high). Similar to the study by McLanders et al [25], the display was placed in the upper arm for hygienic and safety reasons.

The prototype was tested initially by 12 participants with no medical background and then by 12 nurses to determine which alerts were better in terms of usability and comfort. The alert set shown in Figure 13 was chosen as most appropriate because of better IS identification. Although the chosen pattern was chosen as being most appropriate, it is worth noting that it may not be ideal for other tactile displays depending on the number of variables monitored, the tactile display position, and the context of use. Participants were also asked to complete a system usability scale (SUS) questionnaire to evaluate usability and a comfort rating scale (CRS) to evaluate the comfort of the prototype. The mean SUS was 95 (out of 100, which indicates very good usability), and a positive result for the CRS was also found. However, some participants reported that the device imposed arm movement limitations, revealing the importance of requiring the completion of physical tasks when testing these types of devices.

**Figure 13.** An elasticized sleeve on the upper arm holding 3 tactors (A, B, and C). Three vibration patterns indicated 3 levels of urgency, with the pattern repeating itself after a 800 milliseconds pause (a model of the concept presented in the paper by Cobus and Heuten [26]).

Burdick et al [27] investigated the effect of a multisensory alarm system that combined an auditory display with a tactile display. The multisensory display was compared with a unisensory display (auditory display only) regarding alert identification (identification of the variable, point of change, and direction of change). Interestingly, the auditory display used musical instruments to represent the variables: HR (drums), BP (piano), and blood oxygenation (guitar). Each variable had 3 levels of
decrease, a normal level, and 3 levels of increase. The different levels were represented by changes in the timbre of the respective instrument. In the multisensory display, the different levels were also represented by a tactile display, where the auditory information was translated into vibration with equal rhythm and amplitude. Testing with nonmedical participants revealed that participants were better able to identify alerts when using the multisensory display. The authors commented that multisensory display might relieve auditory alarm fatigue in critical care.

The tactile display studies discussed varied significantly in design (eg, variables monitored, location of the display, and vibration pattern). This reveals a lack of consensus on the best tactile display design for critical care medicine. Gomes et al [14] aimed to address this literature gap by conducting 2 experiments. In the first one, the authors evaluated the usability of the 3 main parameters of tactile displays: intensity of vibration, vibration pattern, and position of tactors. In total, 22 health care professionals were asked to test a tactile display, similar to the one described in Figure 13, and answer a set of usability questions about the alerts presented. On the basis of the results of the first experiment, Gomes et al [14] then designed the tactile display presented in Figure 14. Like Ferris and Sarter [22], Gomes et al [14] understood that the use of mapping can be an effective way to improve the device’s usability. However, instead of mapping the location of the tactors to the physical body location of the corresponding variable, the tactors were mapped to the display locations in a PM. For instance, SpO\textsubscript{2} and mean arterial BP values were displayed on the left side of the PM used by the participants, with SpO\textsubscript{2} located above mean arterial BP, whereas end-tidal carbon dioxide partial pressure (EtCO\textsubscript{2}) was shown on the right side.

A total of 19 participants (9 attendings, 7 residents, and 3 certified registered nurse anesthetists) tested the developed tactile display and identified the presented cues with a response accuracy of ≥90%.

A summary of the results of the studies involving tactile displays is presented in Appendix 2 [14,17-22,25-35]. It should be noted that it is sometimes difficult to compare the same metrics across different studies, as study design differences can make comparison meaningless. Most tactile displays reviewed were prototype devices developed to determine the feasibility of using the tactile sense to convey the patient’s physiological state. For this reason, most authors focused on the subject’s capability to detect, identify, and respond to an IS produced by the tactile display. Therefore, the performance metrics most evaluated in the studies involving tactile displays were IS detection; IS identification; response time; and some usability metrics such as comfort, satisfaction, and general usability. These metrics were chosen as they were used by most studies reviewed. For the purpose of uniformity, the values of usability metrics that were evaluated using scales (eg, SUS, Likert-type scales) were converted to a scale of 1 to 7, with 1 being very negative and 7 being very positive (eg, a 3 in a 1-5 scale became a 4 in this 1-7 scale).
Head-Mounted Displays

Sanderson et al [28] evaluated the advantages and disadvantages of HMD for anesthesiologists compared with traditional auditory displays. They asked 16 participants (7 consultants and 9 residents) to supervise the activities of a resident (an actor) during anesthesia under 4 display conditions: visual (PM plus variable-tone pulse oximetry [control condition]), HMD (visual plus HMD), audio (visual plus respiratory sonification and BP audio IS) and both (HMD plus audio conditions). The HMD presented the vital signs in a manner similar to that shown in Figure 15, but without the traces. Significantly more events were detected with audio and both conditions compared with the visual condition only. However, no statistically significant differences were found when comparing HMD and visual conditions. No differences were found regarding the event detection time for all displays. When asked about their preferences, most participants (83%) liked the easy availability of information on the HMD, but 56% disliked comfort aspects such as weight and size and referred to experiencing headaches.

Figure 15. A visual representation of the view of an anesthesiologist wearing the head-mounted displays presented in Liu et al [29]. awRR: airway respiratory rate; CO₂: carbon dioxide; EtCO₂: end-tidal carbon dioxide partial pressure; etN₂O: end-tidal nitrous oxide concentration; etSEV: end-tidal sevoflurane concentration; HR: heart rate; imCO₂: inspired minimum CO₂; inN₂O: inspired nitrous oxide concentration; inSEV: inspired sevoflurane concentration; MAC: minimum alveolar concentration; NBP: noninvasive blood pressure; SpO₂: oxygen saturation.

Liu et al [29] investigated if HMD during anesthesia procedures would worsen inattentional blindness, for example, the HMD may put the anesthesiologist in a state of immersion resulting in him or her missing salient, unexpected events that they would otherwise not miss. This issue has been reported in other domains such as aviation [36]. In the study by Liu et al [29], the variables were displayed in the same format as in the PM, with the waveforms presented on the left and digital numeric values on the right. However, all the variables were displayed in red instead of a color-coded format frequently used in PMs (Figure 15). Two experiments were conducted with an HMD connected to a PM. In the first experiment, 12 anesthesiologists were asked to perform surgical simulation scenarios in 3 different contexts: focal depth of the HMD near, focal depth of the HMD far, and no HMD. It was found that event detection and event detection time were not significantly affected by the use of HMD (near or far focus), suggesting that inattentional blindness may not be a major cause of concern. Importantly, it was found that participants spent more time looking toward the patient rather than the monitor when using the HMD (near or far focus). In general, participants found the non-HMD the easiest and preferred condition. Participants liked that the HMD gave them the capability to monitor the patient’s vital signs, irrespective of the direction of their gaze or their location in the operating room. Nonetheless, they disliked the weight or size of the HMD and associated computer equipment and the difficulty of focusing on the HMD, which caused eye fatigue. Participants also preferred the near-focus setting when using the HMD.

In the second experiment conducted by Liu et al [29], the goal was to examine whether or not HMDs would be useful if anesthesiologists were operationally and physically constrained (PM behind them, forcing participants to rotate their trunks to observe PM). Under these circumstances, participants using the

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HMD significantly improved event detection time in 2 of the 3 scenarios (light anesthesia and hypovolemia). However, in the excess sedation scenario, event detection time was significantly lower. Once again, participants spent more time looking at the patient rather than at the monitor when using the HMD during this experiment. Participants rated the scenarios in which they used the HMD, as being less busy, easier for monitoring patients, and faster for detecting vital sign changes than those scenarios with the PM only. Once again, participants liked not having to turn around to look at the PM but felt somewhat uncomfortable using the HMD because of the weight and size of the device and its associated equipment. The investigation conducted by Liu et al [29] revealed that, by reducing the number of required neck rotations by the anesthesiologist, HMDs had ergonomic benefits. In addition, by keeping the patient in his or her visual field for longer, the anesthesiologist is potentially less likely to miss a critical clinical event (eg, increase in skin pallor). Therefore, HMDs could not just increase comfort but also improve patient safety. In a 2010 paper, Liu et al [30] investigated if using HMD during an anesthesia procedure would result in 6 anesthesiologists spending more time looking at the patient and less time looking at the monitor when delivering anesthesia to 6 real patients, alternating between the experimental condition (PM plus HMD) and control condition (PM plus HMD equipment without the monocle that displayed the vital signs). In the experimental condition, participants spent less time looking toward the workstation and more time looking toward the patient and the surgical field. Regarding comfort and satisfaction, although participants did not have significant positive or negative views about the HMD, they raised the same issues regarding the weight and bulk of the HMD, as in the study by Liu et al [29].

Three researchers evaluated the usability of Google Glass for patient monitoring. Drake-Brockman et al [37] evaluated the acceptance of Google Glass by 40 anesthesiologists in a pediatric anesthesia context. As shown in Figure 16, the interface design was composed only of the digital values for 4 variables: SpO2, HR, BP, and ETCO2.

An important finding was that the HMD comfort issues identified by Liu et al [29] were rectified with Google Glass. Participants reported that the device was comfortable to wear (90%), easy to read (86%), and not distracting (82.5%). Moreover, 76% of participants reported that they would use it again, and 58% indicated that they would recommend the device to a colleague. Anesthetists with less experience (generally younger) were less averse to wearing the device in front of patients (78%) than more experienced ones (43%). Liebert et al [31] also used Google Glass to display patient vital signs during a medical procedure. In the display used in the study by Liebert et al [31], the entire PM screen was visible in the top-right corner of the glasses (Figure 17) instead of only a subsection, as in the study by Brockman et al [37]. In total, 14
surgical residents participated in 2 simulated scenarios: a thoracostomy tube placement and a bronchoscopy, interacting with a high-fidelity mannequin (Laerdal SimMan 3G). Participants in the experimental group (1) recognized the event (hypotension) faster, (2) made significantly fewer glances toward the PM, and (3) spent significantly less time looking at the PM. Similar results were found in the bronchoscopy scenario.

Figure 17. Representation of participant’s view when wearing the Google glasses (a model of the concept presented in the paper by Liebert et al [31]).

Most participants agreed that the device was easy to use (93%), improved their situation awareness (SA; 64%), helped to monitor vital signs (86%), and had the potential to improve patient care (85%). In addition, 86% of participants would consider using Google Glass in their future clinical practice. Iqbal et al [32] evaluated the acceptance and performance of Google Glass with urologists. The interface designed for the experiment and the variables presented in the display were not provided. They asked 37 subjects (24 medical students, 8 urology surgical trainees, and 5 consultant urologists) to perform a simulated surgery (laser prostatectomy), initially using only the PM and then using the PM in conjunction with Google Glass. Response time to the vital sign changes was significantly shorter when using the Google Glass (mean of 35.5 seconds) compared with PM only (51.5 seconds). There may have been an order effect, as all participants performed the control simulation first, followed by the experimental simulation using the same scenario. Most participants reported that Google Glass increased their awareness of vital signs and that they would use the device during surgical procedures. Participants who already wore prescription glasses and were left-handed reported discomfort wearing the device, as it needs to be placed on top of the user’s glasses and only displays data to the right eye. The authors identified battery life and comfort issues for prescription glass users as potential barriers to its adoption into clinical practice. Figure 18 shows one of the study participants wearing Google Glass during a “GreenLight” simulated prostatectomy.
Figure 18. An urologist wearing Google Glass during a GreenLight prostatectomy. The patient monitor is visible in the top of the figure. During prostatectomy surgery, monitoring of patient’s vital signs is primarily the responsibility of the anesthesiologist; however, Iqbal et al [32] argued that Google Glass enabled the urologist to focus on the surgical site without having to discuss vital signs with the anesthesiologist (permission to use the image obtained through RightsLink).

Schlosser et al [33] proposed the use of HMDs by anesthesiologists for vital sign monitoring of multiple patients simultaneously in operating rooms. Schlosser et al [33] used the Vuzix M300 (Vuzix Corporation) glasses and developed the user interface through a user-centered design process. The prototype (Figure 19) was connected to the PM network and could display a subset of the PM vital sign data for up to 6 patients and reproduce the alarm sounds for the different patients. A total of 8 anesthesiologists were asked to monitor 6 patients simultaneously for 3 hours while wearing the HMD and for 3 hours without the HMD. Schlosser et al [33] reported that the number of alarms detected by the anesthesiologists was significantly higher when using the HMD (66.7% vs 7.1%). This is a very significant result. With regard to the usability of the HMD, participants indicated satisfaction in terms of readability, interface structure, and navigation. However, they reported that the HMD interfered with the tie-on laces of the surgical mask. In addition, 4 of the 8 participants considered the HMD too heavy (55 g) and too big. Another important issue raised was that participants considered the HMD alarms distracting when they were performing activities that required focus.

Cobus and Heuten [26], in addition to the upper arm tactile display presented in the previous section, designed an innovative way to silently alert ICU nurses of PM (silenced) alarms. The prototype wearable, presented in Figure 20, uses peripheral lights of 3 different colors to indicate a technical, low-priority, or high-priority alarm. Other wearable displays to present silenced PM alarms were also investigated: a wearable audible display that transmitted the PM alarms via bone conduction speakers using the same sounds used by the PMs and a tactile display that vibrated when an alarm occurred. Figure 21 depicts the light, vibration, and sound patterns generated by the different elements of the wearable.
Figure 19. Schlosser et al’s [33] display, as presented in the head-mounted displays (HMDs) prototype. (A) alarms are displayed on the left side of the screen, and the digital values for heart rate, blood pressure, and saturation of peripheral oxygen are displayed on the right side. (B) A second screen of Schlosser’s display was designed to present more details (such as a snapshot of the electrocardiogram curve) for one specific patient. In addition to the visual alarms, auditory alarms were displayed on the HMDs via bone conduction. To interact with the device, a button on the HMDs had to be pressed to cycle through the patients. (Permission to use the image obtained through RightsLink.) ABP: arterial blood pressure; HF: heart rate; NBP: noninvasive blood pressure; OP: operating room; SpO₂: oxygen saturation.
Figure 20. Cobus and Heuten’s [26] head-mounted displays displaying a high-priority alarm. All light-emitting diodes (LEDs) were activated simultaneously for the alarms. The peripheral light followed the alarm colors commonly used by patient monitors. Red was used for high-priority alarms, yellow for low-priority alarms, and blue for technical alarms (alarm indicating a technical problem, e.g., sensor not connected).

Figure 21. Lights, vibration, and sound patterns generated by the “peripheral light, tactile, and auditory” displays, respectively by Cobus and Heuten [26].

The research team asked 12 ICU nurses to identify several alarms using the peripheral light, audible, and tactile displays individually versus the PM audible alarm. It was found that participants made significantly more errors with wearable...
audible alarms and PM audible alarms. However, participants reported that they were used to, when hearing the PM alarm sound, to look at the PM display to identify the alarm’s cause. This indicates that as the purpose of the wearable’s display is to augment the PM, it would have been desirable to have the PM as part of the test scenario. In terms of IS identification time, although participants were faster when using the peripheral lights display in comparison with all others, participants raised concerns regarding the brightness of the lights of the peripheral light display, indicating that it was exhausting for the eyes and prone to triggering headaches.

Klueber et al [34] evaluated 2 displays designed for multiple patient monitoring: an HMD and an auditory display. The Vuzix M100 (Vuzix Corporation), which is an opaque monocular HMD that includes an earpiece for audio, was used for both displays. The design of the HMD interface can be seen in Figure 22. Using the Vuzix M100 earpiece, the auditory display presented time-compressed recordings of 500 milliseconds duration, verbalizing the variable name and variable level. For example, to convey that the values for SpO2 and HR were normal, the auditory display verbalized sat normal pulse normal. The pitch and tone of the verbal cues were different depending on the severity of the patient’s state. A total of 57 undergraduate students were randomly assigned to test 1 of the 3 groups: visual HMD, auditory HMD, or combined HMD. In terms of IS identification, participants using combined HMD or visual HMD alone performed significantly better than participants using auditory HMD. When asked to do a parallel activity (a precision computer task), which required constant visual attention, participants using the combined HMD performed better than participants using the visual HMD. Nonetheless, further studies involving clinicians are necessary to assess the suitability of these displays in critical care settings.

Pascale et al [35] also evaluated the use of HMD for continuous monitoring of multiple patients augmenting PM alarm sounds (Figure 23). In the first experiment with 76 undergraduate participants, it was verified that the PM alarms+HMD group responded to the alarms statistically significantly faster than participants in the PM alarm–only group. In the second experiment, the focus was to investigate if HMDs would improve SA. The authors developed an advanced auditory display (referred to as notifications) as a replacement for the PM alarms and tested it in conjunction with an improved version of the HMD. The notification display sounded in the earpiece of the HMD (Vuzix M100) when a variable value threshold was crossed, including when a variable value moved from abnormal to normal.

Figure 22. Information on the head-mounted displays by Klueber et al [34]. In this scenario, patients P-1, P-2, P-3, and P-4 have abnormal variables. Patient P-1 has exceeded the first high threshold for saturation of peripheral oxygen (SpO2, 95%), and patient P-2 dropped below the second low threshold for SpO2. Patient P-3 has exceeded the first high threshold for heart rate (a model of the concept presented in the paper). HR: heart rate; P: patient; SpO2: oxygen saturation.
A sound was played for each patient, based on their status, in the same order as the visual display. Therefore, notifications consisted of 6 consecutive sounds. The notification could be one of three 500 milliseconds tones: (1) a low-pitched beep with no tremolo indicating normal, (2) a medium-pitched beep with slow tremolo indicating that the first threshold was crossed for at least one vital sign for that patient, and (3) a high-pitched beep with faster tremolo indicating that the second threshold was crossed for at least one vital sign. In total, 13 second- and third-year nursing students participated in the experiment and tested the 3 display modalities: (1) PM alarm, (2) PM alarm+visual HMD, and (3) PM alarm+visual and auditory HMD. It was verified that participants answered the SA questions significantly more accurately, obtained higher scores on the ongoing patient assessment, and reported lower workload when they used the display modalities (2) and (3) in comparison to modality (1). Additionally, when using display modality (3), participants answered the SA questions significantly more accurately than when using modality (2).

A summary of the results of HMD studies is presented in Multimedia Appendix 2. Most studies were performed with experienced clinicians as test subjects, which allowed researchers to test if these devices could improve clinicians’ detection of clinical events during simulations. For this reason, event detection, event detection time, and response time were the main performance metrics used in these studies. As each study used different test events during the experiments and had different study designs, it is difficult to compare results across studies. However, most studies included the PM (screen or auditory alarm system) as a control display, which provides us with an opportunity to evaluate how the HMDs compared with the PM under the same test conditions.

**Smartwatches**

Another wearable that is starting to be explored for use in critical care patient monitoring is the smartwatch. McFarlan et al [38] tested the applicability of nurses using smartwatches when monitoring multiple patients simultaneously. A smartwatch app was developed to support ICU nurses to respond to alarms quickly. The smartwatch displayed alarms and patient vital signs and interacted with the actual PM, silencing it when an app button was pressed. The screens from the smartwatch app and explanation of the interface can be seen in Figure 24.
In total, 16 nurses undertook highly realistic multitasking within a simulated clinical unit using patient mannequins. The outcome measure used in this study was response time. The nurses received information and instructions about the patients and were asked to use their clinical judgment in deciding how and when to respond to alarms and call button events. Testing involved 20 simulated patients and 4 nurses; each nurse was assigned randomly to 5 patients. The experiment was divided into 2 parts (randomized across nurses): 90 minutes in the control conditions (using the PM only) and experimental conditions (with the smartwatch and PM).

It was observed that nurses responded to the alarms significantly faster with the PM+smartwatch display, with a median difference of $-6.14$ minutes (cumulative response time for all alarms in the experiment for each nurse) in the response time to important alarms or alerts. It was reported that the smartwatch display did not interfere with nurses’ workflow. The smartwatch display gave the nurses the possibility of silencing the alarm without being near the PM and was rated positively in terms of usability; all nurses said they would use the system in real conditions.

**Discussion**

**Tactile Displays**

**Overview of the Studies**

Tactile displays were one of the first wearable devices investigated as a means to augment PMs in critical care medicine. This review found that tactile displays can potentially diminish the noise generated by PM alarms and enable the clinician to be alerted when the patient’s vital signs cross alarm thresholds, without having to avert their gaze from the patient toward the PM.

**Tactile Device Location and Number of Monitored Variables**

Regarding the ideal location of a tactile device on the clinician’s body, different authors had different design approaches. For example, for a small number of monitored vital signs, the forearm and wrist were initially found to be suitable locations [18], with more recent studies proposing the upper arm as a better location for hygienic purposes [25,26]. In the case of a higher number of monitored vital signs, the waist was identified as a suitable location because of the greater number of tactors, which must be accommodated [19-21]. Only 2 studies have tried mapping as a strategy to provide clinical information in a more user-friendly manner, reflecting best practices in usability engineering [39]. Ferris and Sarter [22] mapped the tactors’ location to the physical location of the corresponding variable, and Gomes et al [14] mapped the location of the tactors according to the position of the respective variables on the PM display.

Subjects wearing tactile displays with a higher number of monitored variables (consequently, a higher number of different IS) are likely to achieve lower IS detection and identification compared with subjects wearing tactile displays to monitor fewer variables. **Response time** also seems to be profoundly affected by the number of variables monitored, with participants monitoring more than 3 variables taking generally longer to respond to the IS than participants monitoring a maximum of 2 variables. Therefore, using tactile displays to monitor a large number of variables might not be desirable.

**Usability and Ergonomics Aspects**

Regardless of the tactile device’s positioning on the clinician’s body or the number of monitored variables, **comfort** was a recurring theme, with several participants reporting discomfort or lack of mobility when wearing the displays [17,22,26]. It should be noted that the evaluated devices were prototypes fabricated in a research setting, and thus, the devices may not have been optimized from a design or fabrication perspective. A commercial product that incorporated these concepts would benefit from miniaturization using state-of-the-art manufacturing techniques and a full industrial design intervention and would thus be expected to overcome some of these usability issues. For instance, by using new technological components (wireless tactors), McLanders et al [25] reported fewer discomfort issues.
than previous studies. In conclusion, researchers must keep in mind that comfort has a significant impact on the perception of end users of a wearable device. The user may be reluctant to adopt a novel wearable technology that would enhance their performance if they do not feel comfortable wearing it.

**Performance Metrics**

As the purpose of these devices is to augment critical care patient monitoring by increasing a clinician’s ability to perceive a change in a variable, it is expected that IS detection will be higher when using the tactile display (to augment the PM). However, the number of IS detections does not necessarily correspond to the number of IS identifications, as it is possible to detect an IS but to then identify it incorrectly. Consequently, it is equally important or potentially even more critical to measure IS identification, which corresponds to the percentage of IS detected and correctly identified. Most studies have achieved more than 90% accuracy for both metrics (see Multimedia Appendix 2 for more details). Therefore, the studies reviewed successfully demonstrated that conveying clinical information through tactile displays is possible. Nonetheless, the real significance of tactile displays for critical care can only be verified by conducting user testing with clinicians in real (or close to real) contexts of use. For example, the IS detection and IS identification of their tactile display were considerably lower in the study by Dosani et al [20] than in the study by Ng et al [19], although the same tactile display was used in both studies. The context of use in the study by Dosani et al [20] was in a pediatric unit with patients, whereas in the study by Ng et al [19], the testing was conducted in a laboratory setting without patients.

*Response time* to a change in the patient state is one of the most common metrics used to assess clinicians’ performance with a new display, and this metric can be affected by several factors (eg, clinician’s experience, the tasks being performed in parallel with patient monitoring, and the monitoring device’s physical location in the room). Regarding response time, tactile displays alone have a clear disadvantage compared with visual displays, as the IS from a tactile display requires more time to be conveyed in its entirety to the clinician. For example, the duration of a tactile display IS can range from 0.5 seconds [22] to 3.5 seconds [17] (Figure 25). It is important to note, however, that tactile displays are intended to augment PMs in a critical care setting. Therefore, response time can be reduced by looking at the PM as soon as they feel the initial stimuli on their skin without waiting for the full IS to be conveyed.
HMDs and Smart Glasses

Overview of the Studies

HMDs have also been considered for augmenting PMs in critical care. Our review identified 10 studies in which potential end users were asked to wear HMDs in simulated conditions or real practice. Most experiments were not able to provide robust evidence that HMDs or smart glasses led to an improvement in the user’s performance (e.g., event detection, response time, and treatment efficiency) when used to monitor single patients during anesthesia or surgical settings [28,29,31]. However, promising results were achieved when HMDs were used to monitor multiple patients simultaneously [33,35].

Time Looking Toward the Patient

In all cases where the user’s gaze was monitored, it was verified that clinicians spent significantly less time looking toward the PM and more time looking toward the patient, while maintaining the same level of SA [29-31]. These findings indicate that HMDs can be useful from an ergonomics point of view in reducing the amount of clinician trunk and neck rotations associated with changing gaze, especially in environments where clinicians are physically constrained [29]. Beyond the possible comfort benefits of not averting their gaze from the patient, anesthesiologists could monitor changes in the patient’s skin pallor, chest movement, and other signs more quickly under these conditions. Therefore, HMDs may also enhance patient safety.

Usability and Ergonomics

Only Sanderson et al [28] and Liu et al [29] (experiment 1) asked participants about their preference in terms of PM used. These two studies presented conflicting results, with most participants in the study by Sanderson et al [28] preferring to use the HMD and most participants in the study by Liu et al [29] preferring not to use the HMD. However, it is important to note that participants in the study of Sanderson et al [28] were not monitoring a simulated patient but were supervising...
an actor who was monitoring a simulated patient, whereas in the study by Liu et al [29], participants were monitoring a simulated patient.

Regarding comfort and satisfaction, initial experiments with HMDs revealed a concern about the devices’ weight and wired nature, which affected the user experience negatively [28-30]. In general, this problem was not reported in studies involving smart glasses because of their lightweight form and their incorporation of wireless technology, except for 1 study [33]. Most participants in the experiments with smart glasses stated that they would like to use them in their work, and they would recommend their use to colleagues. This level of acceptance was mainly observed among younger participants [31,32,37]. However, some participants commented that wearing the HMD could distract them when they were doing tasks that required focus [33]. Others reported that they had to mentally focus on the data displayed by HMDs to observe and interpret it [29], which could generate eye fatigue. More research investigating the correlation between the use of these systems and eye strain or fatigue needs to be conducted to verify this finding.

**Smartwatches**

Regarding the use of smartwatches for patient monitoring, McFarlan et al [38] have demonstrated promising results, which hopefully will lead to further studies investigating the feasibility and acceptance of these devices in the ICU. However, it is vital to keep in mind that the **bare below the elbows** policy, adopted in several hospitals in some jurisdictions, might impose an impediment in adopting these devices as they are currently designed. Researchers might have to identify ways of adjusting the design of these devices to be compliant with regulatory trends.

**General Comments on Wearable Devices for Critical Care**

Most wearable devices (tactile displays, HMDs, or smartwatches) for critical care medicine (anesthesia, surgery, or the ICU) are intended to be used to augment current monitoring practices and not as a replacement. It is expected that, by adding another source of information, the likelihood of nurses and doctors missing a clinical event will be reduced, and they will be able to detect abnormalities faster. Researchers reported significant improvements in various metrics when participants used the PM plus a wearable display in comparison with participants using a PM only [17,28-33,35,38]. Some researchers explored the benefits of conveying information through multiple channels by developing multisensory displays. These prototypes integrate, for example, auditory and tactile stimuli [27] or auditory, tactile, and visual stimuli [30] to inform the ICU nurse about patient alarms, thus increasing their SA and reducing alarm fatigue. Figures 3 and 4 illustrate how wearables can use different senses as communication channels. Beyond performance, conveying information through multiple channels might also be important for safety reasons if one of the wearable communication channels fails. Nonetheless, given their potential to overwhelming the users, the suitability of multisensory wearable devices for critical care monitoring needs to be further investigated under conditions that reflect the proposed context of use.

It is important to note that enhancing the detection and identification of variable changes using wearable displays does not necessarily automatically translate into enhanced patient outcomes. Ultimately, clinical trials would be required to effectively demonstrate improved outcomes for patients.

**Limitations**

Although all the studies reviewed presented wearable devices to augment patient monitoring in critical care, the studies diverged significantly in terms of the intended uses of the devices and the study designs adopted to evaluate them. Therefore, we acknowledge that, because of this heterogeneity in the literature, the ability to synthesize findings was reduced.

**Conclusions and Recommendations**

This study aimed to review the literature on state-of-the-art wearable devices for critical care vital sign monitoring and to present the findings with a critical analysis of the usability and human factors performance of these devices. A total of 20 studies were identified: 9 on tactile displays, 9 on HMDs, 1 on a hybrid tactile and HMD display, and 1 on smartwatch displays. The studies on tactile displays have successfully demonstrated that these devices can be used to convey information on patient vital signs to critical care nurses and doctors. However, at this point, there is not enough evidence to indicate that tactile displays can positively impact the user’s performance compared with the PM only, and thus, more testing with critical care nurses and doctors is necessary. The issue of discomfort has been a significant challenge to be overcome in the design of these devices, with many participants reporting some level of discomfort when wearing tactile displays. Researchers should attempt to create more **finished** prototypes, ideally developed following an industrial design exercise, although this process can add significantly to the research cost.

The studies involving smart glasses for critical care patient monitoring have successfully demonstrated that these devices overcame the discomfort-related issues associated with their predecessor’s HMDs. When monitoring patients wearing HMDs or smart glasses, it was found that doctors spent more time looking at the patient and the surgical field than at the PM, compared with the case when they are using a PM only. This outcome can be potentially useful from an ergonomics point of view, in reducing the amount of trunk and neck rotations associated with changing gaze, especially in environments where clinicians are physically constrained. Additionally, this outcome can be useful from a patient safety point of view, in reducing the amount of time when the clinician is not directly observing the patient.

On the basis of our experience of reviewing these studies, we believe that future researchers can improve their investigations of novel wearable devices for critical care vital sign monitoring by (1) conducting experiments involving control (PM) and experimental displays, tested using the intended end users; (2) paying particular attention to comfort and technical performance aspects of their devices; and (3) using postexperiment interviews to enable the study to benefit from a qualitative analysis of issues such as comfort, user experience, and the likelihood of adopting the technology.
Acknowledgments
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Authors’ Contributions
This review was conducted by a multidisciplinary team of engineers, health scientists, nurses, anesthesiologists, human factors specialists, and medical consultants. EA, LQ, RH, and GOL were responsible for defining the methodology, extracting the data, and writing the manuscript. DB, SC, FK, MS, JL, PP, and AB reviewed the manuscript and provided feedback related to the medical aspects. EF, MK, POC, and DOH reviewed the manuscript to provide support with human factors expertise.

Conflicts of Interest
None declared.

Multimedia Appendix 1
Terminology used in the review.
[DOCX File, 16 KB - humanfactors_v8i2e16491_app1.docx ]

Multimedia Appendix 2
Summary of the experiments reviewed.
[DOCX File, 35 KB - humanfactors_v8i2e16491_app2.docx ]

References


Abbreviations

BP: blood pressure
CRS: comfort rating scale
HMD: head-mounted display
HR: heart rate
ICU: intensive care unit
IS: interaction signal
PM: patient monitor
PRISMA: Preferred Reporting Items for Systematic Reviews and Meta-analyses
SA: situation awareness
SUS: system usability scale

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Impact of Individual, Organizational, and Technological Factors on the Implementation of an Online Portal to Support a Clinical Pathway Addressing Psycho-Oncology Care: Mixed Methods Study

Lindy Masya1,2, BSocSci (C Hons), MBA; Heather L Shepherd1,3, BA (Hons), DipHE, RN, PhD; Phyllis Butow1,3, BA (Hons), DipEd, MClinPsych, MPH, PhD; Liesbeth Geerligs1, BLib Stud (Hons), MCP; Karen C Allison1, BSc Health Sciences, MPH; Colette Dolan4, RN, RSCN, Grad Dip, DipPM; Gabrielle Prest5,6, RN, PG (Onc Cert), BAppSc, MPH, GAICD; The ADAPT Program Group7; Joanne Shaw1,3, BApplSc, BPsych (Hons), PhD

1Psycho-Oncology Co-operative Research Group, School of Psychology, The University of Sydney, Sydney, Australia
2Sydney Local Health District, Camperdown, Australia
3Centre for Medical Psychology and Evidence-based Decision-Making, School of Psychology, The University of Sydney, Sydney, Australia
4The Kinghorn Cancer Centre, Sydney, Australia
5Australian College of Nursing, Sydney, Australia
6College of Nursing and Health Sciences, Flinders University, Adelaide, Australia
7see Acknowledgments

Corresponding Author:
Heather L Shepherd, BA (Hons), DipHE, RN, PhD
Psycho-Oncology Co-operative Research Group
School of Psychology
The University of Sydney
Griffith Taylor Building (A19)
Sydney, NSW 2006
Australia
Phone: 61 2 86270828
Email: heather.shepherd@sydney.edu.au

Abstract

Background: Clinical pathways (CPs) can improve patient outcomes but can be complex to implement. Technologies, such as clinical decision support (CDS) tools, can facilitate their use, but require end-user testing in clinical settings.

Objective: This study applied the Technology Acceptance Model to evaluate the individual, organizational, and technological contexts impacting application of a portal to facilitate a CP for anxiety and depression (the ADAPT Portal) in a metropolitan cancer service. The ADAPT Portal triggers patient screening on patient reported outcomes, alerts staff to high scores, recommends evidence-based management, and triggers review and rescreening at set intervals.

Methods: Quantitative and qualitative data on portal activity, data accuracy, and health service staff perspectives were collected. Quantitative data were analyzed descriptively, and thematic analysis was applied to qualitative data.

Results: Overall, 15 (100% of those invited) health service staff agreed to be interviewed. During the pilot, 73 users (36 health service staff members and 37 patients) were registered on the ADAPT Portal. Of the 37 patients registered, 16 (43%) completed screening at least once, with seven screening positive and triaged appropriately. In total, 34 support requests were lodged, resulting in 17 portal enhancements (technical issues). Health service staff considered the ADAPT Portal easy to use and useful; however, some deemed it unnecessary or burdensome (individual issues), particularly in a busy cancer service (organizational issues).

Conclusions: User testing of a CDS to facilitate screening and assessment of anxiety and depression in cancer patients highlighted some technological issues in implementing the ADAPT CDS, resulting in 17 enhancements. Our results highlight the importance of obtaining health service staff feedback when piloting specialized CDS tools and addressing contextual factors when implementing them.
decision support systems; clinical decision making; psycho-oncology; health informatics; clinical pathways; health services research

Introduction

In the last 25 years, health care has focused on improving the quality and value of care delivery through standardization of the management of specific conditions with guidelines and clinical pathways (CPs) [1,2]. CPs are structured, multidisciplinary, evidence-based management plans for a specific health condition. They outline the appropriate management with respect to clinical interventions, resources, timeframes, progress milestones, and expected outcomes, with the aim of standardizing improved co-ordination and continuity of patient care across different specialties and services [3].

The Australian clinical pathway for the screening, assessment, and management of anxiety and depression in adults with cancer (ADAPT CP) [4] highlights the need for routine psychological screening with appropriate follow-up for patients being treated for cancer. Cancer patients report a high unmet need for psychosocial care [5], and health professionals commonly underestimate or fail to detect patients’ psychosocial concerns [6]. Screening and follow-up of anxiety and depression improve patient adherence to cancer treatment, reduce health service utilization, improve quality of life, and reduce suffering, as well as decrease the risk of patients developing a major mood disorder [7-9]. The ADAPT CP provides a structured pathway for screening, assessing, and responding to anxiety and depression in cancer care to ensure optimal patient outcomes are achieved.

However, studies across numerous health conditions confirm that guidelines and CPs are not enough to guide patient care within complex health systems owing to knowledge gaps, poor communication, and insufficient implementation efforts [2,10,11]. There is growing evidence that technology can facilitate the adherence of health care organizations to CPs. Clinical decision support (CDS) tools comprise computerized alerts, reminders, and standardized data collection formats to assist health professionals with clinical decision making at the point of care [12]. Earlier CDS tools were often cost prohibitive, utilized unvalidated tools, were disruptive to clinical care processes, provided inconsistent information, or were not presented at vital points in the clinical decision-making process [13]. However, more recent CDS tools have demonstrated the benefits of improved treatment management, reduced time to treatment, standardized data collection [14], reduced clinician documentation time, lower medication errors, reduced adverse drug events [15], and greater guideline adherence [16-18]. Our group recently developed a CDS for ADAPT (the ADAPT Portal) to optimize ease of delivery of the ADAPT CP and ensure all patients receive care according to the CP.

Several theoretical models have been proposed to explain uptake and guide assessment of CDS tools, and the most widely used is the Technology Acceptance Model [19] for assessing health care technology uptake [20,21]. This model (an adaptation of Fishbein and Ajzen’s theory of reasoned action [22]) presumes a mediating role of perceived ease of use and usefulness in association with system characteristics (external variables) for explaining system uptake and usage. Perceived usefulness is defined as the degree to which a user believes that using a specific system will enhance the job performance, while perceived ease of use is defined as the degree to which a user believes that using a particular system will be effort free. External variables have been less well defined, but include aspects, such as user experience and role, and external factors in the work environment that impact usage.

This study sought to apply the Technology Acceptance Model in a pilot of the ADAPT Portal with target end users to rigorously evaluate its utility prior to a large-scale evaluation of the ADAPT CP overall. Our aim was to refine the system to best meet users’ needs prior to a large-scale implementation of the ADAPT Portal. More specifically, the study aimed to evaluate the individual, organizational, and technological contexts impacting the ADAPT Portal’s perceived usability, usefulness, and appropriateness within a clinical cancer service.

Methods

Study Setting and Design

The study was conducted in a cancer service within a large Australian metropolitan hospital. The cancer service elected to include patients receiving chemotherapy as part of their care in the study.

A triangulation mixed methods design [23] was employed. It combined qualitative and quantitative data sources to obtain different but complementary data to best understand these issues.

Recruitment Procedure

After senior management confirmed participation in the study and a research participation agreement was established with the cancer service, a subset of health service staff at the oncology service (purposively selected to ensure diversity in professional backgrounds and ADAPT CP roles) was invited to participate in the study. Staff received an email from the study team inviting them to participate and provide written informed consent. Participating staff were interviewed after the implementation period to capture their experience of planning for and using the ADAPT Portal within their service.

All patients commencing treatment during the study period at the site were invited to participate in the study. Interested patients provided written consent to participate in ADAPT screening and allow the research team to access their medical records.
Study Procedure
A lead team comprising management staff, nursing staff, social work staff, psychology staff, clinical system specialists, medical oncology specialists, and service improvement staff worked with the research team to tailor the ADAPT Portal to their local needs, resources, and preferences. The lead team mapped the CP and cancer service operations and compiled these into a workflow that operationalized how the ADAPT Portal would be used at the center. User training on the tailored ADAPT CP and Portal was provided to medical oncology, nursing, and allied health staff, with key ADAPT Portal users attending individual training sessions according to their roles and responsibilities in the ADAPT CP and associated tasks within the ADAPT Portal.

The ADAPT CP was then implemented for 5 months among several tumor streams within the medical oncology service. During implementation, users (health service staff and patients) had access to online, phone, and email support from the research team. After implementation, staff interviews were carried out, and portal usage and contacts with the research team were collated.

The study was approved by the Human Research Ethics Committee of the participating health care institution.

ADAPT Portal
The ADAPT Portal was developed by a multidisciplinary working group (comprising psycho-oncologists, oncologists, researchers, patient representatives, and information technology [IT] web designers and programmers) tasked with defining the ADAPT Portal’s scope and functionality via agile design [24]. The goal was to operationalize the ADAPT CP [4] to make it as easy as possible for cancer services to enact within current workflows. A task analysis was conducted to identify required user interactions and data elements. This allowed tasks (dialogue between users and the system) to be grouped into modules that framed the functionality of the system (registration, screening, triage, referral, progress review, and rescreening). Components of the system that could be automated to reduce workload and facilitate health professional action where required (eg, via notifications, alerts, reminders, and reports) were identified. Complex algorithms were developed to cover all contingencies to ensure the CP was appropriately enacted for all patients. Visual mock-ups were iteratively developed and reviewed for flow and an optimal interface. User access levels were set to ensure privacy and confidentiality.

The web-based ADAPT Portal ultimately consisted of two parts. The first part was a patient-directed portal where patients verify their registration and create a password to activate their portal account, and are directed to the home page where information and resources are available. At scheduled time points, patients receive an email alert with a direct link to complete anxiety and depression screening measures and can access self-management and information resources. The second part was a health service staff portal where health service staff log in using a password, register patients who have agreed to participate in the CP with their contact details, receive alerts of patients scoring above clinical cutoffs, and are prompted to complete evidence-based actions according to CP recommendations. Clinical staff can visually track patients’ longitudinal screening data and CP progression, as well as generate reports at an individual or service level. Links to education and training resources are accessible to staff via the portal along with portal user guides and a support messaging service.

Measures
Quantitative Data Collection
ADAPT Portal user activity was reviewed to identify system functionality and uptake. A random selection of registered consenting patients’ medical records was reviewed to assess the quality of data captured and discrepancies between CP documentation in the ADAPT Portal and patients’ electronic medical records.

During the 5-month implementation, user support contacts were tracked, capturing the reason for contact and duration of support required. This information was reviewed and coded according to the ADAPT Portal functional domains (ie, registration, screening, referral, review, rescreening, user error, and system error) for analysis. Additionally, potential design improvements identified during lead team meetings, training sessions, and user support contacts to improve system performance and user satisfaction of the ADAPT Portal were logged throughout the study. These were reviewed by the study team and classified as critical (potential cause of system breakdown), serious (cause of frustration and nonengagement, but not critical to system function), or minor (mostly cosmetic issues that were not of major concern to staff).

Qualitative Data
Data were obtained via health service staff user interviews, review of user support contacts, and field observations by the ADAPT research team. Using purposive sampling, 15 health service staff members participated in semistructured interviews with an interviewer independent of the core ADAPT research team. Interviews explored perceived acceptability and utility of the ADAPT Portal, problems and challenges encountered with the system, and recommendations for improvement. Interviews were transcribed for analysis. Additional data from the staff interviews focusing on staff and organizational barriers to utilizing the ADAPT CP are published elsewhere [25]. The ADAPT research team also recorded extensive field observations after each user support contact with staff as well as during meetings with the lead team during the implementation process to record issues raised and resolutions reached.

Analysis
Quantitative data were entered into the Statistical Package for the Social Sciences (SPSS) database. Descriptive statistics (means and medians for continuous data and percentages for categorical data) were generated.

Interview transcripts were thematically analyzed by two researchers using the platform NVIVO. The two researchers independently performed initial coding to group information according to the modified Technology Acceptance Model themes [19-21] as follows: (1) individual context, individual user’s perceptions about compatibility and attitude toward the...
ADAPT Portal; (2) organizational context, facilitators of acceptance such as infrastructure, support, and social norms; and (3) technological context, perceived ease of use, problems reported, and change in habits resulting from using the ADAPT Portal. Any disagreements were resolved through discussion and consensus. Thematic analysis was then applied within each category to further refine the themes [26]. Each coder read six transcripts and generated a draft coding tree to capture the underlying meaning of the text, which was discussed until consensus was reached. The coding tree was iteratively revised after further coding. The text was compared and contrasted with existing themes until a final comprehensive coding structure was achieved, and the remaining transcripts were then coded.

Results

Portal Users
A total of 73 ADAPT Portal users (36 health service staff and 37 patients) were registered on the ADAPT Portal during the pilot, of whom 67 (92%) accessed the Portal.

Health Service Staff Participants
Registered health service staff included one administrator, two data managers, eight medical oncologists, 13 registered nurses, three cancer care coordinators, one clinical nurse specialist, one clinical nurse educator, four clinical psychologists, and three social workers. Of these, 15 were purposively selected (to ensure diversity of background and ADAPT CP roles) to participate in the postimplementation interview (all agreed). The interview sample included both full-time and part-time staff, who had been in their current role for an average of 3 years (Table 1).

Table 1. Interviewee demographic profile.

<table>
<thead>
<tr>
<th>Demographic</th>
<th>Total (n=15)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Age, n (%)</strong></td>
<td></td>
</tr>
<tr>
<td>26-50 years</td>
<td>12 (80%)</td>
</tr>
<tr>
<td>51-75 years</td>
<td>3 (20%)</td>
</tr>
<tr>
<td><strong>Gender, n</strong></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>15</td>
</tr>
<tr>
<td><strong>Role, n</strong></td>
<td></td>
</tr>
<tr>
<td>Oncologist</td>
<td>1</td>
</tr>
<tr>
<td>Nurse-RN(^a)</td>
<td>2</td>
</tr>
<tr>
<td>Nurse-CNS(^b), CNC(^c), coordinator</td>
<td>3</td>
</tr>
<tr>
<td>NUM(^d)/clinical managers</td>
<td>3</td>
</tr>
<tr>
<td>Clinical psychologist</td>
<td>3</td>
</tr>
<tr>
<td>Social worker</td>
<td>1</td>
</tr>
<tr>
<td>Clinical trial manager</td>
<td>1</td>
</tr>
<tr>
<td>Data manager</td>
<td>1</td>
</tr>
<tr>
<td><strong>Duration in the current role, mean (range)</strong></td>
<td>3.4 years (5 months to 10 years)</td>
</tr>
<tr>
<td><strong>Employment status, n (%)</strong></td>
<td></td>
</tr>
<tr>
<td>Full time</td>
<td>9 (60%)</td>
</tr>
<tr>
<td>Part time</td>
<td>6 (40%)</td>
</tr>
</tbody>
</table>

\(^a\)RN: registered nurse.
\(^b\)CNS: clinical nurse specialist.
\(^c\)CNC: clinical nurse consultant.
\(^d\)NUM: nursing unit manager.

Portal Usage
Of the 37 patients registered, 16 (43%) completed screening once, with seven screening positive. In response to system alerts sent to nominated clinical staff, staff triaged all seven patients. Following triage, the step allocation for two patients was downgraded and documented in the ADAPT Portal, two patients declined additional support, and three patients were referred via the ADAPT Portal to psychosocial services (Table 2).
Table 2. Portal user activity.

<table>
<thead>
<tr>
<th>Portal activity</th>
<th>Patients, n</th>
<th>Health service staff, n</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number registered</td>
<td>37</td>
<td>36</td>
</tr>
<tr>
<td>Number accessed the portal</td>
<td>35</td>
<td>32</td>
</tr>
<tr>
<td>Number screened</td>
<td>16</td>
<td>N/A a</td>
</tr>
<tr>
<td>Total number of screening events</td>
<td>17</td>
<td>N/A</td>
</tr>
<tr>
<td>Total number of positive screens</td>
<td>7</td>
<td>N/A</td>
</tr>
<tr>
<td>Number of patients triaged</td>
<td>7</td>
<td>N/A</td>
</tr>
<tr>
<td>Number of referrals</td>
<td>3</td>
<td>N/A</td>
</tr>
</tbody>
</table>

aN/A: not applicable.

Support Requests and Suggested IT Improvements

A total of 34 research support requests were lodged during the 5-month implementation period, with the majority lodged by health service staff (n=32, 94%) and 2 (6%) by patients. Table 3 lists the types of support requests lodged. Over a third requested clarification regarding management of patient scenarios in alignment with the CP/Portal workflow (n=13, 38%), including screening (n=5), registering (n=4), triage (n=3), and referral (n=1). The remaining support contacts lodged by health service staff were related to user errors, such as requesting password resets (n=7, 21%), system or network errors, such as Wi-Fi dropout (n=6, 18%), health service set-up and configuration issues, such as health service staff not verifying accounts (n=3, 9%), and staff training (n=3, 9%). Usability was raised in two support requests around user habits of pressing “Enter” to move between fields, which in the ADAPT Portal, triggered field validation prompts and cleared input data from some fields.

Table 3. Summary of unplanned support contact.

<table>
<thead>
<tr>
<th>Support contact domain</th>
<th>Total (n=34), n</th>
</tr>
</thead>
<tbody>
<tr>
<td>Workflow</td>
<td>13</td>
</tr>
<tr>
<td>User error</td>
<td>7</td>
</tr>
<tr>
<td>System &amp; network error</td>
<td>6</td>
</tr>
<tr>
<td>Set-up &amp; configuration</td>
<td>3</td>
</tr>
<tr>
<td>Training</td>
<td>3</td>
</tr>
<tr>
<td>Usability</td>
<td>2</td>
</tr>
</tbody>
</table>

Regular review of support contacts and researcher observations led to 17 suggestions for improvements in the system, and of these, five were classified as critical and four were classified as serious (Table 4). Most identified improvements pertained to screening (n=5), reporting (n=4), and patient registration (n=4) functionality. However, other improvements were identified in the triage (n=2), system configuration (n=1), and referral (n=1) functional domains. Examples included additional reporting items to record the reasons why patients did not complete screening, the ability to resend user registration emails to staff who had not verified their accounts, and allowing the “Start Screening” button to continuously display until the patient completed screening (to account for rescheduled appointments and other delays).

Table 4. Summary of system improvements.

<table>
<thead>
<tr>
<th>Functionality domain</th>
<th>Severity, n</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Critical</td>
</tr>
<tr>
<td>Reporting</td>
<td>N/A a</td>
</tr>
<tr>
<td>Screening</td>
<td>2</td>
</tr>
<tr>
<td>Patient registration</td>
<td>N/A</td>
</tr>
<tr>
<td>Triage functionality</td>
<td>1 N/A</td>
</tr>
<tr>
<td>Configuration</td>
<td>1</td>
</tr>
<tr>
<td>Referral</td>
<td>1</td>
</tr>
</tbody>
</table>

aN/A: not applicable.
Portal Data Accuracy

Ten patients’ electronic medical records (EMRs) were compared with ADAPT Portal extracts to evaluate data capture and accuracy. These highlighted frequent missing or incorrect data on cancer diagnosis date and cancer staging in the ADAPT Portal, which occurred when these data were not available in the EMR system at the time of patient registration and were not subsequently updated in the ADAPT Portal when the information became available. CP activity recorded in the ADAPT Portal was consistent with actual psychosocial care documented in the EMR, except in two cases where the patients refused treatment. In these cases, users did not document this via the ADAPT Portal referral functionality, but rather as a free text note similar to current EMR documentation practice.

Individual Views on Usability

Interview length ranged from 16 to 50 minutes (average, 25 minutes), and the themes identified focused on usability and views of ADAPT Portal processes. Staff reported that the system was easy to use and navigate as follows:

“I’m not very tech savvy, but it was fine, it was very easy.” [Interview participant #5 (i5), nursing unit manager/clinical manager]

However, some staff reported difficulty logging into the ADAPT Portal owing to forgetting their passwords or poor Wi-Fi connectivity, while others reported that the time lag between training and actually using the system was too long, impacting their ADAPT Portal use confidence. Nevertheless, these challenges were quickly overcome as shown in the following comment:

“By the time we got a referral we thought, oh how do we do this? How do we log in? What do we do? But, it was fine – you know, we figured it out and we could email [the support team] and she helped us.” [i3, social worker]

Staff also commented positively on system support, preferring this to user guides. One staff user made the following comment:

“Contact was good – if staff asked team for resources or help, response was prompt.” [i15, psychologist]

Feedback on the usefulness of the ADAPT Portal for patient care was polarized. Some staff believed the ADAPT Portal did not improve on existing service processes that were well established, demonstrated in this comment:

“So I think it [the ADAPT Portal] has a very good role but we’re already covering those areas.” [i9, nurse-clinical nurse specialist, clinical nurse consultant, coordinator]

Others reported that the ADAPT Portal was a useful mechanism to formally document psychosocial processes and remind staff that psychosocial assistance was part of standard patient care. One participant clarified their view:

“I think we need to probably formalize what processes we’ve already got in place… I think it’s important we’re doing it with all patients, it’s part of the ongoing assessment of them.” [i11, nursing unit manager/clinical manager]

Staff endorsed the patient resources containing local and national support information, as patients could access relevant information in one location at their own convenience. An example of a comment made by participants was:

“It’s useful to have and it’s good for the patient.” [i3, social worker]

Staff reported varied responses from patients, with most patients open to and positive about using the ADAPT Portal, but others rejected routine screening as unnecessary or too complex. One staff user observed an elderly patient having trouble screening via a tablet and decided to abandon screening.

Organizational Context

Staff reported the need for the ADAPT Portal to be linked with the existing EMR as staff already log into multiple systems for patient care and other patient screening assessments are integrated into the EMR. Participants noted that the service has undergone major technological change in the last 2 years and were therefore reluctant to undertake further technological change. This was highlighted in the following comment:

“We’ve only had that I think, just two years or, so we’ve just had a massive change with that, when everybody made electronic referrals and things, and I guess maybe this was just another thing that was put onto people.” [i10, nurse-clinical nurse specialist, clinical nurse consultant, coordinator]

Technological Context

Staff reported that their work habits changed during the implementation period because they had to access an additional system, and their workload increased. For one user, the role expanded. Regarding the ADAPT Portal, a health service staff member made the following comment:

"...was an extra thing that you’re being asked to do." [i1, nurse-registered nurse]

The service found it necessary to nominate one nurse to remind staff when their patients were due for screening, despite the ADAPT Portal automatically alerting staff, to ensure screening was completed, as summarized in the comment below:

"Even though there’s a reminder we still forget sometimes. So, I think that one person [overseeing] is good.” [i2, nurse-registered nurse]

Discussion

Principal Findings

This study is the first to review an online clinical decision support system for a CP addressing anxiety and depression screening and management (the ADAPT Portal) in an Australian cancer service. We assessed the individual, organizational, and technological contexts impacting the ADAPT Portal’s perceived usability, usefulness, and appropriateness, and adjusted the system where possible to facilitate uptake in a larger implementation study. This is a critical step in the development

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(page number not for citation purposes)
of new systems for use in clinical care, and is rarely evaluated qualitatively and quantitatively.

Testing the system, responding to staff support contacts, making changes to the CDS, and providing training in altered processes and components took some time and delayed patient registrations for some weeks. Ultimately, 37 patients were successfully registered, and their progress through the system was tracked.

Our study highlighted a number of usability issues, technical barriers, and training requirements that resulted in 17 improvements to the ADAPT Portal. Improvements to the ADAPT Portal allowed better recording of the rationale behind decisions and adjustment for real-world variations in patient flow through the system. These findings highlight the importance of addressing perceived usability to ensure the smooth delivery of CDS tools, such as the ADAPT CP, and mirror findings from other studies on diverse CDS tools (such as a movie recommendation system [27], social networking system [28], and health care information system [29]) that have found usability to be a key factor in determining uptake.

Nevertheless, while a number of usability issues were revealed and rectified during the study, staff on the whole had positive perceptions regarding the usefulness of the ADAPT Portal to their patients and the oncology service, which proved to be a strong motivator for ongoing use of the portal. This finding further supports the validity of the Technology Acceptance Model and reflects findings from previous studies [20,21], which have reinforced the importance of perceived usefulness in determining the uptake of health-related technology. As ease of use has been shown to impact perceived usefulness [30], both variables are clearly key to ensuring the successful introduction of technology into diverse workplaces, including the health system.

Not all staff perceived the ADAPT CP to be useful in their practice. Some believed that their existing internal processes were already effective in identifying patients requiring psychosocial support, thus rendering the ADAPT Portal unnecessary in their eyes. In contrast, 7 of 16 patients screened on the ADAPT Portal scored in the range requiring triage and referral, and may have been missed without the system in place. The PARiHS implementation framework, commonly applied to health service change efforts, suggests that staff require evidence of intervention efficacy from not only randomized controlled trials, but also their own and patient experiences, and local evidence of needs and benefits [31]. Thus, finding clear ways to communicate local benefits to staff is vital to implementation success.

While ADAPT Portal usability was addressed in this study and staff were positive about the system on the whole, some contextual issues remained as barriers. These included our inability to integrate the portal into the established electronic record management system, which increased staff burden in learning and accessing an additional system. Furthermore, staff had only recently experienced a sharp learning curve in adapting to a new EMR, reducing their capacity to learn another. James Tcheng from the US National Academy of Medicine [13] noted that technology is primarily useful for “its potential to ameliorate the burden that exponentially expanding clinical knowledge as well as care and choice complexity place on the finite time and attention of clinicians, patients, and every other member of the care team.” Thus, it remains important to ensure that technology realizes this promise by ultimately reducing burden. Furthermore, this finding reinforces the utility of measuring external factors, as well as perceived usability and usefulness in assessing technology implementation.

This study had a number of strengths, including a mixed methods design that produced a rich and complementary data set and the use of a recognized model for evaluating technology acceptance. A number of study limitations must also be considered. This was a small pilot in one urban site and may not reflect findings in other oncology services, including those in small rural areas. Implementation was for 5 months, and some issues related to technology usability may not have arisen in that time. Evaluation over a longer implementation period is required.

Conclusion

As a clinical decision support system, the ADAPT Portal achieved its goal in aligning patient care at a metropolitan cancer service with the recommendations of the ADAPT CP [4]. The pilot study results revealed that staff perceived the ADAPT Portal to be easy to use, and identified system improvements around design and additional functionality to increase usability, performance, and user satisfaction of the system at point of care. The usefulness of the ADAPT Portal was acknowledged by staff; however, some deemed it unnecessary or too burdensome, highlighting the importance of contextual factors when implementing change. The findings were invaluable for the research team in terms of refining the ADAPT Portal and structuring the implementation strategies and other supporting resources planned for evaluation in a large-scale implementation trial with cancer services [32]. Results of the large-scale implementation study will provide evidence of the effectiveness of the ADAPT Portal as a CDS system for bringing about large-scale adherence to evidence-based practice within cancer services and in differing contexts.

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Conflicts of Interest
None declared.

References


Abbreviations

**ADAPT CP:** Australian clinical pathway for the screening, assessment, and management of anxiety and depression in adults with cancer

**CDS:** clinical decision support

**CP:** clinical pathway

**EMR:** electronic medical record

**IT:** information technology
Impact of an Educational Comic to Enhance Patient-Physician–Electronic Health Record Engagement: Prospective Observational Study

Maria A Alkureishi1, MD; Tyrone Johnson2, MD; Jacqueline Nichols3, MD; Meera Dhodapkar4*, BS; M K Czerwiec5*, RN; Kristen Wroblewski6*, MS; Vineet M Arora7*, MD, MAPP; Wei Wei Lee7*, MD, MPH

1Department of Academic Pediatrics, University of Chicago, Chicago, IL, United States
2Department of Internal Medicine, University of California, San Francisco, San Francisco, CA, United States
3Department of Obstetrics and Gynecology, University of Washington, Seattle, WA, United States
4Yale University School of Medicine, New Haven, CT, United States
5Center for Medical Humanities & Bioethics, Feinberg School of Medicine, Northwestern University, Chicago, IL, United States
6Department of Public Health Sciences, University of Chicago, Chicago, IL, United States
7Department of Medicine, University of Chicago, Chicago, IL, United States
*all authors contributed equally

Corresponding Author:
Maria A Alkureishi, MD
Department of Academic Pediatrics
University of Chicago
5841 S Maryland Ave
MC 6082 Rm C124
Chicago, IL, 60637
United States
Phone: 1 773 834 8927
Email: malkureishi@peds.bsd.uchicago.edu

Abstract

Background: Electronic health record (EHR) use can impede or augment patient-physician communication. However, little research explores the use of an educational comic to improve patient-physician-EHR interactions.

Objective: To evaluate the impact of an educational comic on patient EHR self-advocacy behaviors to promote patient engagement with the EHR during clinic visits.

Methods: We conducted a prospective observational study with adult patients and parents of pediatric patients at the University of Chicago General Internal Medicine (GIM) and Pediatric Primary Care (PPC) clinics. We developed an educational comic highlighting EHR self-advocacy behaviors and distributed it to study participants during check-in for their primary care visits between May 2017 and May 2018. Participants completed a survey immediately after their visit, which included a question on whether they would be interested in a follow-up telephone interview. Of those who expressed interest, 50 participants each from the adult and pediatric parent cohorts were selected at random for follow-up telephone interviews 8 months (range 3-12 months) post visit.

Results: Overall, 71.0% (115/162) of adult patients and 71.6% (224/313) of pediatric parents agreed the comic encouraged EHR involvement. African American and Hispanic participants were more likely to ask to see the screen and become involved in EHR use due to the comic (adult \( P=.01 \), \( P=.01 \); parent \( P=.02 \), \( P=.006 \), respectively). Lower educational attainment was associated with an increase in parents asking to see the screen and to be involved (\( \rho=-0.18, P=.003 \); \( \rho=-0.19, P<.001 \), respectively) and in adults calling for physician attention (\( \rho=-0.17, P=.04 \)), which was confirmed in multivariate analyses. Female GIM patients were more likely than males to ask to be involved (median 4 vs 3, \( P=.003 \)). During follow-up phone interviews, 90% (45/50) of adult patients and all pediatric parents (50/50) remembered the comic. Almost half of all participants (GIM 23/50, 46%; PPC 21/50, 42%) recalled at least one best-practice behavior. At subsequent visits, adult patients reported increases in asking to see the screen (median 3 vs 4, \( P=.006 \)), and pediatric parents reported increases in asking to see the screen and calling for physician attention (median 3 vs 4, \( Ps<.001 \) for both). Pediatric parents also felt that the comic had encouraged them to speak up and get
more involved with physician computer use since the index visit (median 4 vs 4, \( P = .02 \)) and that it made them feel more empowered to get involved with computer use at future visits (median 3 vs 4, \( P < .001 \)).

Conclusions: Our study found that an educational comic may improve patient advocacy for enhanced patient-physician-EHR engagement, with higher impacts on African American and Hispanic patients and patients with low educational attainment.

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KEYWORDS
electronic health records; patient; comic; education; engagement

Introduction

Electronic health record (EHR) use in clinical care has become the norm in the United States [1-3]. Studies on the impact of EHR use have found that certain physician behaviors (eg, poor eye contact, long silences) may lead to decreased patient satisfaction with the patient-physician relationship and communication [4-11]. While studies show there are certain patient-centered care behaviors that can positively impact patient satisfaction and health outcomes, with Table 1 serving as a model for incorporating many evidence-based behaviors, physicians are faced with the challenge of staying focused on their patients while efficiently navigating the EHR during clinical encounters [4,6,12-20].

In a 2016 study on patient perceptions of physician EHR use in an academic primary care practice, patients were dissatisfied when physicians appeared more focused on the computer than on them and frustrated with lack of transparency and poor body positioning, which contributed to perceptions of decreased quality of care [7]. While best practices to promote patient-centered EHR use have been identified, most physicians and patients are unaware of these strategies to improve patient-physician-EHR communication [6,12,20-26].

Educational comics have emerged as an innovative way to promote patient education and engagement in a variety of clinical settings including pediatric, gynecology, radiation oncology, neurology, and endocrine practices [27-34]. Despite these findings, to our knowledge, no studies have looked at using educational comics to promote patient-centered EHR use in academic primary care practices. Furthermore, prior studies have found that Black and Hispanic patients and those with lower educational attainment level experience increased health care disparities, which in turn may result in poorer health outcomes [35-47]. As such, we aim to assess the impact of an educational comic on patient self-advocacy behaviors to enhance patient engagement with the EHR and to determine if there are variable impacts of the comic on different patient demographic variables such as ethnicity and education attainment level.

Table 1. HUMAN LEVEL—10 tips to enhance patient-centered electronic health record use [20].

<table>
<thead>
<tr>
<th>Initial</th>
<th>Tip</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>H</td>
<td>( H )onor the “Golden Minute”</td>
<td>Make the start of the visit completely technology-free. Greet the patient, start with their concerns, and establish an agenda for the visit before engaging technology.</td>
</tr>
<tr>
<td>U</td>
<td>( U )se the “Triangle of Trust”</td>
<td>Create a triangle configuration that puts you, the patient, and the computer screen at each of the three corners. This allows you to look at both the patient and screen without shifting your body position, and also enables shared screen viewing.</td>
</tr>
<tr>
<td>M</td>
<td>( M )aximize patient interaction</td>
<td>Encourage patient interaction. Pause for questions and clarification. Allow time for questions and to verify understanding.</td>
</tr>
<tr>
<td>A</td>
<td>( A )cquaint yourself with chart</td>
<td>Review the chart before you enter the room to prepare, inform, and contextualize your visit.</td>
</tr>
<tr>
<td>N</td>
<td>( N )ix the screen</td>
<td>When discussing sensitive information, completely disengage from the EHR(^a) (look at the patient, turn away from screen, take hands off keyboard, etc).</td>
</tr>
<tr>
<td>L</td>
<td>( L )et the patient look on</td>
<td>Share things on the screen with your patients.</td>
</tr>
<tr>
<td>E</td>
<td>( E )ye contact</td>
<td>Maintain eye contact with patients as much as possible. Treat patient encounters as you would a conversation with friends or family members.</td>
</tr>
<tr>
<td>V</td>
<td>Value the computer</td>
<td>Praise the benefits of the EHR and take advantage of opportunities to use technology as a tool to engage patients (pull up lab result to review together, utilize graphics, etc).</td>
</tr>
<tr>
<td>E</td>
<td>( E )xplain what you’re doing</td>
<td>Be transparent about everything you do. Avoid long silences, aim for conversational EHR use by explaining what you are doing as you are doing it.</td>
</tr>
<tr>
<td>L</td>
<td>( L )og off</td>
<td>At the end of the visit, log off of the patient’s chart while they are still in the exam room. This reassures patients that their medical information is secure.</td>
</tr>
</tbody>
</table>

\(^a\)EHR: electronic health record.
Methods

Setting and Participants

The study was conducted at the University of Chicago’s General Internal Medicine (GIM) and Pediatric Primary Care (PPC) clinics between May 2017 and May 2018. Adult GIM patients and pediatric parents who were scheduled to see faculty physicians were approached by trained research assistants in the waiting room and verbally consented to participate in the study. Inclusion criteria included ability to consent and English proficiency. GIM and PPC faculty physicians were given information about the study at their respective section meetings and via email communications, and all consented to having their patients participate. Of note, the ergonomic room layout in both clinics is such that the screen is usually not easily viewed by the patient unless it or the chairs in the room are moved to encourage shared viewing.

Comic Development

The educational comic (Figure 1), “Computers in the Clinic: Your Role,” was developed by the authors (MAA, WWL, VMA, MKC) based on a literature review of the impact of EHR use on patient-physician communication [4-6,8,9]. The comic was drawn by author MKC, a practicing nurse with experience in designing educational comics for patient education interventions. It highlights three patient self-advocacy behaviors aimed at improving patient EHR engagement: (1) A for “Ask to see the screen” to promote screen sharing, (2) B for “Become involved with your doctor’s use of the computer” to encourage patient-physician-EHR interaction and patient education, and (3) C for “Call for attention” to encourage patients to speak up if they feel their physician is distracted by the EHR.
Figure 1. Patient EHR self-advocacy comic. The educational comic was given to adult patients and parents of pediatric patients when registering for their clinic visits to encourage EHR self-advocacy behaviors and engagement. EHR: electronic health record. © Alkureishi ML, Czerwiec MK, Arora V, Lee WW and the Arnold P. Gold Foundation.

Postvisit Survey and Telephone Interview Script Development

Using findings from a literature review, a 33-item postvisit survey was developed containing open-ended and Likert scale questions to assess the comic’s impact on patient (1) self-advocacy behaviors for more engaging and meaningful patient-physician-EHR interactions, (2) satisfaction with physician EHR use, and (3) perceptions of physician communication at the current visit compared to patient recollections of communication with the same provider at prior visits [4-6,8,9] (Multimedia Appendix 1). Studies have shown that patient self-report is a reasonable method of assessing whether educational interventions improve subsequent behaviors.
and self-advocacy [48-52]. Furthermore, we wanted to directly ask patients what they thought about the patient-physician-EHR interaction and impacts of the comic on their behavior and perceptions, rather than use an observer or their clinician’s perceptions as an indirect proxy.

A semistructured telephone interview script was developed to assess (1) patient recall of the comic and (2) impact of the comic on patient perceptions and self-advocacy behaviors and EHR engagement at subsequent physician visits (Multimedia Appendix 2). The interview script contained 6 5-point Likert-style questions to assess patient perceptions of the comic and impact on behaviors since the index visit (eg, “The comic encouraged me to speak up and get more involved with the computer at my subsequent visits with my doctor.”) as well as open-ended questions to prompt patient responses (eg, “Can you give me some examples of how you’ve asked to get more involved with your doctor’s use of the computer during clinic visits?”).

**Intervention**

The hypothesis for our study was that more than 50% of respondents would agree that the comic made them get more involved with the computer (null hypothesis: \( p=50\% \) vs alternative hypothesis: \( p>50\% \)). Our calculations assumed 80% power and one-sided exact binomial test with \( \alpha=.025 \). Based on this, we found that a sample size of 200 in each group would be sufficient to reject the null hypothesis if the true rate was 60%, which is why we estimated a total of 400-500 postvisit surveys in total would be needed to assess our outcomes. This sample size estimation was consistent with prior telephone interview studies at the University of Chicago with the same patient population and similar survey and interview techniques [7,53].

Adult GIM patients and pediatric parents who consented to the study were given the educational comic and a postvisit survey. Participants were instructed to (1) review the comic while waiting for their appointment and (2) complete the survey at the end of their visit. The postvisit survey included a question on whether participants would be interested in participating in a follow-up telephone interview at a mean of 8 months (range 3-12 months) after their clinic visit. Of those who expressed interest, 50 participants each from the adult and pediatric parent cohorts were selected at random for the interviews, which were conducted between July 2017 and October 2018. Participants orally consented to participate in the phone interview (Multimedia Appendix 2). A US $20 gift card was offered as compensation for their time. Phone interviews were digitally recorded and transcribed to ensure accuracy.

**Data Analysis**

Descriptive statistics of patient postvisit surveys and phone interview responses were examined. Standard descriptive statistics were calculated including frequency counts and percentages, mean (standard deviation), or median. Univariate analyses were initially performed; since survey responses were on an ordinal Likert scale, nonparametric tests were used. Comparisons of survey responses involving three or more groups (eg, race) were made using Kruskal-Wallis tests, while comparisons involving two groups (eg, gender) were made using Wilcoxon rank sum tests. Associations between educational attainment and survey responses were examined using Spearman rank correlation coefficients. Pairwise comparisons were completed using Tukey’s honestly significant difference test. Phone survey versus postvisit survey response comparisons were completed using the Wilcoxon signed rank test for matched pairs. Multivariate analyses looking at whether gender, race, and education were independently associated with the odds of agreeing with a particular survey question (eg, “agree” was defined as a Likert response \( \geq 4 \)) were performed using logistic regression. Analysis was performed using Stata 14 (StataCorp LP, College Station, Texas). No adjustment for multiple testing was made. Our paper conforms to the SQUIRE 2.0 Revised Standards for Quality Improvement Reporting Excellence [54]. This study was approved by the University of Chicago’s Institutional Review Board.

**Results**

**Overview**

The study enrollment rate was 83.5% (197 consented/236 approached) for adult patients and 77.9% (325 consented/417 approached) for the pediatric parent cohort for a total of 522 participants (Table 2). In both cohorts, there were some patients who had at least one of the 18 survey questions missing an answer (142/197, 72.1% of adults and 104/325, 32% of pediatric parents). As such, data analyses are based on those who answered each question. In the adult cohort, the only significant difference in demographic characteristics between those who completed the entirety of the survey and those who did not was race distribution (\( P=.004 \)), with 61% of noncompleters being African American compared to 46% of those who did complete it. In the pediatric cohort, the only statistically significant difference between survey completers and noncompleters was age, with noncompleters being significantly older (\( P<.001 \)) than those who completed the survey.

The mean age was 58 (SD 17.3) years old for adult patients and 37 (SD 9.7) years old for pediatric parents. Overall, 65.6% (124/189) of adult patients and 85.8% (272/317) of pediatric parents were female, and 57.1% (104/182) of adult patients and 55.7% (176/316) of pediatric parents identified as African American. Less than half (72/181, 39.8%) of adult patients and a quarter (81/313, 25.9%) of pediatric parents reported educational attainment below a college degree, and 50.3% (91/181) of adult patients and 67.7% (212/313) of pediatric parents reported educational attainment at or above a bachelor’s degree. The average duration of the patient-physician relationship was 4.3 years in the GIM sample and 3.3 years in the pediatric sample.
Table 2. Participant demographics.

<table>
<thead>
<tr>
<th>Participant demographics</th>
<th>Adult sample (n=197)</th>
<th>Pediatric parent sample (n=325)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years), n (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>18-19</td>
<td>2 (1.0)</td>
<td>5 (1.7)</td>
</tr>
<tr>
<td>20-29</td>
<td>11 (5.8)</td>
<td>55 (18.2)</td>
</tr>
<tr>
<td>30-39</td>
<td>19 (10.0)</td>
<td>138 (45.5)</td>
</tr>
<tr>
<td>40-49</td>
<td>21 (11.1)</td>
<td>69 (22.8)</td>
</tr>
<tr>
<td>50-59</td>
<td>40 (21.1)</td>
<td>29 (9.6)</td>
</tr>
<tr>
<td>60 and older</td>
<td>97 (51.1)</td>
<td>7 (2.3)</td>
</tr>
<tr>
<td>Gender, n (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>124 (65.6)</td>
<td>272 (85.8)</td>
</tr>
<tr>
<td>Male</td>
<td>65 (34.4)</td>
<td>45 (14.2)</td>
</tr>
<tr>
<td>Race</td>
<td></td>
<td></td>
</tr>
<tr>
<td>White</td>
<td>47 (25.8)</td>
<td>76 (24.1)</td>
</tr>
<tr>
<td>African American</td>
<td>104 (57.1)</td>
<td>176 (55.7)</td>
</tr>
<tr>
<td>Asian</td>
<td>17 (9.3)</td>
<td>18 (5.7)</td>
</tr>
<tr>
<td>Hispanic or Latino</td>
<td>8 (4.4)</td>
<td>31 (9.8)</td>
</tr>
<tr>
<td>Mixed/Other</td>
<td>6 (3.3)</td>
<td>15 (4.7)</td>
</tr>
<tr>
<td>Educational attainment, n (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Less than high school graduate</td>
<td>5 (2.8)</td>
<td>3 (1.0)</td>
</tr>
<tr>
<td>High school graduate or GED(^a) equivalent</td>
<td>31 (17.1)</td>
<td>20 (6.4)</td>
</tr>
<tr>
<td>Some college, no degree</td>
<td>36 (19.9)</td>
<td>58 (18.5)</td>
</tr>
<tr>
<td>Associate degree</td>
<td>18 (9.9)</td>
<td>20 (6.4)</td>
</tr>
<tr>
<td>Bachelor’s degree</td>
<td>31 (17.1)</td>
<td>81 (25.9)</td>
</tr>
<tr>
<td>Graduate or professional degree</td>
<td>60 (33.2)</td>
<td>131 (41.9)</td>
</tr>
<tr>
<td>Length of relationship with physician (years), mean</td>
<td>4.3</td>
<td>3.3</td>
</tr>
</tbody>
</table>

\(^a\)GED: General Educational Development.

Postvisit Survey Results

**Impact of Comic on Patient Advocacy to Enhance Patient-Physician-EHR Interactions**

Nearly three-quarters of adult patients (115/162, 71.0%) and pediatric parents (224/313, 71.6%) agreed the comic “encouraged them to be more involved in the EHR.” Almost half of all participants (76/161, 47.2% of adult patients; 137/311, 44.1% of pediatric parents) agreed that the comic made them “feel more empowered about getting involved with the computer.” As a result of the comic, approximately a third of all participants (60/162, 37.0% of adult patients; 81/310, 26.1% of pediatric parents) asked to see the screen and to be more involved with their physician’s computer use by asking “to review their chart in EHR” (61/161, 37.7% of adult patients; 92/310, 29.9% of pediatric parents). As well, as a result of the comic, over one-third of participants (74/161, 46.0% of adult patients; 118/309, 38.2% of pediatric parents) felt more comfortable “asking their doctor to pay full attention to them if a sensitive topic came up.” More than half of participants (93/161, 57.8% of adult patients; 169/310, 54.5% of pediatric parents) felt that because of the comic, they were “more likely to get involved with their doctor’s computer use at future visits.” The remainder of the responses given on the entire survey are provided in Multimedia Appendix 3.

Based on univariate analyses, African American and Hispanic participants were more likely than White participants to “ask to see the screen” and “be involved due to the comic” (median 4 vs 3 for both; adult \( P=.01, P=.01 \); pediatric parent \( P=.02, P=.006 \), respectively). In both groups, lower educational attainment level was associated with significantly higher rates of self-reported advocacy behaviors to promote patient EHR engagement. Specifically, in the adult patient population, this included increased rates of “calling for physician attention” (\( \rho=-0.17, P=.04 \)); and in the pediatric cohort, these behaviors included “asking to see the screen” (\( \rho=-0.18, P=.003 \)) and “asking to be involved with the EHR” (\( \rho=-0.19, P<.001 \)) as a result of the comic. Additionally, adult female patients were more likely than male patients to ask to be involved with their physician’s computer use due to the comic (median 4 vs 3, \( P=.003 \)); no gender differences were found in the pediatric parent population. Multivariate logistic regression analyses...
confirmed independent associations with education, especially in the pediatric cohort. In addition, robust associations with race and ethnicity remained in the pediatric cohort.

Table 3. Association between demographic characteristics and patient perceptions of comic in multivariate analyses.a

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Statement “Because of the comic...”</th>
<th>Adult cohort</th>
<th>Pediatric cohort</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>I asked to see the screen</td>
<td>I asked to be more involved with the computer</td>
<td>I felt more empowered about getting involved with the computer</td>
</tr>
<tr>
<td>Female gender (vs male), odds ratio (95% CI)</td>
<td>1.65 (0.74-3.67)</td>
<td>1.55 (0.72-3.32)</td>
<td>0.96 (0.45-2.05)</td>
</tr>
<tr>
<td>Educationb, odds ratio (95% CI)</td>
<td>0.70** (0.54-0.90)</td>
<td>0.82 (0.64-1.04)</td>
<td>0.80 (0.63-1.01)</td>
</tr>
<tr>
<td>Race/ethnicity (vs white), odds ratio (95 % CI)</td>
<td>1.52 (0.61-3.76)</td>
<td>1.49 (0.63-3.51)</td>
<td>1.12 (0.47-2.64)</td>
</tr>
<tr>
<td>African American</td>
<td>2.00 (0.76-5.23)</td>
<td>1.69 (0.66-4.31)</td>
<td>1.05 (0.45-2.48)</td>
</tr>
<tr>
<td>Asian</td>
<td>2.12 (0.54-8.97)</td>
<td>1.26 (0.30-5.27)</td>
<td>1.08 (0.30-3.88)</td>
</tr>
<tr>
<td>Hispanic</td>
<td>3.49 (0.59-20.52)</td>
<td>2.81 (0.49-16.22)</td>
<td>1.50 (0.28-8.22)</td>
</tr>
<tr>
<td>Other</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Model chi-square (df)</td>
<td>15.6 (5)</td>
<td>14.2 (5)</td>
<td>5.2 (5)</td>
</tr>
<tr>
<td>P value</td>
<td>0.008</td>
<td>0.01</td>
<td>0.39</td>
</tr>
<tr>
<td>n</td>
<td>135</td>
<td>135</td>
<td>135</td>
</tr>
<tr>
<td>Female gender (vs male), odds ratio (95% CI)</td>
<td>0.86 (0.39-1.91)</td>
<td>0.95 (0.43-2.10)</td>
<td>1.13 (0.56-2.31)</td>
</tr>
<tr>
<td>Educationb, odds ratio (95% CI)</td>
<td>0.75** (0.61-0.91)</td>
<td>0.74** (0.61-0.90)</td>
<td>0.76** (0.63-0.92)</td>
</tr>
<tr>
<td>Race/ethnicity (vs white), odds ratio (95 % CI)</td>
<td>1.41 (0.39-5.87)</td>
<td>1.34 (1.45-9.34)</td>
<td>1.34 (0.71-2.54)</td>
</tr>
<tr>
<td>African American</td>
<td>2.41 (0.97-13.59)</td>
<td>3.68** (1.54-21.42)</td>
<td>1.34 (0.68-6.12)</td>
</tr>
<tr>
<td>Asian</td>
<td>3.64 (0.97-13.59)</td>
<td>5.75** (1.54-21.42)</td>
<td>2.04 (0.68-6.12)</td>
</tr>
<tr>
<td>Hispanic</td>
<td>5.03** (1.66-15.20)</td>
<td>6.17** (1.95-19.56)</td>
<td>1.72 (0.68-4.35)</td>
</tr>
<tr>
<td>Other</td>
<td>4.54* (1.14-18.06)</td>
<td>12.60*** (3.00-52.98)</td>
<td>7.28** (1.82-29.11)</td>
</tr>
<tr>
<td>Model chi-square (df)</td>
<td>23.9 (6)</td>
<td>34.3 (6)</td>
<td>20.3 (6)</td>
</tr>
<tr>
<td>P value</td>
<td>&lt;.001</td>
<td>&lt;.001</td>
<td>0.003</td>
</tr>
<tr>
<td>n</td>
<td>290</td>
<td>287</td>
<td>290</td>
</tr>
</tbody>
</table>

aNumbers in table are odds ratios (95% CI) from 6 separate multivariate logistic regression models for agreeing with given statement (agree or strongly agree vs not). * P<.05, ** P<.01, *** P<.001.
bTreated as a continuous measure using integer scores for educational level (higher scores = more education).
cNot applicable.
**Satisfaction With Physician EHR Use**

The large majority of adult patients (151/192, 78.6%) and pediatric parents (294/323, 91.0%) agreed that their physician “made sure they could see the screen” during the clinic visit and “made sure they could talk face to face even though they were using the computer” (180/194, 92.8% and 301/325, 92.6%, respectively). Most adult patients (128/189, 67.7%) and pediatric parents (260/325, 80%) agreed that their physician encouraged them to “interact with the computer” (eg, showing information in EHR, encouraging them to use the patient portal). Nearly three-quarters of adult patients (125/172, 72.7%) and pediatric parents (247/325, 76%) agreed their “physician valued the computer and was positive about the benefits.”

**Perceptions of Physician Communication at Current Visit Compared to Prior Visits**

When comparing the current visit with recollections of prior visits with the same physician, more than half of participants (109/163, 66.9% of adult patients; 186/325, 57.2% of pediatric parents) agreed that at the current visit, their physician “used the computer more effectively to communicate with them” and was “less distracted by the computer and more focused on them” (97/157, 61.8% of patients; 186/325, 57.2% of pediatric parents). Further, compared to prior visits, more than half of all participants (99/160, 61.9% of adult patients; 179/325, 55.1% of pediatric parents) agreed that they “understood more about their/their child’s health and plan,” and 56.2% (81/144) of adult patients and 46.6% (131/281) of pediatric parents were “more satisfied with their relationship with their/their child’s doctor because of how they used the computer with them.”

**Follow-up Telephone Interview**

A total of 148 adult patients (148/197, 75.1%) and 196 pediatric parents (196/325, 60.3%) were interested in participating in follow-up phone interviews. Patients were randomly selected from this group, and a total of 83 adult patients (83/148, 56.1%) and 60 pediatric parents (60/196, 30.6%) were called to reach 50 completed interviews for each cohort. Follow-up phone interviews were conducted on average 8 months (range 3-12 months) post visit. There were no significant differences in age, sex, race, educational attainment level, or length of physician relationship between those that completed phone interviews, those that were interested in taking part in phone interviews but did not (eg, they were unavailable or were not randomly selected to take part), and those that were only initially surveyed after their visit and were not interviewed by phone because they declined to take part.

All pediatric parents (50/50) and 90% (45/50) of adult patients remembered the comic, and almost half of adult patients (23/50, 46%) and pediatric parents (21/50, 42%) recalled at least one of the comic’s three ABC best-practice behaviors without prompting. When asked if they used the advocacy behaviors suggested in the comic at subsequent physician visits, adult patients reported that they were more likely to ask to see the screen (Multimedia Appendix 2, question 3, median response 3 vs 4, \( P = .006 \)), and pediatric parents reported increases in asking to see the screen (Multimedia Appendix 2, question 3, median response 3 vs 4, \( P < .001 \)) and calling for physician attention (Multimedia Appendix 2, question 4, median response 3 vs 4, \( P < .001 \)). Pediatric parents also felt that the comic had encouraged them to speak up and get more involved with physician computer use since the index visit (Multimedia Appendix 2, question 2, median response 4 vs 4, \( P = .02 \)) and that it made them feel more empowered to get involved with computer use at future visits (Multimedia Appendix 2, question 5, median response 3 vs 4, \( P < .001 \)). There were no significant differences in adults feeling more empowered to get involved at future visits (Multimedia Appendix 2, question 5, median response 4 vs 4, \( P = .23 \)) or in either group thinking the comic was effective in encouraging continued involvement with the computer at physician visits (Multimedia Appendix 2, question 6, median response 5 vs 4, \( P = .26 \) for adults; median response 4 vs 4, \( P = .06 \) for pediatrics).

Open-ended question responses were collectively pooled. Content analysis identified unique themes, subthemes, and representative quotations in order to build a picture of the respondents’ collective experiences (Table 4) [55].
Table 4. Themes and subthemes relevant to the educational comic and EHR use.

<table>
<thead>
<tr>
<th>Themes and subthemes</th>
<th>Representative quotes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Patient perceptions</strong></td>
<td></td>
</tr>
<tr>
<td>EHR awareness</td>
<td>“The effort as a whole did make me more aware of the computer and I feel like, oh, I notice the screen and the doctor’s use”</td>
</tr>
<tr>
<td>Screen viewing</td>
<td>“The comic was great because I didn’t know it was my right to look at the computer”</td>
</tr>
<tr>
<td>Asking questions</td>
<td>“The comic was really good; I wasn’t sure if you could ask questions”</td>
</tr>
<tr>
<td>Time for EHR involvement</td>
<td>“Patients often feel like they are rushed, the comic gives assurance that it’s okay to ask questions”</td>
</tr>
<tr>
<td>Encouraging engagement</td>
<td>“I already do the ABCs; for someone who is more bashful or reserved, the comic may be more helpful.”</td>
</tr>
<tr>
<td><strong>Patient behaviors</strong></td>
<td></td>
</tr>
<tr>
<td>EHR engagement</td>
<td>“I’ve had several appointments since the appointment and it’s been much better, I was very involved, one physician did on a laptop which was cool so I could see.”</td>
</tr>
<tr>
<td>Asked to see screen</td>
<td>“Comic was first time to see the screen. Comic helped me ask, prior to the visit I had never asked to see the screen”</td>
</tr>
<tr>
<td>Asked for clarification</td>
<td>“I ask can I see the screen, talk to me about what you see”</td>
</tr>
<tr>
<td>Asked about clinician behaviors</td>
<td>“Asked him to further explain to me what he was doing and inputting on the computer”</td>
</tr>
<tr>
<td>Corrected errors</td>
<td>“Asked to see my record and make corrections”</td>
</tr>
<tr>
<td>Watched what clinician was typing</td>
<td>“I liked to see what she is typing. Also it helps me understand what is happening during our visit. Great idea.”</td>
</tr>
<tr>
<td>Asked to see things in the EHR</td>
<td>“When showing child growth, I asked to see the graph”</td>
</tr>
<tr>
<td><strong>Physician behaviors</strong></td>
<td></td>
</tr>
<tr>
<td>EHR use in visit</td>
<td>“My doctor is awesome, when she's pulling up my history and my labs she pulls up the screen so I can see it and she looks at my medications and she asks me are you taking this, are you still taking them twice a day”</td>
</tr>
<tr>
<td>Patient portal use</td>
<td>“My doctor involved me by encouraging me to go online and look at the chart”</td>
</tr>
<tr>
<td><strong>Suggestions for comic modification</strong></td>
<td></td>
</tr>
<tr>
<td>Improved readability</td>
<td>“Bigger font in speech bubbles, more lay language”</td>
</tr>
<tr>
<td>Translation</td>
<td>“Have it in other languages such as Spanish”</td>
</tr>
<tr>
<td>Increased visibility</td>
<td>“Place cartoon in rooms, on the wall”</td>
</tr>
<tr>
<td>Provide script examples</td>
<td>“Like using key phrases / trigger points, give phrases that patients can use”</td>
</tr>
<tr>
<td>Orientation to EHR content</td>
<td>“Give more examples of what one may find on computer screen that he/she may wish to see”</td>
</tr>
<tr>
<td>Highlight benefits of involvement</td>
<td>“Give more detailed examples of the benefits of getting involved”</td>
</tr>
<tr>
<td>Highlight drawbacks of uninvolve ment</td>
<td>“I would add an example that would scare them to get involved”</td>
</tr>
<tr>
<td><strong>Suggestions for EHR engagement</strong></td>
<td></td>
</tr>
<tr>
<td>Patient-facing portions of EHR</td>
<td>“Have a portion of the EHR where pts can interact w/computer themselves”</td>
</tr>
<tr>
<td>Mobile technology</td>
<td>“A tablet to follow along with the chart as doc is on computer”</td>
</tr>
<tr>
<td>Patient portal training</td>
<td>“If someone showed me how to use MyChart”</td>
</tr>
<tr>
<td>General technology training</td>
<td>“Teaching us how to use a computer and how to learn”</td>
</tr>
<tr>
<td>Room ergonomics</td>
<td>“Screen where patient and doc can see without doc’s back to patient”</td>
</tr>
<tr>
<td>Nursing involvement</td>
<td>“Nurses can tell patients/parents to ask dr to share computer screen”</td>
</tr>
<tr>
<td>Highlight importance of patient involve ment</td>
<td>“Maybe take a moment at the beginning to reiterate what they’re doing every step of the way on the computer and let patients know that they have the right to see the screen - gives partnership in their own personal care”</td>
</tr>
<tr>
<td>Physician training</td>
<td>“Train the doctor to be more involved”</td>
</tr>
<tr>
<td>Reset physician EHR expectations</td>
<td>“Wish drs had to always show info unless confidential info is on screen”</td>
</tr>
</tbody>
</table>

*EHR: electronic health record.*
Discussion

To our knowledge, this is the first study evaluating the impact of an educational comic on patient advocacy for enhanced patient-physician-EHR interactions. This easily replicable intervention may help improve patient self-advocacy for patient-centered engagement with the EHR in pediatric and adult primary care settings, which can promote both patient education and satisfaction with physician EHR use. Importantly, the effect was more pronounced in African American and Hispanic patients and patients with lower levels of educational attainment.

Prior studies have found that non-White patients, those with lower educational attainment, and non–English-speaking patients experience health care disparities which may result in poor health outcomes [35-47]. These patients may also come to visits with lower levels of health literacy and agency, which can be associated with difficulty understanding their diagnoses and treatment plans [35-47]. The open-ended comments in our study (Table 4) highlighted that some patients do not feel empowered to ask questions during their visits, and handing out the educational comic may serve as a simple but powerful invitation to speak up and ask questions of their physicians.

Additionally, patients from disadvantaged backgrounds are more likely to report distrust of their health care team when compared to patients from nondisadvantaged social and educational backgrounds [44,45,47,56]. Sharing the EHR screen and enhancing transparency and engagement with the EHR may increase a patient’s sense of partnership and trust with their physician, which may help promote increased trust of the medical system [26,44-47]. Moreover, patients from disadvantaged groups may need more formal encouragement to engage with their physicians and the EHR, which is important because enhanced engagement with providers and health care technology can help increase patient understanding of care plans and improve preparation for future visits [6,12,44-47,57]. Our educational comic may be used as a tool to empower vulnerable patients to be more engaged in their care and promote agency. In addition, patients with limited health literacy may rely on health information from social media and blogs, which can contain lower quality health information [47]. Encouraging patients to ask their physicians questions may help dispel health myths, promote health literacy, and help reduce health disparities [44-47].

With regard to patient satisfaction with physician EHR use, patients reported that their physicians demonstrated more patient-centered behaviors when using the EHR at the index visit as compared to prior visits. This may be due to the patient’s increased EHR engagement during the visit, which could have prompted physicians to engage in more patient-centered EHR behaviors. Future research is needed to better understand how enhanced patient EHR engagement is perceived by physicians and the impact on physicians’ EHR-related behavior.

Lastly, there were no significant differences in either adult or pediatric respondents thinking the comic was effective at encouraging continued involvement with the computer on phone follow-up. However, what is perhaps more important is that when describing the comic’s impacts on specific behaviors at subsequent physician visits, both adult and pediatric patients reported increased use of the self-advocacy behaviors in the comic since their initial visit, particularly in the pediatric cohort; this perhaps suggests that it may have been effective in contributing to lasting impacts on their subsequent EHR interactions, especially when advocating on behalf of someone else (ie, their child).

Our study has several limitations. First, it was a single-institution study, and we had an overrepresentation of women and advanced degree holders in our sample, both of which may limit generalizability. In addition, while it may be difficult to directly compare pediatric parent to adult patient responses, findings from pediatric parents may be generalizable to family members who accompany adult patients to visits or serve as proxies for those who cannot speak or advocate for themselves. Our study did not include a control group, and we did not conduct a preintervention survey due to resource constraints. To adjust for this, the postvisit survey asked participants to rate their perceptions, advocacy behaviors, and satisfaction with their physician’s EHR use at the current visit as compared to their recollection of these measures from prior visits with the same providers. These responses may have been subject to recall and response bias, and phone interviews may have been affected by the variable follow-up period. Our findings were dependent on reports from adult patients and pediatric parent participants without direct observation of physician or patient behavior. Further, we did not include a control group with a text-only nongraphic version of the comic, so it is not possible to say if a nongraphic intervention would have had the same impacts. Lastly, physicians were generally deemed by their patients to be adept at engaging them with the EHR, perhaps because they were biased to providing positive responses, and physicians were aware that the study was occurring, which may have influenced their EHR behaviors. In order to help minimize this impact, physicians were not shown the patient comic or the survey.

Further work is needed to understand how to tailor educational comics to different patient populations and clinical settings, such as the inpatient hospital environment, to effectively engage patients and physicians with the EHR. While this educational intervention targeted patients, it is also important to teach patient-centered EHR behaviors to physicians to promote patient-physician-EHR engagement [20-26,58,59], and these efforts should be pursued in tandem. Additionally, EHRs should evolve to account for user experience, patient health literacy levels, and language needs to help reduce the digital divide and health disparities [19,60-68].

In conclusion, to our knowledge, this is the first study evaluating the impact of an educational comic intervention on patient-centered EHR use and patient self-advocacy for EHR engagement. We found that our educational comic was well received, participant ratings showed benefits in the outcomes measured, and there was no harm to participants as a result of their participation. Our comic may be effective in promoting patient-driven initiatives to enrich patient-physician-EHR interactions and may be most impactful in engaging African American patients, Hispanic patients, and patients with lower educational backgrounds [44,45,47,56]. Sharing the EHR screen and enhancing transparency and engagement with the EHR may increase a patient’s sense of partnership and trust with their physician, which may help promote increased trust of the medical system [26,44-47]. Moreover, patients from disadvantaged groups may need more formal encouragement to engage with their physicians and the EHR, which is important because enhanced engagement with providers and health care technology can help increase patient understanding of care plans and improve preparation for future visits [6,12,44-47,57]. Our educational comic may be used as a tool to empower vulnerable patients to be more engaged in their care and promote agency. In addition, patients with limited health literacy may rely on health information from social media and blogs, which can contain lower quality health information [47]. Encouraging patients to ask their physicians questions may help dispel health myths, promote health literacy, and help reduce health disparities [44-47].

With regard to patient satisfaction with physician EHR use, patients reported that their physicians demonstrated more patient-centered behaviors when using the EHR at the index visit as compared to prior visits. This may be due to the patient’s increased EHR engagement during the visit, which could have prompted physicians to engage in more patient-centered EHR behaviors. Future research is needed to better understand how enhanced patient EHR engagement is perceived by physicians and the impact on physicians’ EHR-related behavior.

Lastly, there were no significant differences in either adult or pediatric respondents thinking the comic was effective at encouraging continued involvement with the computer on phone follow-up. However, what is perhaps more important is that
educational attainment. This simple intervention can be easily replicated, and future work should focus on studying the impact of the educational comic in other clinical settings and objectively measuring behaviors related to the patient-physician-EHR interaction. Educational comics should be considered in future initiatives to promote patient education and humanistic patient-centered EHR use.

Acknowledgments

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Conflicts of Interest

None declared.

Multimedia Appendix 1

Adult patient comic initial survey.
[DOCX File, 21 KB - humanfactors_v8i2e25054_app1.docx ]

Multimedia Appendix 2

Adult patient phone interview script.
[DOCX File, 17 KB - humanfactors_v8i2e25054_app2.docx ]

Multimedia Appendix 3

Patient perceptions of comic intervention: postvisit survey results.
[DOCX File, 18 KB - humanfactors_v8i2e25054_app3.docx ]

References


Wolfe L, Chisolm MS, Bohsali F. Clinically Excellent Use of the Electronic Health Record: Review. JMIR Hum Factors 2018 Oct 05;5(4):e10426 [FREE Full text] [doi: 10.2196/10426] [Medline: 30291099]


Abbreviations

EHR: electronic health record
GIM: general internal medicine
PPC: pediatric primary care
SQUIRE: Standards for Quality Improvement Reporting Excellence
Developing a Decision Aid to Facilitate Informed Decision Making About Invasive Mechanical Ventilation and Lung Transplantation Among Adults With Cystic Fibrosis: Usability Testing

Katherine L Dauber-Decker¹, PhD; Melissa Basile¹, PhD; D'Arcy King¹, PhD; Jennifer Polo¹, BA; Karina Calise², BSc; Sundas Khan¹, MD; Jeffrey Solomon¹, BFA; Daniel Dunne³, MA; Negin Hajizadeh¹, MD, MPH

¹Donald and Barbara Zucker School of Medicine at Hofstra/Northwell, Feinstein Institutes for Medical Research, Center for Health Innovations and Outcomes Research, Manhasset, NY, United States
²School of Health Professions and Human Services, Hofstra University, Hempstead, NY, United States
³iDEAL Institute, Loyola Marymount University, Los Angeles, CA, United States

Corresponding Author:
Jennifer Polo, BA
Donald and Barbara Zucker School of Medicine at Hofstra/Northwell
Feinstein Institutes for Medical Research
Center for Health Innovations and Outcomes Research
600 Community Drive
Manhasset, NY, 11030
United States
Phone: 1 3474004684
Email: jpolo1@northwell.edu

Abstract

Background: Cystic fibrosis (CF) is a life-limiting genetic disease that causes chronic lung infections. We developed an internet-based decision aid (DA) to help patients with CF make better informed decisions regarding treatments and advance care planning. We built the DA around two major treatment decisions: whether to have a lung transplant and whether to agree to invasive mechanical ventilation (intubation).

Objective: This study aims to conduct usability testing of the InformedChoices CF DA among key stakeholder groups.

Methods: We performed a patient needs assessment using think-aloud usability testing with patients with CF, their surrogates, and CF clinicians. Think-aloud participants provided feedback while navigating the DA, and after viewing, they answered surveys. Transcripts from the think-aloud sessions and survey results were categorized into common, generalizable themes and optimizations for improving content, comprehension, and navigation. We assessed the ease of use of the DA (System Usability Scale) and also assessed the participants’ perceptions regarding the overall tone, with an emphasis on emotional reactions to the DA content, level of detail, and usefulness of the information for making decisions about either intubation or lung transplantation, including how well they understood the information and were able to apply it to their own decision-making process. We also assessed the DA's ease of navigation, esthetics, and whether participants were able to complete a series of usability tasks (eg, locating specific information in the DA or using the interactive survival estimates calculator) to ensure that the website was easy to navigate during the clinic-based advance care planning discussions.

Results: A total of 12 participants from 3 sites were enrolled from March 9 to August 30, 2018, for the usability testing: 5 CF clinicians (mean age 48.2, SD 12.0 years), 5 adults with CF, and 2 family and surrogate caregivers of people with CF (mean age of CF adults and family and surrogate caregivers 38.8, SD 10.8 years). Among the 12 participants, the average System Usability Scale score for the DA was 88.33 (excellent). Think-aloud analysis identified 3 themes: functionality, visibility and navigation, and content and usefulness. Areas for improvement included reducing repetition, enhancing comprehension, and changing the flow. Several changes to improve the content and usefulness of the DA were recommended, including adding information about alternatives to childbearing, such as adoption and surrogacy. On the basis of survey responses, we found that the navigation of the site was easy for clinicians, patients, and surrogates who participated in usability testing.

Conclusions: Usability testing revealed areas of potential improvement. Testing also yielded positive feedback, suggesting the DA's future success. Integrating changes before implementation should improve the DA’s comprehension, navigation, and usefulness and lead to greater adoption.
Introduction

Background

Cystic fibrosis (CF) is a life-limiting, progressive genetic disease that causes chronic lung infections [1,2] and persistent symptoms, including coughing, pneumonia, bronchitis, wheezing, difficulty breathing, and lack of weight gain and growth [3]. The average life expectancy for a person with CF is currently estimated at approximately 37 years [4]. However, because of variability among patients related to the natural course of pulmonary decline, it is difficult to estimate prognoses [5-10]. Therefore, it is often unclear when clinicians should initiate advance care planning (ACP) discussions with patients with CF. ACP allows patients' early consideration of the kind of end-of-life care they may want while they are able to fully understand the implications of different treatment options. ACP is recommended by the American College of Chest Physicians [11]; however, it is not widely practiced in patients with CF [12]. Encouraging patients to plan their care is important so that their end-of-life desires and needs are fully acknowledged and protected.

As part of the Cystic Fibrosis Foundation initiative to foster innovative approaches in CF-specific palliative care, our team at the Center for Health Innovations and Outcomes Research at Northwell Health undertook a multiphased study to develop an internet-based patient decision aid (DA) called InformedChoices [13]. We developed DA content around 2 crucial decisions that advanced patients with CF commonly face as their condition progresses: whether to have a lung transplant and whether to agree to intubation (invasive mechanical ventilation [IMV]) in the event of acute respiratory failure (Figure 1). The goal of the DA is to increase preference-congruent care at the end of life for patients with advanced stage CF by fostering shared decision-making conversations among adults with CF, their clinicians, and family caregivers. Therefore, the purpose of the DA is to be used by the CF clinician with their patients with CF and family members during outpatient clinic visits. The development of our DA content was guided by several key bodies of literature—DA design—specifically the International Patient Decision Aid Standards (IPDAS) Collaboration criteria for DA design, which presents a checklist of quality standards for the development of DA content [14]. For example, the IPDAS criteria provides patients a range of visual options for viewing prognostic survival estimates. Therefore, we included icon arrays, percentages, and graphs to convey information on the prognostic outcomes [15]. IPDAS also encourages the inclusion of methods to clarify patients’ values and goals of care. This is known as preference elicitation. Previous work encourages interactive and hierarchical approaches to eliciting preferences [16-18]. Therefore, we chose an interactive exercise offering patients a range of possible outcomes related to both lung transplantation and IMV. For each risk and benefit offered, users are able to slide a tab along a continuum from not important to very important. Finally, patients could view their results with the risks and benefits placed in hierarchical order from most important to least important. Additional criteria that we considered when designing the DA and on which we focused our usability testing included the use of plain language that could be understood by end users of various educational backgrounds, using stories or narratives that represent a range of outcomes, and presenting information in a balanced manner. Regarding the last point, when offering the risks and benefits of the various treatment options, we presented this information in side-by-side columns to allow clear visual representation of the risks and benefits.

We also explored the literature on both current DA development specific to ACP decision making [19-21] and literature on specific ACP and palliative care concerns faced by people with CF [22,23]. From this literature, we learned that individuals incorporate various types of knowledge into their decision making and often draw on previous lived experiences, which may compete with the biomedical information being conveyed. This influenced the study design of our usability testing, that is, the extent to which competing knowledge frameworks may actually impact users’ ability to understand the biomedical information being conveyed. This is reflected in our usability testing questions, which seek to determine the extent to which users not only understood the information but were then able to apply it to their own medical condition. Finally, there is a more recent body of literature on developing models of primary palliative care for CF. The focus is on allowing CF care teams to offer basic palliative care services, including ACP and goals of care discussions to people with CF on an ongoing basis, throughout the life course [22,23].
Objectives

Our DA is meant to be used in such contexts, that is, shared decision making among patients with CF, CF providers, and family and surrogate caregivers. Therefore, one of our usability testing goals was to ensure that CF clinicians were comfortable conveying the information contained in the DA about advanced CF treatments and that patients and caregivers could understand the information. We also sought to assess the possible emotional reactions to the information among patients and their caregivers. Usability testing allowed us to assess these factors with our target end users before rollout of a larger scale feasibility and acceptability study undertaken in outpatient clinic settings.

Finally, the design of the DA was further informed by a qualitative needs assessment where we interviewed adult patients with CF and family caregivers about their information needs as they pertained to ACP and CF treatment decisions and any previous discussions with their clinicians about both intubation and lung transplantation [13]. We also informally surveyed CF clinicians, asking them to tell us what information they felt their patients needed to know to make an informed decision about both intubation and transplant and to provide us with relevant peer-reviewed articles on which to base DA content. Guided by the abovementioned IPDAS criteria, review of literature, and direct stakeholder engagement, the DA’s website content includes descriptions of both intubation or IMV and lung transplantation, including the risks and benefits of each procedure. We also provided tailored prognostic estimates using multiple displays of data to accommodate different levels of health numeracy and preferences for information styles [24].

The needs assessment revealed that several participants preferred to learn about IMV and lung transplantation by hearing directly from patients with CF who had experienced intubation or lung transplantation. They expressed a desire for a more personal connection, that is, to know *what it felt like to go through lung transplant or IMV*, as opposed to the more clinical descriptions of the procedures that they were often given by their providers. This type of information allowed for greater emotional engagement with the DA content, which we believe may appeal to certain individuals’ learning styles and preferences for information. Therefore, we conducted interviews with patients with CF or family members about these treatments and edited them for inclusion in the DA. We also included additional content areas covering CF-specific mental health care, palliative care, and ACP based on what CF clinicians believed to be important for informed decision making related to CF ACP. Furthermore, from the needs assessment, we discovered that people’s desire for information varied, with some people wanting to know very detailed information about their treatment options and others preferring to know less. On the basis of this, our DA design allowed for basic as well as detailed information, as we allow individuals to navigate to a resources page that contains all of the references we used to write DA content (to accommodate those with high information-seeking preferences) and preference elicitation exercises for both IMV and lung transplantation, per IPDAS guidelines. Our overall goal was to ensure that our DA could accommodate a wide array of learning styles and information preferences to ensure the uptake of the information presented.

Following the initial design of the DA, we performed usability testing to maximize adoption, comprehension, and end user benefit before the final phase of the study—feasibility and acceptability testing of the DA among adults with CF, providers, and family members in ACP shared decision-making conversations in outpatient clinic settings. Although the DA is intended for shared decision-making conversations, our focus in undertaking a usability testing phase was to assess, among the 3 key stakeholder groups (patients, clinicians, and family surrogate caregivers), individual-level comprehension of the written content; perceptions of the usefulness for communicating about the risks and benefits of both pursuing or not pursuing lung transplant; and accepting or refusing intubation, visibility,
and ease of navigating the website. Our intention was to ensure that we had addressed any potential design problems and that content was understandable before the rollout of a larger scale feasibility and acceptability study. Herein, we present the results of the testing conducted among key CF stakeholders.

Methods

Study Design and Data Collection
Eligible participants were clinicians, patients, and surrogate caregivers who met the criteria described in the Eligibility section. On enrollment, each participant completed a basic demographic and health survey. Participants were then shown the DA either in person or remotely via Webex, a Health Insurance Portability and Accountability Act–compliant web-based conferencing platform. In both scenarios, a member of the research team observed the process and took detailed notes. Participants were asked to navigate through the DA at their own pace and click on the pages in any order they wished. Participants were encouraged and reminded throughout the testing session to think aloud as they progressed through the content and to voice their comments and reactions to the information and images in real time. This process was captured using Hypercam (Microsoft), a screen capture and audio recording software. Once participants viewed the DA, they were asked to complete 3 questionnaires to elicit their postexperience feedback. First, the validated System Usability Scale (SUS) [25] was used to measure the ease of use of the DA. The next 2 questionnaires were developed specifically to assess this specific CF DA. One questionnaire asked open- and closed-ended questions designed to measure the participants’ perceptions of the overall tone, with an emphasis on emotional reactions to DA content (eg, personalized prognostic estimates indicating survival over a 3-year period and reactions to images of an intubated patient), level of detail, and usefulness of the information for making decisions about either intubation or lung transplantation, including how well people understood the information and were able to apply it to their own decision-making process. This questionnaire also addressed the ease of navigation and esthetics of the DA. The other questionnaire focused on having participants complete a series of usability tasks (eg, locating specific information in the DA or using the interactive survival estimates calculator) to ensure that the website was easy to navigate during the clinic-based ACP discussions (Multimedia Appendices 1-4). We also administered participant demographics surveys (Multimedia Appendix 5 and Multimedia Appendix 6). All questionnaires were administered directly via REDCap, where the responses were stored, anonymized, and exported to Excel for analysis. All Hypercam recordings were transcribed for qualitative analysis. Feedback from the surveys and recordings were coded into usability themes, as described in Data Analysis section.

Eligibility

Clinician Participants
Doctors, other advanced practice providers (nurses, nurse practitioners, and respiratory therapists), or social workers who treat patients with CF aged >18 years were eligible for the study.

Patients
Patients with lung function score of forced expiratory volume in the first second <55% and/or clinician’s assessment of moderate to advanced stage CF, who had already undergone lung transplant, who were aged >18 years, and who speak English were eligible.

Surrogate Caregiver Participants
English-speaking individuals aged >18 years and currently caring for patients who meet the inclusion criteria mentioned earlier and caregivers of patients who died within the year before enrollment were eligible. Caregivers were primary caregivers and decision makers for people with CF and either parents or significant others of adults with CF; however, they did not need to be related to the patients who were enrolled in the study (ie, we did not enroll patients and caregivers as dyads).

In addition, all those participating remotely were required to have access to a computer with internet capability and a web camera installed or attached to their computer.

Recruitment and Consent
All participants were recruited from the Northwell Health CF Care Center, the University of Pennsylvania Perelman Center for Advanced Medicine, or the University of California San Diego Health Adult Cystic Fibrosis Program. Clinicians were recruited by the nonclinician members of the research team (ie, research coordinators) to avoid potential pressure to participate from their clinician peers who were members of the research team. Clinician-specific informed consent forms specifically stated that participation was voluntary and that decisions to not enroll in the study would not impact their employment. After being approached by a member of the research team at their respective sites, interested patients, surrogate caregivers, or clinicians were then referred to the research team at Northwell Health, the lead study site, where an investigator reviewed the main points of the study, answered any additional questions, and scheduled a time for the testing session. For in-person testing, written informed consent was obtained on site before initiating the testing session. For remote consent, the Northwell Health institutional review board–approved methods for remote consent were used. This involved using a phone script and sending consent forms via email before the scheduled testing day.

All participants received US $100 compensation for their time, regardless of their stakeholder groups. Before the initiation of our study, we obtained approval from the Northwell Health institutional review board. The funding agency had no role in the design of the study.

Data Analysis
Audios from the Hypercam recordings were transcribed and analyzed qualitatively by the Northwell Health Usability Lab to identify usability issues, including whether users were able to complete assigned tasks, and to identify any barriers encountered (eg, whether content was understood and whether users were able to navigate efficiently through the DA). Usability Lab members performed a thematic analysis of the transcripts from the Hypercam recordings. This involved coding
the transcripts into the following themes: functionality, visibility and navigation, and content and usefulness. Members of the Usability Lab first met to ensure that all readers were coding in a similar fashion and establish interrater reliability. This was established through discussion following the individual coding of a subset of transcripts. Each transcript was then coded and analyzed by a member of the Usability Lab, and a summary of common suggestions for each theme was generated. Usability Lab members brainstormed and discussed changes that could be made to the website to address common issues and suggestions, which were then incorporated into a subsequent round of DA revisions.

Data from closed-ended questions administered during testing were summarized descriptively. Our sample size was limited to 12 participants; therefore, we were unable to perform rigorous statistical analyses. As the established rule of usability testing states that 5 participants are sufficient to detect 80% of a product’s usability issues [26], we chose a total sample of 12 participants, including 5 patients with CF, 5 clinicians, and 2 surrogate caregivers.

Results

Participant Characteristics

A total of 12 participants from 3 sites were enrolled from March 9 to August 30, 2018. Our sample included 5 CF clinicians (physicians, social workers, and nurse practitioners), 5 adults with CF (2 of whom had already undergone a lung transplant), and 2 family and surrogate caregivers of people with CF. A summary of the participants’ demographic characteristics is available in Table 1.

Quantitative Analysis of Questionnaire Responses

Our quantitative analysis was performed using the SUS [25] to assess the usability of the DA. Among the 12 participants, there was an average SUS score of 88.33, which indicates an excellent score of B on the scale. The 5 clinicians gave the tool an average SUS score of 89.5; the 7 patients and surrogates gave an average score of 87.5. A summary of each participant’s SUS scores is presented in Table 2.

Table 1. Participants’ demographic characteristics.

<table>
<thead>
<tr>
<th>Participant</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clinicians (n=5)</td>
<td></td>
</tr>
<tr>
<td>Age (years), mean (SD)</td>
<td>48.2 (12.0)</td>
</tr>
<tr>
<td>Gender (female), n (%)</td>
<td>5 (100)</td>
</tr>
<tr>
<td>Years of experience with patients with cystic fibrosis, mean (range)</td>
<td>17.6 (9-29)</td>
</tr>
<tr>
<td>Profession, n (%)</td>
<td></td>
</tr>
<tr>
<td>Physician</td>
<td>2 (40)</td>
</tr>
<tr>
<td>Nurse practitioner</td>
<td>1 (20)</td>
</tr>
<tr>
<td>Social worker</td>
<td>2 (40)</td>
</tr>
<tr>
<td>Patients and surrogates(a) (n=7)</td>
<td></td>
</tr>
<tr>
<td>Age (years), mean (SD)</td>
<td>38.8 (10.8)</td>
</tr>
<tr>
<td>Gender (female), n (%)</td>
<td>3 (40)</td>
</tr>
<tr>
<td>Role, n (%)</td>
<td></td>
</tr>
<tr>
<td>Patient</td>
<td>5 (70)</td>
</tr>
<tr>
<td>Surrogate</td>
<td>2 (30)</td>
</tr>
</tbody>
</table>

\(a\)For the patients and surrogates group, 5 of the 7 participants provided age and gender information.
Table 2. System Usability Scale scores.

<table>
<thead>
<tr>
<th>Participant number</th>
<th>Participant category</th>
<th>System Usability Scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Clinician</td>
<td>82.5</td>
</tr>
<tr>
<td>2</td>
<td>Clinician</td>
<td>90</td>
</tr>
<tr>
<td>3</td>
<td>Clinician</td>
<td>100</td>
</tr>
<tr>
<td>4</td>
<td>Clinician</td>
<td>92.5</td>
</tr>
<tr>
<td>5</td>
<td>Clinician</td>
<td>82.5</td>
</tr>
<tr>
<td>6</td>
<td>Surrogate</td>
<td>90</td>
</tr>
<tr>
<td>7</td>
<td>Patient</td>
<td>100</td>
</tr>
<tr>
<td>8</td>
<td>Patient</td>
<td>100</td>
</tr>
<tr>
<td>9</td>
<td>Patient</td>
<td>92.5</td>
</tr>
<tr>
<td>10</td>
<td>Surrogate</td>
<td>90</td>
</tr>
<tr>
<td>11</td>
<td>Patient</td>
<td>47.5</td>
</tr>
<tr>
<td>12</td>
<td>Patient</td>
<td>92.5</td>
</tr>
<tr>
<td>_a</td>
<td>—</td>
<td>88.33</td>
</tr>
</tbody>
</table>

The average System Usability Scale score for all participants is presented in the last row. This does not imply missing data.

Thematic Analysis of Questionnaires and Think-Aloud Hypercam Recording Responses

Participants’ comments from all think-aloud testing sessions and surveys were grouped into 3 overarching themes: functionality, visibility and navigation, and content and usefulness. Major suggestions from these themes and accompanying participant quotes from the surveys and session transcripts are summarized in Table 3 and in the following sections.
### Usability theme and participants’ observations and comments

<table>
<thead>
<tr>
<th>Usability theme and participants’ observations and comments</th>
<th>Solutions implemented</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Functionality</strong></td>
<td></td>
</tr>
<tr>
<td>The Breathing Tube and Lung Transplant page drawers do not flow logically:</td>
<td><strong>Rearrange drawers (Figure 2):</strong></td>
</tr>
<tr>
<td>• “Situations in which a CFb patient... may need to decide about a breathing tube for procedures... this might go first... before we even look at the risks and benefits.” (Patient)</td>
<td>• Describe why it is important to think about getting a breathing tube or lung transplant</td>
</tr>
<tr>
<td>• Discuss factors associated with good and poor prognoses</td>
<td>• List risks and benefits associated with the treatment option</td>
</tr>
<tr>
<td>• Provide more information about the treatment option and situations in which a patient may need to decide about the treatment</td>
<td></td>
</tr>
<tr>
<td><strong>Visibility and navigation</strong></td>
<td><strong>Add an enlarge feature to the images</strong></td>
</tr>
<tr>
<td>The details in the pictures showing intubation and tracheostomy are difficult to see:</td>
<td><strong>Condense the risks and benefits sections of these pages and eliminate the repetition</strong></td>
</tr>
<tr>
<td>• “I wish I could see a bit more detail.” (Patient)</td>
<td><strong>Visually emphasize the statement at the top of the page telling users that estimates are for before treatment by bolding the text and enlarging the font size (Figure 3)</strong></td>
</tr>
<tr>
<td>• “Add [an] enlarge feature to read the small labels.” (Patient)</td>
<td><strong>Emphasize the following statement by bolding the text: “Remember these are only estimates and the numbers may not apply specifically to you” (Figure 4)</strong></td>
</tr>
<tr>
<td>The risks and benefits sections of the Breathing Tube and Lung Transplant pages are repetitive:</td>
<td><strong>Add a cancel button and close window option to the bottom of each story</strong></td>
</tr>
<tr>
<td>• “I would take away the repetitive risks vs benefits tables for each procedure.” (Clinician)</td>
<td><strong>Add the following phrase to the What’s Important to Me slider: “Seeing my children grow up is important to me” (Figure 5)</strong></td>
</tr>
<tr>
<td>• “…possibly revamping the pro and con section so that it doesn’t have so much repeating info throughout.” (Patient)</td>
<td><strong>Add descriptions of alternative options for becoming a parent, including adoption and surrogacy, to the decision aid (Figure 6)</strong></td>
</tr>
<tr>
<td>Participants were unclear on whether the survival estimates calculator provides estimates for before or after lung transplant or intubation:</td>
<td></td>
</tr>
</tbody>
</table>
Figure 2. Areas recommended for improvement on the cystic fibrosis decision aid. Drawer design as seen by study participants. Drawers on the Breathing Tube/Intubation (shown) and Lung Transplant (not shown) pages have now been reordered as follows: (1) why it is important to think about getting a breathing tube or lung transplant, (2) factors associated with good and poor prognoses, (3) more information about the treatment option, (4) situations in which a patient may need to decide about the treatment, and (5) risks and benefits associated with each treatment option. CF: cystic fibrosis; ICU: intensive care unit.

Figure 3. Survival estimates calculator. The initial phrase explaining the survival estimates calculator has been visually emphasized by bolding and enlarging the font. CF: cystic fibrosis.
Figure 4. Survival estimates calculator page as seen by study participants. The statement that the percentages generated by the survival estimates calculator are only estimates and do not necessarily apply to individual patients has now been bolded for emphasis. CF: cystic fibrosis.

First, the changes in functionality were identified. For example, one suggestion involved the drawer design of the Breathing Tube and Lung Transplant pages. A drawer design helps to minimize the content to prevent the user from seeing too much text at one time and becoming overwhelmed. By expanding each drawer category, the user has the ability to view additional content of interest. One suggested optimization was that the drawers on the Breathing Tube and Lung Transplant pages should be reordered to improve the logic of the DA’s flow. We have reordered the drawers, accordingly, as shown in Table 3 (Figure 2). Reordering the topics to make the flow of information more logical should make content more accessible and improve individual-level comprehension.

Visibility and Navigation
We also identified areas for improvement in the visibility of CF DA. For example, participants suggested that we enlarge the pictures displaying intubation and tracheostomy to increase the visibility of the smaller details of the images. One participant suggested that we:

add [an] enlarge feature to read the small labels.

With this change, users’ ability to engage with this content should improve.
In addition, several participants pointed out the repetition in the risks and benefits sections of the Breathing Tube and Lung Transplant pages. One participant from the patient and surrogate group suggested:

...possibly re-vamping the pro and con section so that it doesn’t have so much repeating info throughout.

Condensing this section should eliminate repetition.

Next, several users were unclear on whether the survival estimates calculator provided patients with estimates before or after lung transplantation or intubation. In a survey response, one clinician said:

I actually took the estimates to mean post-transplant...

Accordingly, we have bolded the text and enlarged the font size of the statement at the top of the page, telling users that these are pretreatment estimates (Figure 3). In addition, there was concern among clinicians that some patients might take these percentages too literally. One of our clinician participants said:

I just think that the concrete thinkers...could have a difficult time with that information even though you explained that they’re estimates and how you got the estimates...that it’s not written in stone.

On the basis of this feedback, we have emphasized the following statement by bolding the text: “Remember these are only estimates and the numbers may not apply specifically to you” (Figure 4). These changes should help with users’ emotional responses to and individual-level understanding of the prognostic estimates so that they can better understand and use this information.

Finally, our testing revealed an area for improvement in navigation. One clinician participating in our testing referred to a navigation issue on the patient and caregiver Stories page. The clinician said:

I chose to read the transcripts and when I got to the end of the lengthy transcript, I had to scroll all the way to the top to X out of the story.

As a result, the navigation on this page has been amended with the addition of a cancel button or close window option to the bottom of each story, rather than the requirement that users scroll back to the top of the page to close each of the individual stories.

Although we identified areas in which to improve visibility and navigation, our usability testing participants’ ability to navigate to the tasks was already excellent. When asked whether they were able to navigate to the pages containing information about lung transplants, the patient and caregiver stories, and the What’s Important to Me slider, all clinicians were able to do so. In addition to page navigation, all clinicians were able to complete the What’s Important to Me slider, all clinicians were able to do so. In addition to page navigation, all clinicians were able to complete the What’s Important to Me slider and view their results. Finally, 4 of 5 clinicians (80%) were able to find the resources for making an advance directive (Table 4). The patients and surrogates were asked to complete the same tasks. All patients and surrogates participating in our testing were able to find the pages with information about lung transplants, the patient and caregiver stories, and the What’s Important to Me slider. All patients and surrogates were also able to complete the What’s Important to Me slider. Finally, 6 of the 7 patients and surrogates (86%) were able to find the resources for making an advance directive. Overall, the navigation of the site was easy for the clinicians, patients, and surrogates who participated in usability testing.

Table 4. Task completion exercises.

<table>
<thead>
<tr>
<th>Question</th>
<th>Clinicians (n=5), n (%)</th>
<th>Patients and surrogates (n=7), n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Navigate to the page containing basic information about lung transplant. Were you able to complete this task?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>5 (100)</td>
<td>7 (100)</td>
</tr>
<tr>
<td>No</td>
<td>0 (0)</td>
<td>0 (0)</td>
</tr>
<tr>
<td>Find resources for making an advance directive. Were you able to complete this task?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>4 (80)</td>
<td>6 (86)</td>
</tr>
<tr>
<td>No</td>
<td>1 (2)</td>
<td>1 (14)</td>
</tr>
<tr>
<td>Find the page title “What’s Important to Me” for breathing tube. Were you able to complete this task?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>5 (100)</td>
<td>7 (100)</td>
</tr>
<tr>
<td>No</td>
<td>0 (0)</td>
<td>0 (0)</td>
</tr>
<tr>
<td>Complete the exercise and see your results. Were you able to complete the task?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>5 (100)</td>
<td>7 (100)</td>
</tr>
<tr>
<td>No</td>
<td>0 (0)</td>
<td>0 (0)</td>
</tr>
<tr>
<td>Find the page containing patient and caregiver stories about intubation and lung transplant. Listen to “Jeff’s Story.” Were you able to complete this task?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>5 (100)</td>
<td>6 (86)</td>
</tr>
<tr>
<td>No</td>
<td>0 (0)</td>
<td>1 (0)</td>
</tr>
</tbody>
</table>
Content and Usefulness

Finally, several changes to improve the content and usefulness of CF DA were recommended. One clinician mentioned that patients with CF are often motivated by their desire to survive for their children. Accordingly, we have added the following phrase to the slider: “Seeing my children grow up is important to me” (Figure 5). In addition, as posttransplant pregnancy can pose challenges to both mother and fetus [27], one participant suggested that we include information about alternatives to childbearing, such as adoption and surrogacy, on the Lung Transplant page. The clinician said that in their work settings, they are trying to improve the process of explaining to patients that they:

...can't physically carry [children themselves] but we can have [them] meet with an OBGYN or fertility providers prior to transplant to give [them] the best possible outcomes of having children in some other way or even...counseling about adoption..., surrogacy, different things like that.

These alternative options for becoming a parent have been added to the DA and should address an important emotional aspect of patient decision making (Figure 6).

Discussion

Principal Findings

Although both the clinician and patient and surrogate groups were largely able to complete each of the given tasks, our usability testing sessions revealed several areas for improvement on the CF DA, which we have incorporated. In the functionality theme, suggestions included reordering the content for a more logical flow. In the visibility and navigation theme, optimizations included enlarging the pictures, condensing sections to reduce repetition and improve clarity, visually emphasizing certain features, and adding additional cancel button or close window options to reduce unnecessary scrolling. Suggested improvements to content and usefulness included adding information about adoption and surrogacy for those who wish to become parents following lung transplantation.

In addition to their suggestions for ways to improve the CF DA, participants gave us positive feedback and felt that the DA would be of great benefit to future users. Notably, one of our participants, a surrogate who had children with CF and was also a nurse, said the following:

...I think it's a great tool. I think it's good to have this discussion. Even on my job learning, we talk about lung transplant but it's nice to have something to, you know, to open up the conversation.

One participant pointed to the DA's completeness, describing it as:

Very well done, very clear; hits all important considerations people need to make.

Another participant from the patient and surrogate group stated:

...this website is very informative and it's my belief that it will help a lot of people in the decision-making process.

Therefore, although there was room for improvement, participant responses point toward the future success of the DA in helping patients with CF and clinicians to make informed treatment decisions.

In designing the DA website content, one goal was to facilitate informed decision making via patient or clinician shared decision making. Previous work on informed decision making explores how to best present biomedically based information to ensure that those with low health literacy and numeracy can understand the information being presented. This correctly assumes that an informed decision rests on the individual-level understanding of the information being presented. Various studies have explored language levels (eg, readability should be at the eighth-grade level), and numeric data should be presented to ensure comprehension. Our previous work in DA design has further identified the importance of uptake, that is, the extent to which individuals are able to comprehend information and then apply it to their own decision making. In this way, our work adds to the literature on informed decision making by emphasizing patient-level self-assessment of what makes the patient similar to or different from the data being presented and thereby the extent to which the information is relevant to them. We were concerned with factors that may impact uptake, including previous lived experiences and emotional responses to the information. Therefore, our usability testing questions focused on assessing reactions to the tone of information about end-of-life and advanced CF treatment options. For example, all participants were asked the following survey question: “Was the tone of the information in the decision aid website appropriate?” Importantly, every participant answered “Yes” to this question. Similarly, participants were asked to comment on their reactions to seeing images of an intubated patient. None of the participants indicated emotional distress in their answers, and some even wanted to see the images in more detail. Taken together, participants’ overall feedback on the website combined with their responses to these questions eliciting emotional reactions to the website’s content indicated that the tone of the website was appropriate and would not elicit emotional responses that would interfere with their ability to comprehend and use the website’s content.

Our usability testing needs to be understood within the wider context of our multiphased study to develop and test the InformedChoices CF ACP DA. Beginning with a needs assessment, we sought to design a communication tool that asks people with a lifelong chronic illness to consider their future treatment choices in the event that their illness has progressed to the point at which they need to decide between life-extending treatment and comfort care. As a result, it was essential to assess both the functionality of the DA and individual-level reactions to the content in a controlled setting. Usability testing also allowed us to determine how comfortable clinicians would be accessing and communicating DA content to their patients with CF and how patients would react emotionally to the information before we undertook feasibility and acceptability testing within
the context of an outpatient clinic setting, on a wide scale, across multiple sites.

Next Steps

On the basis of the feedback from the usability testing, we revised the DA. We are currently undertaking multisite feasibility testing of the DA, where we are observing clinicians using it with patients with CF and surrogate caregivers during outpatient clinic visits. Following this, we will make additional revisions before rolling out the DA for use in our clinics and beyond. Our plan is to update the DA regularly as new information and treatments become available, including the survival estimates calculator as survival estimates change, and to add additional patient narratives.

Limitations

One major limitation of our study is that we did not administer the SUS again after revisions were made to the DA. Ideally, we would hope to see an increase in the SUS score after making our changes to the website; however, this was not a part of our study. Another limitation is that we did not test the end user comprehension of the DA. Further analysis of end user response to the DA will be performed as part of a feasibility study in the future. This will consist of observing clinicians, patients, and family caregivers using the DA during 2 ACP conversations in outpatient settings, where we will measure feasibility and acceptability as well as changes in knowledge and decisional conflict over multiple time points. The sample size will also be larger for this phase of our study. Our usability study results are also limited by sample size; however, usability testing is often performed iteratively and with small samples to allow for more in-depth understanding of barriers to use. We are confident that our usability testing sample of 12 participants was large enough for us to obtain substantial feedback, as small sample sizes have been shown to be sufficient to detect most of the usability issues of a product [26]. However, the small sample size precluded us from performing statistical analyses of our survey response data. Another limitation comes from our highly health literate test population, including clinicians who treat patients with CF and well-informed patients with CF and their surrogates. It is possible that not all of our future end users will be as health literate as our usability testing participants; however, as the DA’s end users will be clinicians, patients with CF, and surrogates of patients with CF engaged in shared decision-making conversations, it is highly likely that the opinions of our test population provide an accurate representation of the views of our target audience.

Conclusions

Usability testing helped us identify several areas for improvement of the CF DA. On the basis of user feedback, we have included these changes before implementation of the tool to improve the comprehension, navigation, retention, and overall usefulness of the DA. By integrating participant feedback and making these changes to the CF DA, we hope to improve the site in terms of end user benefits. We expect that these enhancements will lead to higher overall adoption rates of DA by clinicians, patients, and surrogates within our health system. We hope that in the future, this web-based clinical DA tool can be expanded for use in other health systems to help patients with CF and clinicians with ACP and the difficult decisions associated with CF.

Practice Implications

We modified the CF DA based on the user feedback obtained from our usability testing. Integrating changes before implementation should improve the DA’s comprehension, navigation, and usefulness. Importantly, this should also lead to a greater adoption of the DA.

Acknowledgments

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Authors’ Contributions

NH, the principal investigator of the study, was responsible for the design of the study, had full access to all of the data, and provided substantial editorial comments to the manuscript. KD contributed substantially to the analysis and interpretation of the quantitative and qualitative data from the study and to the writing of the manuscript. MB contributed substantially to data collection and contributed to the writing of the manuscript. DK contributed substantially to the writing of this manuscript. JP contributed substantially to the data collection. KC, SK, and JS contributed substantially to data analysis and interpretation. DD served as our CF patient partner and contributed to the data collection.

Conflicts of Interest

None declared.

Multimedia Appendix 1

Surveys and measures used as part of the usability testing.

[DOCX File, 12 KB - humanfactors_v8i2e21270_app1.docx]
The system usability scale is a 10-item questionnaire with 5 response options: strongly agree (5), agree (4), neither agree nor disagree (3), disagree (2), or strongly disagree (1).

Usability task completion exercises.

Usability testing survey.

Clinicians demographics.

Patient and surrogate demographics.

References


Abbreviations

ACP: advance care planning
CF: cystic fibrosis
DA: decision aid
IMV: invasive mechanical ventilation
IPDAS: International Patient Decision Aid Standards
SUS: System Usability Scale

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Development and Implementation of a Multidisciplinary Electronic Discharge Readiness Tool: User-Centered Design Approach

Angela Keniston1, MSPH; Lauren McBeth1, BA; Jonathan Pell Sr1, MD; Kasey Bowden1, MSN, FNP, AG-ACNP; Stephen Ball2, BSc; Kristin Stoebner2, BSN; Elaina Scherzberg2, BHA, RT(R); Susan L Moore3, PhD, MSPH; Jamie Nordhagen2, MS, RN; Amanda Anthony2, DNP, CCNS, ACNS-BC; Marisha Burden1, MD

1Division of Hospital Medicine, Anschutz Medical Campus, University of Colorado, Aurora, CO, United States
2UCHealth, Denver, CO, United States
3Colorado School of Public Health, University of Colorado, Aurora, CO, United States

Corresponding Author:
Angela Keniston, MSPH
Division of Hospital Medicine
Anschutz Medical Campus
University of Colorado
12401 E. 17th Avenue
Mail Stop F782
Aurora, CO, 80045
United States
Phone: 1 720 240 1431
Email: Angela.Keniston@cuanschutz.edu

Abstract

Background: Typical solutions for improving discharge planning often rely on one-way communication mechanisms, static data entry into the electronic health record (EHR), or in-person meetings. Lack of timely and effective communication can adversely affect patients and their care teams.

Objective: Applying robust user-centered design strategies, we aimed to design an innovative EHR-based discharge readiness communication tool (the Discharge Today tool) to enable care teams to communicate any barriers to discharge, the status of patient discharge readiness, and patient discharge needs in real time across hospital settings.

Methods: We employed multiple user-centered design strategies, including exploration of the current state for documenting discharge readiness and directing discharge planning, iterative low-fidelity prototypes, multidisciplinary stakeholder meetings, a brainwriting premortem exercise, and preproduction user testing. We iteratively collected feedback from users via meetings and surveys.

Results: We conducted 28 meetings with 20 different stakeholder groups. From these stakeholder meetings, we developed 14 low-fidelity prototypes prior to deploying the Discharge Today tool for our pilot study. During the pilot study, stakeholders requested 46 modifications, of which 25 (54%) were successfully executed. We found that most providers who responded to the survey reported that the tool either saved time or did not change the amount of time required to complete their discharge workflow (21/24, 88%). Responses to open-ended questions offered both positive feedback and opportunities for improvement in the domains of efficiency, integration into workflow, avoidance of redundancies, expedited communication, and patient-centeredness.

Conclusions: Survey data suggest that this electronic discharge readiness tool has been successfully adopted by providers and clinical staff. Frequent stakeholder engagement and iterative user-centered design were critical to the successful implementation of this tool.

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KEYWORDS
user-centered design; stakeholder engagement; health information technology; implementation science; interdisciplinary; teamwork; discharge planning; discharge readiness tool
Introduction

Communication across care teams in hospitals is often disjointed, which can lead to delays in care and adverse outcomes and can negatively affect team dynamics [1-4]. Planning for care progression and discharge relies on complex communication across multiple care teams, which are often physically separated from each other [1,5,6]. Discharging patients efficiently and safely continues to challenge health care systems worldwide [7-9]. Delays in discharge have been found to be associated with adverse patient outcomes, including mortality, medical complications such as infections, and impaired mobility or activities of daily living, as well as with slowed patient flow from the emergency department and throughout the hospital; these delays are also associated with increased hospital capacity challenges [7,10-14].

Typical approaches for moving discharge to earlier in the day and improving the flow of hospitalized patients rely on one-way communication mechanisms, static documentation in the electronic health record (EHR), and in-person care team huddles or telephone calls, which often take place on the day a patient is expected to be discharged [2,15-22]. Multidisciplinary rounds are a common workflow in many hospitals during which discharging patients are discussed. However, multidisciplinary rounds often vary in execution across clinical units; some approaches are more or less effective than others, with variable start times, different clinical staff in attendance, different processes for discussing the discharge of patients, and variable perception of effectiveness [23-25]. Many of these solutions rely on processes taking place outside of the EHR and interrupt patient care [26,27].

Effective use of health information technology (HIT) may introduce a degree of standardization to multidisciplinary rounds and huddles, improve discharge communication workflows, and alleviate delays in discharge [28]. Although communication between providers using the EHR is not well studied, data indicate that well-executed communication and collaboration between providers is associated with better patient outcomes, and the application of HIT in specific domains is associated with improved health care quality and safety [29,30].

Tools that enable dissemination of information at both the patient level and team level may provide the greatest utility, as providers and other clinical staff would be able to access information for each individual patient as well as for groups of patients being cared for by a specific team or on a specific floor. Given the success found in the application of HIT in specific domains, such as provider order entry or prescribing of medications [29-32], there is potential for the application of real-time electronic provider-to-provider or provider-to-service communication around the activity of discharge planning.

Addressing the need for a seamless solution to coordinating discharge processes, we developed an innovative tool (the Discharge Today tool) within Epic, the EHR in use at the University of Colorado Hospital, to facilitate communication in real time between hospitalists and other clinical staff regarding discharge readiness and barriers to discharge [2]. We hypothesized that systematic application of stakeholder engagement and workflow analyses as a part of a user-centered design process would lead to a well-designed HIT innovation that would be readily adopted and consistently used by providers and other clinical staff.

Methods

To guide the design of this tool, we applied several frameworks, including the analytic-deliberative model of stakeholder engagement [33] to enhance our stakeholder engagement efforts, the Coiera communication paradigm [34] to incorporate communication theory, and the Chokshi and Mann process model for user-centered digital development [35] to direct the iterative development of the tool.

Applying the analytic-deliberative model of stakeholder engagement [33], we involved our stakeholder partners, including patients, families and caregivers, clinical staff, clinical leadership, and administrative leadership. The analytic-deliberative model links analysis using information collected and deliberation by stakeholders with the intent of reconciling different viewpoints and making recommendations.

To that end, we met with clinical and administrative staff to gain an understanding of their experiences with the discharge process as well as the communication methods and tools currently used to disseminate information on barriers to discharge and readiness for discharge. We conducted workflow analyses with clinical staff directly involved in discharge communication and care of hospitalized patients. Finally, we engaged with patients who experienced discharge from the hospital through one-on-one discussions with patients and their families or caregivers. Stakeholder engagement to inform user-centered design was imperative to ensure that our Discharge Today tool was successfully integrated into existing workflows such that all clinical staff would use this tool with every patient. However, stakeholder engagement was only one aspect of our systematic approach to user-centered design in a clinical setting.

Similar to other types of computer-supported cooperative work technologies that support asynchronous collaboration, such as email, collaborative creation of documents, technologies designed to capture recommendations, repositories for shared information, and particularly workflow applications, the Discharge Today tool is an asynchronous communication tool [36]. To improve the flexibility, agility, efficiency, and accuracy of communication around discharge, we applied the Coiera communication paradigm [34]. This model describes four stages for communication (task identification, connection, communication, and disconnection) in which errors may occur at any point during the sequence, including how the communication system functions or is used or in the information available to those involved. By supporting asynchronous collaboration, building feedback loop capabilities, and implementing user role-dependent functionality, the Discharge Today tool reduces inefficiencies and, potentially, errors in the delivery of health care during the discharge process.

Using the Chokshi and Mann process model for user-centered digital development [35], we applied the four phases described with a continuous feedback loop between Discover, Define,
Develop, and Deliver. Phase one requires understanding the concepts and processes associated with the work being done, and phase two involves engaging with users to understand how they would use a tool and observing users in a laboratory environment before going live using two specific methods: “think-aloud” and “near-live” [35]. Phases three and four involve iterative development, testing, and optimization of a tool in the setting where the work is actively being done.

Using the methods described in this model, we were able to identify any fundamental incompatibilities between the EHR and typical clinical workflows, which are potential points of failure for provider-facing innovations. In addition, this model helped guard against overdesign of the tool to accommodate workflows, which can actually inhibit adoption.

As a part of our stakeholder engagement process, we applied a novel strategy, brainwriting premortem [37], to specifically engage stakeholders in identifying potential barriers that we might encounter when implementing the discharge readiness functionality in the EHR. The brainwriting premortem exercise was designed by researchers to rapidly stimulate ideas of ways in which an intervention or tool could fail in a focus group setting. This exercise has been found to be an efficient method for engaging stakeholders and generating feedback, specifically because it is designed to imbue a sense of psychological safety among participants [37]. During this exercise, participants were asked to write down all the reasons each of them could think of that would cause this tool to fail. This process was repeated iteratively, with stakeholders adding ideas to existing pages until no new ideas emerged. Upon completion of the exercise, the pages were collected and the content was collated later for consideration by the project team.

Following multidisciplinary stakeholder meetings and the brainwriting premortem exercise, we constructed the first of 14 low-fidelity prototypes. These prototypes were presented on paper to stakeholders for feedback and revision. The EHR application analysts building this tool provided guidance regarding the capabilities and limitations of the existing EHR functionality.

Using the final low-fidelity prototype produced, the Discharge Today tool was constructed in the test EHR environment (Figure 1). We convened “think-aloud” sessions with users from the Division of Hospital Medicine for two purposes. First, we asked users to interact with the tool following minimal instructions and using a modified cognitive task analysis approach [38], while we made note of challenges users encountered or questions asked. This information was used to inform both revisions made to the tool and instructions developed for users. Second, we asked users to talk about their perceptions of the tool, specifically its utility and usability, as they interacted with the tool. This feedback informed modifications made to the tool. Following these sessions, we transitioned to “near-live” testing, in which we conducted preproduction user testing with both hospital medicine providers and ancillary department staff using real patient data and updated instructions. The purpose of this testing was to identify any components of the tool that were not functioning as intended prior to transitioning to the pilot test.

Following any changes or additions to the Discharge Today tool, functionality testing took place in the test EHR environment with a secondary validation stage in a shadow EHR environment with real patient data on a set delay. In addition, the end users each tested any revision or addition to the functionality in the test EHR environment prior to moving updates to production. Monitoring of the functionality of the tool occurred via periodic testing of the tool in both the test EHR environment and the production environment to isolate issues with the tool that were not otherwise identified prior to the go-live phase. In addition, feedback was solicited from end users to identify issues that became apparent during clinical work. We approached clinical staff in their workplaces to obtain real-time feedback on the functionality of the tool.

Surveys were conducted following the final month of the pilot phase using Research Electronic Data Capture (REDCap), a secure, web-based application for building and managing web-based surveys and databases [39]. Physicians, advanced practice providers, nurses, care management staff, and other clinical staff were asked to complete surveys regarding the usability of the Discharge Today tool and their experience with it. The factors chosen for evaluation, including time required to use the tool, accuracy of data collected via the tool, and helpfulness of the tool, were selected based on stakeholder feedback from both providers and other clinical staff.
Results

During the Discover and Define stage of development, applying the analytic-deliberative model, we engaged with 20 different stakeholders in 28 separate meetings across disciplines and settings, including care managers, nurse managers, patients and caregivers, an established, university-based patient advisory panel, and EHR builders and consultants. We also met several times with clinical directors, advanced practice providers, and physicians from departments of hospital medicine, infectious diseases, cardiology, endocrinology, hematology, pulmonary/critical care, and nephrology. Finally, we met multiple times with clinical staff and managers from respiratory therapy, rehabilitation services (specifically occupational, physical, and speech therapy), interventional radiology, pharmacy, glucose management, echocardiography, the heart and vascular team, and dialysis (Table 1).
Table 1. Key stakeholders and their engagement activities.

<table>
<thead>
<tr>
<th>Key stakeholders</th>
<th>Engagement activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patients</td>
<td>• 1 Patient Advisory Panel meeting</td>
</tr>
<tr>
<td></td>
<td>• 10 telephone conversations</td>
</tr>
<tr>
<td>Hospital medicine providers</td>
<td>• 2 lunch meetings</td>
</tr>
<tr>
<td></td>
<td>• 1 avoidable delay survey</td>
</tr>
<tr>
<td></td>
<td>• 1 user testing session</td>
</tr>
<tr>
<td></td>
<td>• 2 usability and experience surveys</td>
</tr>
<tr>
<td>Nursing staff</td>
<td>• 2 meetings</td>
</tr>
<tr>
<td></td>
<td>• 2 usability and experience surveys</td>
</tr>
<tr>
<td>Case management/social work staff</td>
<td>• 2 meetings</td>
</tr>
<tr>
<td></td>
<td>• 1 usability and experience survey</td>
</tr>
<tr>
<td>Physical therapy/occupational therapy/speech-language pathology staff</td>
<td>• 3 meetings</td>
</tr>
<tr>
<td></td>
<td>• 1 usability and experience survey</td>
</tr>
<tr>
<td>Glucose management team members</td>
<td>• 1 meeting</td>
</tr>
<tr>
<td>Pharmacy staff</td>
<td>• 2 meetings</td>
</tr>
<tr>
<td></td>
<td>• 1 usability and experience survey</td>
</tr>
<tr>
<td>Respiratory therapy staff</td>
<td>• 3 meetings</td>
</tr>
<tr>
<td></td>
<td>• 1 usability and experience survey</td>
</tr>
<tr>
<td>Echocardiography staff</td>
<td>• 2 meetings</td>
</tr>
<tr>
<td>Interventional radiology staff</td>
<td>• 1 meeting</td>
</tr>
<tr>
<td>Department of Medicine clinical directors</td>
<td>• 1 meeting</td>
</tr>
<tr>
<td>Infectious disease staff</td>
<td>• 2 meetings</td>
</tr>
<tr>
<td>Cardiology staff</td>
<td>• 1 meeting</td>
</tr>
<tr>
<td>Endocrinology staff</td>
<td>• 1 meeting</td>
</tr>
<tr>
<td>Hematology staff</td>
<td>• 1 meeting</td>
</tr>
<tr>
<td>Pulmonary services staff</td>
<td>• 1 meeting</td>
</tr>
<tr>
<td>Renal medicine staff</td>
<td>• 1 meeting</td>
</tr>
</tbody>
</table>

During these meetings, we discussed the stakeholders’ experiences with the discharge process, what went well and what could be improved, and their current workflow related to discharge. We observed clinical staff interacting with the EHR to map how different staff providing care to patients used EHR functionalities and how the Discharge Today tool might best be integrated. Using the information gathered during conversations with and observation of stakeholders, we constructed a user journey to illustrate how the Discharge Today tool might best be integrated with existing workflows and what might be changed (Figure 2).
To work as designed, using guidance provided by the stakeholders involved in our user-centered design process, we developed a framework for our Discharge Today tool, encompassing the following functions and operational processes. First, the tool must populate a list of patients with information from designated data sources and display the results on a user interface dashboard for provider access. Second, the tool must be accessible from the customizable patient worklist available in the provider workflow whenever a provider logs into the EHR. Third, the discharge readiness status for each patient on a provider’s list must be displayed with color-coding (green if the patient is a definite discharge with a discharge order, yellow if the patient is a definite discharge without a discharge order, orange if the patient is a possible discharge this day, blue if the patient could go home tomorrow, red if the patient is not going home this day, and gray if the patient is expected to go home tomorrow).
in the next 24 to 48 hours). Fourth, data collected from primary team providers each morning via the Discharge Today tool must be pushed automatically through three different processes that are integrated seamlessly with existing clinical workflows: the EHR patient worklists via the Discharge Today follow-up column, the Care Progression report, and an auto-generated page. Finally, through a feedback mechanism implemented such that when staff from ancillary departments such as respiratory therapy (RT), physical therapy (PT), occupational therapy (OT), and speech-language pathology (SLP) document patient care in the EHR using their standard workflow, the primary team provider who originally reported a requirement from these ancillary departments must be alerted that something has changed, creating a feedback loop within the EHR. To alert providers using the Discharge Today tool, an icon indicating new information is populated in the Discharge Today tool column displayed in the provider’s list. Combining this functionality creates a tool that enables real-time communication among care team members via the EHR.

All data collected by the Discharge Today tool are stored in the transactional database of the EHR at the level of the patient hospital encounter. This supports real-time use, functional processes, and dashboard population. The tool populates a list of patients managed by individual providers with patient attributes, encounter attributes, provider attributes, and discharge readiness status, timing, and barriers into a user interface dashboard. Providers interact with their patient list in the dashboard and make item entries for each patient from structured category lists (Table 2). The data entered into the tool by the primary team provider populate the “Provider Identified Needs for Discharge” section of the Care Progression report used by providers, nursing staff, and care management staff to view the overall care of the patient during the hospitalization. The data entered also autopopulate a Discharge Today Follow-up column that is used as part of the provider’s patient worklists by consulting teams (eg, cardiology, endocrine, and gastrointestinal) and ancillary services (eg, RT, pharmacy, OT, PT, SLP, and wound care). Finally, for OT, PT, and SLP, an autogenerated page is sent that is populated with patient and discharge barrier data when a patient is identified as a definite discharge waiting on a final evaluation from these services.

### Table 2. Discharge Today data elements and sources in the electronic health record.

<table>
<thead>
<tr>
<th>Data element</th>
<th>Data source/location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patient attributes</td>
<td>Patient record</td>
</tr>
<tr>
<td>Encounter attributes</td>
<td>Hospital encounter record</td>
</tr>
<tr>
<td>Provider attributes</td>
<td>Provider record</td>
</tr>
<tr>
<td>Discharge probability categories</td>
<td>Transactional database tables</td>
</tr>
<tr>
<td>User interface highlight colors</td>
<td>Code extension</td>
</tr>
<tr>
<td>Discharge timing categories</td>
<td>Transactional database tables</td>
</tr>
<tr>
<td>Discharge barriers</td>
<td>Transactional database tables/alert criteria</td>
</tr>
<tr>
<td>Discharge follow-up comments</td>
<td>Transactional database tables</td>
</tr>
</tbody>
</table>

During the Develop and Deliver phase, from March 5 to July 31, 2019, we conducted iterative development, testing, and optimization of the Discharge Today tool while in use by Hospital Medicine advanced practice providers and physicians. During this phase, stakeholders requested 46 modifications, with 85% of these requests occurring in the first two months of the pilot study. Of the 46 modifications, 11 (24%) were set aside due to existing limitations in EHR functionality, and 10 (22%) were considered to have insufficient utility or potential for overdesign and were thus not pursued. A total of 25/46 modifications (54%) were successfully executed, and 3 of the 25 modifications (12%) were fully implemented after the end of the pilot period (Table 3).
Table 3. Modifications to the Discharge Today tool (N=25).

<table>
<thead>
<tr>
<th>Date requested (2019)</th>
<th>Request</th>
<th>Date fully modified (2019)</th>
</tr>
</thead>
<tbody>
<tr>
<td>March 7</td>
<td>Rename columns to help with clarity when providers are wrenching them in</td>
<td>March 8</td>
</tr>
<tr>
<td>March 11</td>
<td>If a provider reselects “possible,” “definite,” or “no,” reset the branching logic</td>
<td>March 14</td>
</tr>
<tr>
<td>March 17</td>
<td>PT/OT/SLP pages are sent out when selected, with lockout if more than one page is selected within 12 hours</td>
<td>March 8</td>
</tr>
<tr>
<td>April 1</td>
<td>Update names of columns to be less confusing for wrenching in or display in larger patient lists</td>
<td>April 8</td>
</tr>
<tr>
<td>March 5</td>
<td>Add Transportation as a barrier</td>
<td>April 12</td>
</tr>
<tr>
<td>March 6</td>
<td>Add PICC Line Placement as a barrier</td>
<td>April 12</td>
</tr>
<tr>
<td>March 8</td>
<td>Add a way to indicate future discharge (ie, in 24-48 hours)</td>
<td>April 12</td>
</tr>
<tr>
<td>March 12</td>
<td>Add DME as a barrier</td>
<td>April 12</td>
</tr>
<tr>
<td>March 12</td>
<td>Update RT barrier to Home O₂</td>
<td>April 12</td>
</tr>
<tr>
<td>March 12</td>
<td>Update the Social Work barrier to Social Work/Care Management</td>
<td>April 12</td>
</tr>
<tr>
<td>March 12</td>
<td>Add “Other consultant not listed” as a barrier</td>
<td>April 12</td>
</tr>
<tr>
<td>March 12</td>
<td>Update pager system to allow a page once every 12 hours</td>
<td>April 12</td>
</tr>
<tr>
<td>April 19</td>
<td>Combine PT and OT pager numbers</td>
<td>April 26</td>
</tr>
<tr>
<td>April 24</td>
<td>Indicate in the page set to PT/OT which discharge selection was made (“Possible” or “Definite”)</td>
<td>April 26</td>
</tr>
<tr>
<td>March 11</td>
<td>Reset column after 3 days</td>
<td>May 23</td>
</tr>
<tr>
<td>March 11</td>
<td>Automatically update to definite (green) when a discharge order is placed</td>
<td>May 23</td>
</tr>
<tr>
<td>April 11</td>
<td>Change the order of the barrier selections</td>
<td>May 23</td>
</tr>
<tr>
<td>April 12</td>
<td>New column to display barrier selections from the Discharge Today Primary column</td>
<td>May 23</td>
</tr>
<tr>
<td>April 12</td>
<td>Make the “In 24-48 hours” selection gray in color</td>
<td>May 27</td>
</tr>
<tr>
<td>March 5</td>
<td>Develop a feedback loop</td>
<td>June 24</td>
</tr>
<tr>
<td>April 26</td>
<td>Add Test Results (Laboratory, Radiology) as a barrier</td>
<td>June 27</td>
</tr>
<tr>
<td>June 14</td>
<td>Add Wound Care as a barrier</td>
<td>June 27</td>
</tr>
<tr>
<td>May 7</td>
<td>Add fields to capture more information about PT/OT barriers</td>
<td>July 30</td>
</tr>
<tr>
<td>July 2</td>
<td>Change “No” to “&gt;48 hours”</td>
<td>September 27</td>
</tr>
<tr>
<td>March 15</td>
<td>Add option to select for anticipated discharge tomorrow</td>
<td>December 3</td>
</tr>
</tbody>
</table>

*a: PT: physical therapy.
*b: OT: occupational therapy.
*c: SLP: speech-language pathology.
*d: PICC: peripherally inserted central catheter.
*e: DME: durable medical equipment.
*f: RT: respiratory therapy.

We found that most providers who responded to the usability and experience survey (21/24, 88%) reported that the tool either shortened or did not change the amount of time required to complete the discharge workflow. Of the nursing, care management, and other clinical staff surveyed who reported using the Discharge Today tool during the pilot study (34/67, 51%), all felt that the tool either shortened or did not change the amount of time required to complete their workflows. In addition, a majority of ancillary staff who completed the survey reported that they believed that hospitalists were updating the discharge information (26/34, 77%), that the information was accurate (22/34, 65%), and that the information was helpful (32/34, 94%). These data suggest that the Discharge Today tool was successfully adopted by providers and other clinical staff (Table 4).
Table 4. Provider (n=24) and clinical staff (n=67) responses to the survey on usability and experience of the Discharge Today tool following the pilot implementation period.

<table>
<thead>
<tr>
<th>Question</th>
<th>Providers (n=24)</th>
<th>Clinical staff (n=67)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Please select the ways in which you used the discharge tool (check all that apply).</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Entered/updated discharge information in patient list column</td>
<td>21 (88)</td>
<td></td>
</tr>
<tr>
<td>Viewed discharge information in patient list column</td>
<td>13 (54)</td>
<td></td>
</tr>
<tr>
<td>Viewed discharge information in the care progression report</td>
<td>3 (13)</td>
<td></td>
</tr>
<tr>
<td>Determine order of rounds, prioritizing early discharges</td>
<td>1 (4)</td>
<td></td>
</tr>
<tr>
<td>For what percentage of your patients did you use the tool?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0%-25%</td>
<td>0 (0)</td>
<td></td>
</tr>
<tr>
<td>26%-50%</td>
<td>5 (21)</td>
<td></td>
</tr>
<tr>
<td>51%-75%</td>
<td>3 (13)</td>
<td></td>
</tr>
<tr>
<td>76%-100%</td>
<td>16 (67)</td>
<td></td>
</tr>
<tr>
<td>When did you utilize the tool the most?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Beginning of shift</td>
<td>21 (88)</td>
<td></td>
</tr>
<tr>
<td>Middle of shift</td>
<td>5 (21)</td>
<td></td>
</tr>
<tr>
<td>End of shift</td>
<td>6 (25)</td>
<td></td>
</tr>
<tr>
<td>How did the tool affect your discharge workflow?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Saved time</td>
<td>6 (25)</td>
<td></td>
</tr>
<tr>
<td>Added time</td>
<td>3 (13)</td>
<td></td>
</tr>
<tr>
<td>Did not change</td>
<td>15 (63)</td>
<td></td>
</tr>
<tr>
<td>Did you use the Discharge Today – Follow-up Ancillary/Consultant tool over the last month?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>34 (51)</td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>33 (49)</td>
<td></td>
</tr>
<tr>
<td>Please select the ways in which you used the discharge tool.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Viewed discharge information in my clinical workflow</td>
<td>31 (91)</td>
<td></td>
</tr>
<tr>
<td>Contacted hospitalist who entered information in Epic</td>
<td>5 (15)</td>
<td></td>
</tr>
<tr>
<td>Viewed discharge information in the care progression report</td>
<td>14 (41)</td>
<td></td>
</tr>
<tr>
<td>Do you feel hospitalists are completing and updating the discharge information?</td>
<td>26 (77)</td>
<td></td>
</tr>
<tr>
<td>Did you find the information accurate?</td>
<td>22 (65)</td>
<td></td>
</tr>
<tr>
<td>Did you find the information helpful?</td>
<td>32 (94)</td>
<td></td>
</tr>
<tr>
<td>How did the tool affect your discharge workflow?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Saved time</td>
<td>21 (62)</td>
<td></td>
</tr>
<tr>
<td>Added time</td>
<td>0 (0)</td>
<td></td>
</tr>
<tr>
<td>Did not change</td>
<td>13 (38)</td>
<td></td>
</tr>
<tr>
<td>Do you find the tool helpful?</td>
<td>31 (91)</td>
<td></td>
</tr>
<tr>
<td>What prevented you from using the tool?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Discharge information not completed by hospitalists</td>
<td>6 (18)</td>
<td></td>
</tr>
<tr>
<td>Information not updated/accurate</td>
<td>7 (21)</td>
<td></td>
</tr>
<tr>
<td>Lack of time</td>
<td>5 (15)</td>
<td></td>
</tr>
<tr>
<td>Lack of knowledge</td>
<td>20 (61)</td>
<td></td>
</tr>
<tr>
<td>Forgot/overlooked</td>
<td>3 (9)</td>
<td></td>
</tr>
</tbody>
</table>
We also collected qualitative usability and experience data from hospital medicine providers and clinical staff following the pilot implementation period using open-ended questions in the REDCap survey. Themes were derived from responses provided to five open-ended questions included in the survey. Free text responses were coded, and a synthesis of the results emerging from the responses to each of the open-ended questions was summarized (Table 5).

Responses were categorized into five themes, namely efficiency, integration into workflow, redundancies avoided, expedited communication, and patient-centered outcomes. The data provided both positive feedback and opportunities for improvement.

Table 5. Qualitative usability and experience data from hospitalists and other clinical staff following pilot implementation of the Discharge Today tool.

<table>
<thead>
<tr>
<th>Theme</th>
<th>Quotes</th>
<th>Opportunities for improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Efficiency</strong></td>
<td>“Noted quick responses from PT/OT for evaluation which expedited discharge.”</td>
<td>“Not all teams are utilizing the tool yet.”</td>
</tr>
<tr>
<td></td>
<td>“I think it is quick and hopefully as all ancillary staff learn to utilize it can continue to improve discharge times.”</td>
<td></td>
</tr>
<tr>
<td><strong>Integration into workflow</strong></td>
<td>“Well integrated into my existing workflow.”</td>
<td>“Sometimes the options available to explain what is holding up a discharge does not apply…would be nice to have an “other” comment box.”</td>
</tr>
<tr>
<td><strong>Avoidance of redundancy</strong></td>
<td>“In theory, it should avoid redundancies and emphasize the hold up to discharges…If nurses know we are consistently updating this it would help eliminate unnecessary pages.”</td>
<td>“Other services/staff learning to utilize it in their workflows.”</td>
</tr>
<tr>
<td></td>
<td>“Some ancillary services are still utilizing old workflows.”</td>
<td></td>
</tr>
<tr>
<td><strong>Expedited communication</strong></td>
<td>“It is nice to be able to state what would be potentially holding up the discharge and not have to call those services/departments directly.”</td>
<td>“A little more feedback about what is happening as we click these things (like a little small font blurb).”</td>
</tr>
<tr>
<td><strong>Patient-centered outcomes</strong></td>
<td>“Per the DC tool knew [the patient was] going to be going home in the next day or two. I was able to decide on a DC plan and send the prescriptions to the pharmacy for fill. Low [sic] and behold, the insulin prescribed was not covered so we were able to revise the plan well before day of DC therefore avoiding a delay.”</td>
<td>“Would it be possible that a checklist could be given to the patient? Allowing patient to follow the process…an opportunity to ask questions?”</td>
</tr>
</tbody>
</table>

**Discussion**

The important findings of this work are (1) providers, hospital clinical staff, and patients are willing to serve as stakeholders to help guide the user-centered design of an EHR-based tool and (2) stakeholder engagement during preimplementation, throughout implementation, and into postimplementation results in positive feedback and substantial adoption by clinical staff.

We applied communication theory to the design of this tool with the intent of fostering interdisciplinary discharge communication and teamwork. Communication across care teams and improved interdisciplinary care has been recognized as an important factor for high-quality patient-centered care and for high-functioning teams. Studies have shown that when care teams communicate better, efficiency outcomes are improved [18]. Patients have also expressed a need for the clinical staff caring for them to communicate with each other more effectively [40].

Studies exploring the use of the EHR for discharge planning have been limited to static electronic reports constructed from EHR data elements, including barriers to discharge documented at admission, care management data, and discharge criteria [19], or other targeted interventions, such as improving discharge summaries for patients or medication reconciliation at discharge [20,21,32,41]. In contrast, our Discharge Today tool was designed to capture and disseminate patient discharge readiness in a real-time, dynamic way, as opposed to merely reporting static discharge information via standard report functionality.

Tyler et al [19] reported developing and implementing an EHR-based discharge readiness report for medical and medical subspecialty patients that provides a summary of information related to patient discharge. As with our tool, this report was easily accessible and readily adopted by clinical staff. Researchers from the University of Wisconsin Hospital and Clinics described designing an EHR-based discharge summary template that was successfully adopted by clinicians hospital-wide [21]. Similar to these other projects designed to improve discharge communication and workflow, our Discharge Today tool was readily adopted by both providers and other clinical staff.
Although common quality improvement tactics, such as identifying champions, Plan-Do-Study-Act cycles, and process mapping, are valuable tools, developing and implementing HIT innovations necessitates frameworks and methods that are specifically designed for HIT. To engage hospitalists, nurses, other clinical staff, patients, families and caregivers, and hospital leadership, we met with 20 different stakeholder groups to obtain feedback about the design and functionality of the tool. Following this engagement process, we made improvements, implemented a pilot tool, and assessed discharge processes and both provider and clinical staff experience with the tool. To guide the development and implementation of our pilot Discharge Today tool, we chose to apply the analytic-deliberative model of stakeholder engagement [33] and the Chokshi and Mann process model for user-centered digital development [35].

Our approach to stakeholder engagement and user-centered design had a number of strengths. We deliberately, proactively applied established frameworks to guide both our stakeholder engagement process and the process of designing our tool. In addition, we leveraged existing functionality in our EHR to create an innovative discharge communication tool based on a design framework developed in collaboration with our stakeholders. Finally, this discharge communication tool facilitates real-time communication across hospital clinical staff, reducing reliance on static communication tools or interruptions to clinical care.

Our approach had a few limitations. We were unable to identify stakeholders in every clinical area of the hospital with whom communication about patient discharge readiness or barriers may occur. In addition, limitations to functionality of the EHR at the time of the development of this tool restricted the development of feedback loops to discharge barriers related to physical therapy, occupational therapy, speech therapy, and respiratory therapy rather than across all clinical areas. We continue to work with hospital leadership to fully integrate the Discharge Today tool with other initiatives implemented to improve discharge processes, improve patient flow, and alleviate capacity problems. Finally, as this tool expands in scale, future work will begin to assess how this type of tool (and future modifications thereof) affects quality measures such as patient experience, teamwork, and potentially readmissions.

By using a deliberate and collaborative stakeholder engagement process, we obtained commitments from numerous key stakeholders to participate in the design and testing of our EHR discharge readiness tool. The tool has been implemented for clinical use, and we have conducted an extensive evaluation of the implementation and effectiveness of the tool from a multistakeholder perspective. Survey data collected from Hospital Medicine providers and ancillary clinical staff suggest that the tool has been successfully adopted by clinical staff.

Acknowledgments
The authors report funding from the Data Science to Patient Value program at the University of Colorado, Anschutz Medical Campus.

Conflicts of Interest
None declared.

References


Abbreviations

- **EHR**: electronic health record
- **HIT**: health information technology
- **OT**: occupational therapy
- **PT**: physical therapy
- **REDCap**: Research Electronic Data Capture
- **RT**: respiratory therapy
- **SLP**: speech-language pathology

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Comparing Single-Page, Multipage, and Conversational Digital Forms in Health Care: Usability Study

Aleeha Iftikhar¹, MSc; Raymond R Bond¹, BSc, PhD; Victoria McGilligan², BSc, PhD; Stephen J Leslie³, BSc, MBChB, PhD; Khaled Rjoob¹, MSc; Charles Knoery³, MBChB; Ciara Quigg⁴, DipNSc; Ryan Campbell⁴, BSN; Kyle Boyd⁵, BSc, MA, PhD; Anne McShane⁶, MSc; Aaron Peace⁴, MRCPE, PhD

¹Computing Engineering and Build Environment, Ulster University, Jordanstown, United Kingdom
²Centre for Personalised Medicine, Ulster University, Londonderry, United Kingdom
³Cardiac Unit, Raigmore Hospital, Inverness, United Kingdom
⁴Department of Cardiology, Altnagelvin Hospital, Western Health and Social Care Trust, Londonderry, United Kingdom
⁵Faculty of Arts, Humanities & Social Sciences, Ulster University, Belfast, United Kingdom
⁶Letterkenny University Hospital, Letterkenny, Ireland

Corresponding Author:
Aleeha Iftikhar, MSc
Computing Engineering and Build Environment
Ulster University
Shore Rd, Newtownabbey
Jordanstown, BT37 0QB
United Kingdom
Phone: 44 07496635353
Email: iftikhar-a1@ulster.ac.uk

Abstract

Background: Even in the era of digital technology, several hospitals still rely on paper-based forms for data entry for patient admission, triage, drug prescriptions, and procedures. Paper-based forms can be quick and convenient to complete but often at the expense of data quality, completeness, sustainability, and automated data analytics. Digital forms can improve data quality by assisting the user when deciding on the appropriate response to certain data inputs (eg, classifying symptoms). Greater data quality via digital form completion not only helps with auditing, service improvement, and patient record keeping but also helps with novel data science and machine learning research. Although digital forms are becoming more prevalent in health care, there is a lack of empirical best practices and guidelines for their design. The study-based hospital had a definite plan to abolish the paper form; hence, it was not necessary to compare the digital forms with the paper form.

Objective: This study aims to assess the usability of three different interactive forms: a single-page digital form (in which all data input is required on one web page), a multipage digital form, and a conversational digital form (a chatbot).

Methods: The three digital forms were developed as candidates to replace the current paper-based form used to record patient referrals to an interventional cardiology department (Cath-Lab) at Altnagelvin Hospital. We recorded usability data in a counterbalanced usability test (60 usability tests: 20 subjects×3 form usability tests). The usability data included task completion times, System Usability Scale (SUS) scores, User Experience Questionnaire data, and data from a postexperiment questionnaire.

Results: We found that the single-page form outperformed the other two digital forms in almost all usability metrics. The mean SUS score for the single-page form was 76 (SD 15.8; P=.01) when compared with the multipage form, which had a mean score of 67 (SD 17), and the conversational form attained the lowest scores in usability testing and was the least preferred choice of users, with a mean score of 57 (SD 24). An SUS score of >68 was considered above average. The single-page form achieved the least task completion time compared with the other two digital form styles.

Conclusions: In conclusion, the digital single-page form outperformed the other two forms in almost all usability metrics; it had the least task completion time compared with those of the other two digital forms. Moreover, on answering the open-ended question from the final customized postexperiment questionnaire, the single-page form was the preferred choice.

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Interoduction

Background
Currently, when a primary percutaneous coronary intervention (PPCI) referral is made, the nurse activator in the coronary care unit will triage the patient using written notes. Typically, when a patient experiences chest pain, paramedics arrive and record an electrocardiogram. If the paramedic suspects a heart attack, they will then contact the PPCI department at a hospital and describe the symptoms and electrocardiogram findings to an activator nurse, who then completes a paper form shown in Figure 1 and decides whether patients need to be accepted or turned down.

Figure 1. The current paper-based form being used at Altnagelvin Hospital.

This is not unusual, as most hospitals and cardiac care units often rely on paper-based forms for data entry for patient admission or drug prescriptions and other general procedures. Working with paper-based systems can be challenging, especially when a health care staff works in a sensitive and highly stressful environment, such as cardiac care. Digitalization is slowly being introduced into the health service to improve the medical workflow at different stages and levels. Many applications serve many purposes, including facilitating communication between a patient and a provider, remotely monitoring patients, and measuring population health objectives, such as disease trends. The collected information can be used
to make informed decisions about health care services, either at the population level or individual level, to improve care [1]. Electronic health record (EHR) adoption rates have introduced efficiencies in health care operations, such as instant access to information, improved practice management, and reduced paperwork. Other findings relate to the impacts that EHR systems have on physicians’ time, expertise, and learning. The literature also present findings on the impact of EHR systems at the length (and sometimes the accuracy) of the clinical notes [1]. Again, multiple factors contribute to these intrusions, including computer availability, physical positioning of computers, design of the user interface, length of the forms, and procedure of filling the forms. Physician-residents have to use EHR systems because of their mandatory nature; however, if they had a choice or power, most physicians would likely use the paper chart [1]. Recent work has suggested that clinical decision support systems integrated within EHR systems hold the promise of improving health care quality. To date, the effectiveness of clinical decision support systems has been less than expected, especially concerning the ambulatory management of chronic diseases [2]. Nevertheless, although digitization is a drive to improve services, clinicians may not always welcome new digital systems [3]. Certain hurdles may make them reluctant to adopt a digital system, such as prior investment and familiarity with a current system (known as baby duck syndrome) [4] and availability, training, and the position of the system [3]. Although it is feasible to use digital forms in medicine, it has its design constraints, including limited display size and the challenge of replicating the user experience of paper forms or checklists [5]. These constraints can be handled; however, there are many conflicting guidelines available on appropriate user-centric designs. Bevan [6] analyzed usability guidelines to inform a user-centric design. Bevan [6] compared these usability methods with those found in textbooks and discussed the most effective way to present user-centric guidelines through a website.

Prior Work

Similar to other fields, digitalization and digital transformation play an essential role in health care. Health care technologies are rapidly growing and evolving; for example, EHR systems are becoming routine [7]. Moreover, different digital forms are being used in medicine in several ways, such as recording triage or referral data, observations of vital signs, and synoptic reporting in pathology. Digital forms and digital checklist systems are computer-based instructions for recording or performing actions as part of managing tasks [6]. Numerous research studies have studied digital forms in medicine, especially the use of mobile digital forms to support high-quality data collection [8]. It has been stated that electronic reporting is often more efficient and representative with higher rates of data completions [9] and is more effective for supporting clinical decision making. One study stated that using a standard single-page digital form called the standardized outpatient osteopathic note form was more efficient and accurate than the paper-based equivalent [10]. There has been a recent demand for smart checklists (often digital) in medical procedures to reduce iatrogenic or medical errors [11]. A comparison of team performance used a paper checklist with a digital checklist to determine whether digitizing a checklist led to improvements in task completion. The researchers found some improvements in team performance when using the digital checklist [12]. A study developed and evaluated two different versions of a tablet-based cognitive aid to support in-hospital resuscitation team leaders. They suggested that digital cognitive aids may help increase effectiveness and eventually improve patient safety [13]. Chatbots and conversational forms are also being tested in different fields. A comparison of surveys presented as traditional web pages versus chatbot or conversational style surveys (text-based virtual agent) found that participants who used the chatbot style survey produced higher-quality data [14].

Goal

Given the demand for effective digital forms, there is a need to research and discover the best-practice interaction design guidelines for designing digital health forms. In this study, we designed three different digital form styles to replace a paper form that is used for patient referrals to a PPCI service. To contribute to future digital form design guidelines in health care, the study also aims to compare the usability of all three forms to analyze which form styles work best for health care professionals. However, measuring usability is difficult because usability does not refer to a single property; rather, it combines several attributes [15]. According to the standard International Organization for Standardization 9421-11, usability is the effectiveness, efficiency, and satisfaction by which users must achieve a certain goal in a particular environment [16]. This study aims to measure and compare the usability of these three interactive form designs in a counterbalanced experiment in a controlled laboratory at Altnagelvin Hospital.

Methods

Overview

Textbox 1 shows the adopted structure describing the usability test flow for this study.
Textbox 1. Adopted structure describing the usability test flow for this study.

**Objective**
- The focus or aim is to compare different digital form designs to evaluate which digital form has greater usability.

**Participants**
- The total study population consisted of 20 health care staff who were either cardiac nurses or research nurses.

**Apparatus**
- Microsoft surface pro to display the digital forms and to facilitate user interaction, a microphone to record the user’s think-aloud data, and screencasting software to video record the user interactions with the digital forms
- Questionnaires (System Usability Scale and User Experience Questionnaire) to measure usability and R-studio for data analysis

**Outcomes**
- System Usability Scale usability score, usability errors, and task completion times

**Procedure**
- Counterbalanced experiment to avoid any learning bias
- Typical patient scenarios were presented to the user to facilitate the form completions.

**Data analysis**
- Summary analysis of System Usability Scale scores, User Experience Questionnaire results, task completion times, error rates using descriptive statistics, and boxplots
- Hypothesis testing (t tests, where α<.05) was used to determine statistical significance between System Usability Scale scores and task completion times

**Data Set**
This study involved the analysis and comparison of three different digital form designs that were developed as candidates for recording patient referrals to a PPCI service at Altnagelvin Hospital (Northern Ireland, the United Kingdom). This study only aims to compare the digital forms, as there are already studies that compare paper forms with digital or electronic forms [17-22]. The paper form was only included to compare the task completion time, and no other metrics were recorded to measure the usability of the paper form. The total study population consisted of 20 health care staff (men: 4/20, 25%; age: 30-39 years) who were either cardiac nurse activators or research nurses. This study included 10 cardiac nurse activators and 10 research nurses.

**Development of Digital Forms**
The three different digital forms were developed using the HTML 5 and cascading stylesheets (CSS3) following the model view controller paradigm. An open-source scripting library was used to convert the web form into a conversational form [23]. The three digital form designs included (1) a single-page form, (2) a multipage form, and (3) a conversational form (chatbot), as shown in Figure 2, Figure 3, and Figure 4, respectively. The single-page form is where all the input fields are organized and given on a single screen, whereas the multipage form segments the input fields over seven different screens or pages in the form of tabs. In this case, the user completes one page of the form and then navigates to the next tab or section. In the conversational form, the questions are presented to the user in a preset sequence of questions where the user can type in the answer or choose from a series of options. The rationale and expected pros and cons of each type of digital form are presented in Table 1.
Figure 2. Screenshots of a part of the single-page form.

Figure 3. Screenshots of the screens from the multipage form.
Table 1. Expected pros and cons of the three digital forms.

<table>
<thead>
<tr>
<th>Form type</th>
<th>Pros</th>
<th>Cons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single-page form</td>
<td>• Easy to understand</td>
<td>• High information rate. Busy looking screen with possible clutter</td>
</tr>
<tr>
<td></td>
<td>• Common form style and meets expectations</td>
<td>• User can be distracted by the number of questions required</td>
</tr>
<tr>
<td></td>
<td>• User can view all questions and input fields expected of them</td>
<td>• The screen can require more mental workload to interpret</td>
</tr>
<tr>
<td></td>
<td>• User can predict the work required to complete the form</td>
<td>• Information overloading can result in visual hierarchy issues</td>
</tr>
<tr>
<td></td>
<td>• Easy to navigate to all information on a single page</td>
<td></td>
</tr>
<tr>
<td>Multipage form</td>
<td>• Deconstructing a task into subtasks reduces cognitive load</td>
<td>• Additional interactions (clicks) to navigate to the different</td>
</tr>
<tr>
<td></td>
<td>• Less distracting for users</td>
<td>sections</td>
</tr>
<tr>
<td></td>
<td>• User can be guided and focused on a small set of related questions</td>
<td>• Misleads the user into thinking the form is shorter than it is</td>
</tr>
<tr>
<td></td>
<td>• Creates a sense of progression</td>
<td>• It might take longer to complete</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• User needs to navigate to change answers from a previous</td>
</tr>
<tr>
<td>Chatbot form</td>
<td>• Easy to use</td>
<td>form subsection</td>
</tr>
<tr>
<td></td>
<td>• Fewer distractions given only one question is presented per</td>
<td></td>
</tr>
<tr>
<td></td>
<td>interaction</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• It is akin to everyday human interaction or to being interviewed</td>
<td>• Not a common form style</td>
</tr>
<tr>
<td></td>
<td>and hence engenders focus</td>
<td>• Editing previous input could be cumbersome and require a lot of</td>
</tr>
<tr>
<td></td>
<td>• Less cognitive demand</td>
<td>interactions</td>
</tr>
<tr>
<td></td>
<td>• It is novel</td>
<td>• It seems too playful for formal settings such as medicine</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Preset sequence to follow</td>
</tr>
</tbody>
</table>

Usability Testing Protocol

The participants identified to be suitable and interested in participating were given a participant information sheet, and written informed consent was obtained from all participants interested in the study (by the author).

This study tested three different digital forms in a simulated setting where each participant was given a brief tutorial on how to use the tablet PC (Microsoft Surface Pro) that hosted the digital forms. Each participant was provided with the same four PPCI triage–simulated scenarios written on a sheet as shown in Multimedia Appendix 1 and was asked to complete a paper form (standard routine clinical form) and each of the three digital form designs. The sequence of when the subject interacted with the digital forms was counterbalanced to avoid any learning bias. Each session took approximately 60 minutes for each participant. Figure 5 shows the session protocol.
The researcher observed the participants while they completed the forms, and notes were taken to record usability issues. Form completion was recorded using a screen recording software (FreeScreenRecorder by Screencast-O-Matic [24]) on the tablet. Usability factors were evaluated, including user satisfaction; error rate (error rate was noted while observing the participants filling in the form as well as after the session by watching the recorded video); classification of the severity of the usability issues or error analysis, which was recorded using Nielsen’s 4-star severity scale, that is, cosmetic to severe (1-4) [25]; task completion time (each form completion time was noted for each participant using a stopwatch and cross-checked with the video timings); and ease of use (ease of use is a basic concept that describes how easily users can use a product). All questionnaires had questions related to ease of use. Moreover, the error rate and task time also depict the user’s ease of using a particular form design. After completing each form, participants were asked to complete the System Usability Scale (SUS) questionnaire [26].

The SUS is commonly used and is a validated questionnaire consisting of 10 items. The scoring of this questionnaire provides a usability score ranging from 0 to 100. An SUS score of >68 is considered above average, and anything <68 is considered below average. A study by Tullis and Stetson [27] performed a comparison of questionnaires for assessing website usability using the Computer System Usability Questionnaire [28]. Brooke [29] developed the SUS in 1996 [29]. The SUS uses a 5-point scale, ranging from strongly agree to strongly disagree. According to Bangor et al [30], the SUS is flexible in assessing a wide range of technologies. The SUS is also relatively quick and easy to use by study participants. Additionally, the SUS provides a single score on a scale that is easily understood. User experience was also recorded using the standard User Experience Questionnaire (UEQ). The UEQ measures six factors: attractiveness, perspicuity, efficiency, dependability, stimulation, and novelty [31]. This questionnaire can be used in different scenarios to record the user experience [32]. The UEQ provides the user with a bidirectional Likert scale with both positive and negative aspects of the system for them to rate, such as questions with positive connotations (easy to learn and creative) and questions with negative connotations (annoying, boring, and not interesting). The questionnaires were completed for all three forms to benchmark and compare the usability of the user interfaces for both positive and negative attributes of each form [33].

A customized postexperiment questionnaire was administered at the end of the session. The postexperiment questionnaire was a final customized researcher-created questionnaire. This questionnaire had 21 usability-related questions that focused more on the needs and types of preferred forms and preferred features.

The recorded data were then analyzed to compare the usability and user experience for each form. This process was used for each subject and also consisted of (1) the concurrent think-aloud protocol and a brief interview, (2) screen recording of the user interactions, and (3) usability evaluation of the final digital form prototypes (60 usability tests: 20 subjects×3 forms). Each participant was observed while they completed each digital form.
form. The screencast was used to analyze and evaluate the user’s behavior.

The data were collected through observations made while the participants were interacting with the digital forms. We then computed the error rate, task completion time, and user satisfaction. For the error rate analysis, a possible error list was made for each form design, and then, the number of errors was noted for each digital form against each user. The least task completion time for a form and the lowest error rate for a particular form can indicate the best form eliciting the highest user satisfaction. User satisfaction was also more explicitly covered in the SUS and UEQ. The postexperimental questionnaire also asked the user about their preferred choice of digital form design.

Data Analysis

Different statistical metrics are used, including median, mean, and SD for the variance. The paired two-tailed $t$ test was used to compare any differences between the task or form completion times and the SUS scores between all the three forms. Owing to the multiple statistical tests on the same data sets, Bonferroni corrections were used. Pearson correlation was used to identify any association between the SUS scores and the task completion times. It was not feasible to perform correlation analysis between other usability factors, such as UEQ answers and error rates, given that they generate categorical results, unlike SUS and the task time, which are numeric values.

Ethical Aspects

Research governance permission was granted by the Western Health and Social Care Trust (WT 19/08, Integrated Research Application System 262557) and complied with the Declaration of International Research Integrity Association (Multimedia Appendix 2).

Results

SUS Score Analysis

On the basis of the research, an SUS score of $>68$ is considered above average [34]. With a mean SUS score of 76 (SD 15), the single-page form outperformed the usability of the multipage and conversational forms. The multipage form was on the borderline with a mean score of 67 (SD 17). The conversational form attained the least scores in the usability testing and it was the least choice of users, with a mean score of 57 (SD 24). The $t$ test indicated statistical significance between the conversational and single-page forms. Figure 6 shows a boxplot of the SUS scores for each digital form. Even with the Bonferroni-corrected $\alpha$ value (.015), the results were still statistically significant.

![Boxplot for the average System Usability Scale score of each form. The single page had a mean System Usability Scale score of 76 (SD 15) and outperformed the usability of the multipage and conversational forms with mean System Usability Scale scores of 67 (SD 17) and 57 (SD 24), respectively. Even with a $\beta$ coefficient of .015, the results are still significant.](image)

UEQ Interpretation

The UEQ used in this study was modified from the original version by making it unidirectional and also included the one-sided factors. The single-page form mostly had higher averages for the positive attributes than the other two digital forms. The conversational form scored higher averages in the negative attributes, which suggests that the conversational form had the least usability. Figures 7 and 8 show the mean average ratings for each UEQ question for each digital form.
Task Time or Form Completion

Task completion refers to the total time a user takes to complete each form. Participants took the least time to complete the paper form. However, the least mean time was recorded for the single-page form, followed by the conversational form among the three digital forms. Users took longer to complete the multipage form. **Figure 9** shows a boxplot of task completion times for each form. The PPCI activator nurses took the least time for the paper form, as they are currently using this for PPCI referrals. However, the research nurses who had no prior exposure to this paper form took almost as long as they took to complete the digital forms (mean 224, SD 54 seconds vs mean 298, SD 60 seconds; $P=.001$).

On the other hand, the activator nurses who took the least time to complete the paper form took almost twice the amount of time to complete the digital form compared with the paper form (165, SD 55 s vs 301, SD 68 s; $P<.001$). The boxplot in **Figure 10** shows the mean time of both groups to complete the paper and digital forms. The paired $t$ test is shown in **Table 2**, where the single-page form shows significance ($P<.001$) with the multipage form and paper form. The multipage form and the conversational form task completion times showed significance ($P<.001$) with the paper form only.
**Figure 9.** Boxplot for the average form completion time of each form. The primary percutaneous coronary intervention activator nurses took the least time for the paper form, as they are currently using this for primary percutaneous coronary intervention referrals. However, the research nurses who had no prior exposure to this paper form took almost as much time as the time activator nurses took to complete the digital forms (mean 224 seconds, SD 54 seconds vs mean 298, SD 60 seconds; $P<.001$).

**Figure 10.** Boxplot for the average form completion time of activators versus research nurses. (A) Activator nurses’ form completion time and (B) research nurses’ form completion time.
Table 2. *P* values between the completion time of all forms.

<table>
<thead>
<tr>
<th>Form comparisons</th>
<th><em>P</em> value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single-page form and multipage form</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Single-page form and conversational form</td>
<td>.02</td>
</tr>
<tr>
<td>Single-page form and paper sheet</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Multipage form and conversational form</td>
<td>.10</td>
</tr>
<tr>
<td>Multipage form and paper sheet</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Conversational form and paper sheet</td>
<td>&lt;.001</td>
</tr>
</tbody>
</table>

**Correlation: SUS Score and Task Time**

There was a weak correlation (*r*=−0.28) between the SUS score and form completion time (Figure 11). This shows that task completion time alone does not measure the usability of a system. Figure 12 shows the scatterplot for the overall correlation between the SUS score and each form completion time.

**Figure 11.** Scatterplot for the overall correlation between the System Usability Scale score and task completion time. There was a weak correlation (*r*=−0.28) between the System Usability Scale score and form completion times. This shows that the task completion time alone does not measure the usability of a system. SUS: System Usability Scale.
Error Rate and Classification

Upon inspection of the video screen recordings, the use errors and their frequency were recorded. A use error can have 1 of 4 severity ratings according to Neilson’s 4-star severity scale, that is, cosmetic, medium, serious, or critical. There were no critical use errors; however, there were many serious use errors in the conversational form. The multipage form errors were 69% medium errors, whereas the single-page form had only 31% medium errors and very few cosmetic errors. Figure 13 shows a bar graph of the error severity of each form.

On the basis of this usability study, approximately 83 use errors (average severity 3.0) were discovered in the conversational form, 35 use errors (average severity 2.0, SD 0) were discovered in the multipage form, and 21 use errors (average severity 1.76, SD 0.44) were discovered in the single-page form. The severity of these use errors is shown in Figure 13.

Postexperiment Questionnaire

Approximately half of the participants preferred the single-page form. In response to an open-ended question, the users mentioned that the single page was “easy to complete,” “easy to understand,” “well-marked and separated,” and “clearer” and that “all the information is available to see at once.” For the multipage form, the users said the “entire information isn’t...
available” and that they “don’t like to navigate.” For the conversational form, the users said that it was “unpredictable” and “difficult to understand and use” and that they “couldn’t go back easily to the options if they need to or want to.”

Discussion

Principal Findings

This study has shown that a single-page digital form outperformed the multipage and conversational forms while performing usability evaluation for the three digital forms designed for PPCI referrals to better understand the usability needs of nurses. This is an interesting finding, as the conversational form was previously used successfully to aid in different areas [35,36]. In terms of task completion times, the single-page form achieved the minimum completion time, followed by the conversational form.

The correlation analysis between the SUS score and task time showed no strong relationship, indicating that task completion time alone cannot measure the usability of a system. All the standard usability metrics considered in this research concluded that the single-page digital form performed better than the multipage and conversational forms. Moreover, while answering an open-ended question in the final questionnaire, more than half of the participants chose the single-page form as their preferred choice. Some of the reasons for preferring the single-page form were that it is easy to complete, easy to understand, well-marked and separated, clear, and all the information is available to see on one screen. For the multipage form, participants did not seem to like navigating between the pages. For the conversational form, participants found it more unpredictable; difficult to understand and use; and, most importantly, to be unable to conveniently go back to change data inputted if they needed to.

Usability assessment and appropriate form design or form design guidelines are vital for health care departments. For form filling in health care, if the form is not well designed, people will have to think harder to complete it. If they think harder, it means they will take longer to fill in the form, so they could miss information or skip it or even enter wrong information. If people take long time to fill the forms, it takes them away from the actual patient care. If they make mistakes and put in wrong information, any algorithms, data analysis, or dashboards that use those data would be wrong. Clinical strategies and decision making at the board level or hospital level based on those data would be wrong because a nurse had not completed a digital form properly. The fact that the digital form is being used routinely and at a high frequency makes their usability crucial because you will think that a system as simple as a form should not require a high mental workload. It should be as intuitive and as simple as possible. A digital form impacts algorithm development and policy decision making because much of the data are based on policy decision making, which means that if data are wrong, then the policies are also wrong. If people are not putting in the right data, then policy decisions will be faulty as well. In this day and age, we make many decisions based on the data, so data can be either new oil or a new snake oil if the data are misleading or wrong. Data are substantial if it is correct, but it can lead to bad decisions if data are not correct. The results from the study clearly show that a single page from has better usability overall than its multipage and conversational form counterparts. This has implications for form design moving forward but, in many ways, reinforces good user experience design guidelines when it comes to form design [37]. By using single-page forms, they allow the layout to be simplified and make a form easily scannable. When people first see a form, they will perceive how long it will take for them to complete it by scanning the form. Therefore, perception does play a role. The more complex it looks, the more likely people will abandon the process. There is also the interaction cost or the reservoir of goodwill. Filling in web forms represents a sum of effort both cognitively and physically that people must put in when interacting with a web form to reach a goal. The more effort required, the less usable the form is. The reservoir of goodwill diminishes, and people abandon the process; single-page forms allow long forms to appear smaller by minimizing the number of fields that are seen at the same time. This creates the perception that the form is shorter than it really is. This is done via progressive disclosure, showing just what the people need on the screen at the right time. By also chunking breaking the form into steps allows people to process, understand, and complete information in a small portion at a time. The trend for web forms is this approach with web builders, such as Google forms [38] and typeform [39], using this approach.

Limitations

The digital forms were trialed at only one hospital with a small group of health care professionals, and the usability results may differ at other centers. However, the ethical approval board is in the process of including another hospital site in the study to increase the number of participants. The study was conducted in a simulated scenario in which the location and patient presentation were simulated. Perhaps in real scenarios, participants would be under more pressure (eg, time pressure). Usability data were not recorded for the paper version. No usability data are available for the paper form, as the usability questionnaires (SUS and UEQ) are designed to assess digital interfaces. Paper forms are what health care staff are very familiar with and might bias any comparisons made. For example, they have already adopted paper systems and have become experts in paper form filling. Hence, it can be argued that it is unfair to compare paper form completion with digital form completion because this compares expert use with novice use. Moreover, another key limitation is that perhaps single-page digital forms are preferred because that format is also widely used and users might have already become familiar with these form styles.

Future Work

How will people complete digital forms in the future? This is an interesting question, especially in the era of artificial intelligence. Perhaps there will be more intelligent smart speakers that will be used for completing forms, for example, an artificial intelligence algorithm that listens to the patient’s details and completes the form using natural language understanding. However, talking to a computer requires more...
effort than selecting options in a form. Further research is required to explore these ideas.

Conclusions
In conclusion, the digital single-page form outperformed the other two forms in almost all usability metrics. The mean SUS score for a single page was 76 (SD 15), with the least task completion time when compared with the other two digital forms. Moreover, on answering the open-ended question, the single-page form was also the preferred choice. However, this preference might change over time as multipage and conversational forms become more common. For example, the conversational form’s SUS scores achieved a greater variance, indicating a possible dichotomy among participants regarding the perceived usability and usefulness of chatbot style form.

Acknowledgments
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Authors’ Contributions
All of the authors were responsible for study conception; the design, analysis, and interpretation of results; and the revision of the manuscript.

Conflicts of Interest
None declared.

Multimedia Appendix 1
Simulated patient scenarios provided for form filling.
[PDF File (Adobe PDF File), 87 KB - humanfactors_v8i2e25787_app1.pdf ]

Multimedia Appendix 2
Ethical approval certificate/letter.
[PDF File (Adobe PDF File), 295 KB - humanfactors_v8i2e25787_app2.pdf ]

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Abbreviations

**EHR:** electronic health record  
**PPCI:** primary percutaneous coronary intervention  
**SUS:** System Usability Scale  
**UEQ:** User Experience Questionnaire
Older Patients’ Competence, Preferences, and Attitudes Toward Digital Technology Use: Explorative Study

Rikke Terp1, MHSc; Lars Kayser2, MD, PhD; Tove Lindhardt1, MScN, PhD

1Department of Internal Medicine, Herlev and Gentofte Hospital, Copenhagen University Hospital, Hellerup, Denmark
2Department of Public Health, University of Copenhagen, Copenhagen, Denmark

Corresponding Author:
Rikke Terp, MHSc
Department of Internal Medicine
Herlev and Gentofte Hospital
Copenhagen University Hospital
Hospitalsvej 4
Hellerup, 2900
Denmark
Phone: 45 26823909
Email: rikke.terp@regionh.dk

Abstract

Background: Malnutrition is prevalent in older patients, which is associated with severe consequences such as a decline in functional status, increased risk of readmission, and increased mortality. A tablet-based eHealth solution (Food’n’Go) was recently developed and introduced at our clinic to support older patients’ involvement in nutritional interventions during their hospitalization, thereby enhancing their awareness and motivation for choosing the right food to obtain sufficient calorie and protein intake. To reap the full benefits from the eHealth solution, the technology should be introduced and accompanied by support that targets the end users’ competence level and needs.

Objective: In this study, we aimed to explore older patients’ readiness (ie, competence, preferences, and attitudes) toward the use of information and communication technology (ICT), and to identify the factors that may act as barriers or facilitators for their engagement with health technology.

Methods: A descriptive and explorative study was performed using triangulation of data derived from semistructured interviews and questionnaires (based on the Readiness and Enablement Index for Health Technology [READHY] instrument). Older hospitalized patients (age ≥65 years; N=25) were included from two hospitals in Denmark.

Results: The majority (16/25, 64%) of the older patients (median age 81 years) were users of ICT. The qualitative findings revealed that their experiences of benefits related to the use of ICT facilitated usage. Barriers for use of ICT were health-related challenges, limited digital literacy, and low self-efficacy related to ICT use due to age-related prejudices by their relatives and themselves. The qualitative findings were also reflected in the low median scores on the eHealth Literacy Questionnaire (eHLQ) READHY scales within dimensions addressing the user’s knowledge and skills (eHLQ1:1.8; eHLQ3: 2.0), and the user experience (eHLQ6: 2.0; eHLQ7: 1.5).

Conclusions: Older patients are potential users of ICT, but experience a variety of barriers for using eHealth. When introducing older patients to eHealth, it is important to emphasize the possible benefits, and to offer support targeting their knowledge, skills, and motivation.

(JMIR Hum Factors 2021;8(2):e27005) doi:10.2196/27005

KEYWORDS

eHealth literacy; eHealth; self-management; older patients; explorative study

Introduction

Malnutrition is a prevalent and challenging area in health care for older patients [1-3] with severe consequences such as decreased physical function [1], prolonged hospitalization [4], readmissions [5], and mortality [1,4,6]. Multiple interventions targeting the prevention of malnutrition in older patients have been investigated, and the majority consist of dietary...
interventions with varying effects [7-9]. To support older patients in eating adequately, interventions that address the individual’s motivation and preferences are required [10]. Hence, patient involvement is a prerequisite, and eHealth technology may be a useful tool in this regard. However, few technology studies have focused on the management of malnutrition, and only a limited number of such studies have included older patients. It is commonly considered that older patients do not utilize and benefit from digital technologies [11-13]. Due to this faulty assumption, older people are given less opportunities to use eHealth [13,14]. Indeed, former studies have described a positive attitude among older patients toward digital technologies [15-18], but that they may have less experience with these tools than younger people [19]. These results are supported by data from Statistics Denmark, which show a steady increase in the use of digital technologies among older age groups; in 2019, 85% of people aged 75 to 89 years used internet banking compared to only 61% in 2011 [20]. Former studies have investigated the specific barriers for older patients to use digital technologies [11,16,17,21], identifying lack of digital literacy, knowledge, and confidence in using technology as predominant barriers. However, this is a new and expanding research area and the evidence remains limited. Moreover, an understanding of older patients’ capacity to engage with digital technologies requires insight into their knowledge, skills, and perception of the technology (ie, eHealth literacy) [22], taking the social context into consideration [23]. Recently the Readiness and Enablement Index for Health Technology (READHY) instrument was developed, which can capture not only individuals’ eHealth literacy but also the social context, and their ability to manage the burden of treatment and illness [24].

In a recent project implemented at two hospitals in the Copenhagen area, our research group, in collaboration with the information technology company Movesca, developed a new eHealth solution (Food’n’Go) with the aim of supporting older patients (>65 years) to participate in nutritional interventions while hospitalized, thereby enhancing their awareness and motivation for eating sufficiently [25]. Food’n’Go is an app provided on a computer tablet where the patients can (1) access a menu of food choices, (2) order meals, (3) register food intake, and (4) receive feedback. To reap the full benefits from such an eHealth solution, it should be introduced and accompanied by support targeted to the end user’s competence and needs. Therefore, as an adjunct study to the above technology study, we are developing an educative intervention supporting older patients in their use of this eHealth tool to increase the adoption and advantages of using the technology. Development of such an educative intervention requires not only knowledge of the end user’s competencies, needs, and abilities to participate in the nutritional interventions but also to address the readiness for usage of technology.

Toward this end, the aim of this study was to explore older patients’ competencies, preferences, and attitudes toward use of information and communication technology (ICT), and to gain an understanding of the barriers and facilitators for their motivation to engage with eHealth.

Methods

Design

The overall design has been reported elsewhere [26]. Briefly, this report builds on field studies that addressed older patients’ competencies, preferences, and attitudes toward food and technology. The focus on nutrition and food has been reported previously [26]. We here report our findings in relation to the technology perspective. In short, we recapture the principles of the study design to establish the context for the results, analysis, and discussion. This study applied a descriptive and explorative design using data triangulation. Table 1 illustrates the methodology for inclusion, recruitment, data collection, and analysis.
Participants and Procedure

The participants (25 hospitalized patients) were recruited from two units specialized in internal medicine from two hospitals under the same administration in Denmark. To capture as much variation as possible in competencies, preferences, and attitudes toward ICT in the group of older patients, we consecutively included the participants using a cross-sectional sampling strategy. On randomly selected days, patients fulfilling the inclusion criteria were included. To ensure heterogeneity in terms of socioeconomic status, we purposefully included participants from two different hospital units. The two hospitals (Hospital A and Hospital B) serve different populations in terms of socioeconomic status. People living in the uptake area of Hospital B have a lower socioeconomic status compared to those in the uptake area of Hospital A. In Table 1, we describe eligible patients and reasons for nonparticipation.

Data Collection and Analysis

The data included both qualitative and quantitative data from semistructured interviews and the READHY questionnaire. The 25 participants were asked to fill in the READHY questionnaire, followed by individual interviews with the first author (RT). The interviews were performed at the hospital to gain an understanding of the experiences, competencies, and attitudes of older patients toward the use of ICT and their management of nutritional needs. An interview guide based on the dimensions from the READHY tool was developed and used. The first author undertook the data collection. We planned to include 10-12 participants from each hospital unit and to evaluate whether categories of participants scoring high and low in the READHY themes of self-management, social support, and eHealth literacy were represented, and that saturation with respect to new aspects of ICT usage or understanding of nutrition was achieved. For Hospital B, we lacked some male representatives and therefore included a total of 13 participants from this hospital.

Qualitative content analysis was used [27,28]. To ensure trustworthiness, the analysis and interpretation of the qualitative data were carried out as follows. The coding of the first three transcribed interviews was reviewed and discussed with all authors. The transverse analysis and interpretation were performed in collaboration between two authors (RT and TL) and were discussed with the other author (LK) until consensus was reached. The interviews were conducted, transcribed, and analyzed in Danish. Quotations included herein were translated into English by a bilingual translator in collaboration with RT to ensure the meaning was not distorted.

Theoretical Framework

As previously reported, we used the READHY instrument as a theoretical framework to explore the informants’ capacity to utilize an eHealth solution. READHY is a psychometrically validated instrument developed to measure an individual’s health technology readiness [24]. It consists of 65 items covering 13 dimensions from three distinct instruments measuring the concepts of eHealth literacy, health literacy, and self-management. The READHY instrument is based on the concepts of eHealth literacy comprising the seven dimensions from the eHealth Literacy Questionnaire (eHLQ) [29], which address: (1) the user’s knowledge and skills (eHLQ1, eHLQ2, and eHLQ3); (2) the user experience (eHLQ6 and eHLQ7); (3) the users’ trust toward digital technology (eHLQ4); and (4) the user’s motivation for engaging with the technology (eHLQ5). It has been argued that an individual’s capability to utilize eHealth is influenced by their competence in managing the

Table 1. Description of participant recruitment, inclusion and exclusion criteria, data collection, and data analysis.

<table>
<thead>
<tr>
<th>Stage of the study</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recruitment: consecutive sampling</td>
<td></td>
</tr>
<tr>
<td>Inclusion criteria</td>
<td>Age ≥65 years (N=25)</td>
</tr>
<tr>
<td></td>
<td>Admitted at one of the two selected hospital units specialized in internal medicine: Hospital A (n=12) and Hospital B (n=13)</td>
</tr>
<tr>
<td>Exclusion criteria</td>
<td>Total excluded N=60</td>
</tr>
<tr>
<td></td>
<td>Already included (n=6, 10%), unwilling to participate (n=12, 20%), terminal illness (n=2, 3%), discharged before inclusion (n=13, 22%), unable to provide informed consent (n=27, 45%)</td>
</tr>
<tr>
<td>Data collection</td>
<td></td>
</tr>
<tr>
<td>Time period</td>
<td>March 2017 to July 2017&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Interviews</td>
<td>Individual semistructured interviews, interview guided by READHY&lt;sup&gt;b&lt;/sup&gt; dimensions</td>
</tr>
<tr>
<td>Data analysis</td>
<td></td>
</tr>
<tr>
<td>Qualitative data</td>
<td>Content analysis; coded with an inductive approach using the management software program NVivo 11</td>
</tr>
<tr>
<td>Quantitative data</td>
<td>READHY scores, participant characteristics</td>
</tr>
<tr>
<td>Descriptive statistics</td>
<td></td>
</tr>
<tr>
<td>Test statistics</td>
<td>χ² (categorical variables), Mann-Whitney U test (continuous variables); P&lt;.05 indicated significance analyzed with SPSS version 25</td>
</tr>
</tbody>
</table>

<sup>a</sup>Except for two male participants who were included in March 2018 due to overrepresentation of women.
<sup>b</sup>READHY: Readiness and Enablement Index for Health Technology.
burden of treatment and illness, as well as the social context such as social support [23,24]. READHY addresses social aspects such as support from relatives and health care professionals in two dimensions from the Health Literacy Questionnaire (HLQ; HLQ1 and HLQ4) [30]. Additionally, READHY contains four dimensions from the Health Education Impact Questionnaire (heiQ) [31], which addresses perspectives of self-management: self-monitoring and insight into their own health (heiQ3), constructive attitudes and approaches (heiQ4), skill and technique (heiQ5), and emotional distress (heiQ8). The 13 distinct dimensions captured in the READHY instrument are measured on a Likert scale with the following response categories: 1, strongly disagree; 2, disagree; 3, agree; and 4, strongly agree. Within each dimension, the items sum up to a composite score: 1 is the least desirable score and 4 is the most desirable score.

**Ethical Considerations**

Mandated by the Danish Data Protection Agency, the study was approved by the Capital Region of Denmark (local record number HGH-2017-021). The Regional Ethical Committee (j.nr H-17006045) evaluated the study and found that ethical approval was not required. Verbal and written information about the study were provided to all participants by RT and they signed an informed consent form.

**Results**

**Patient Characteristics**

A total of 25 out of 85 eligible patients were included in this study. The median age was 81 years and 13 (52%) of the patients were women. Further patient characteristics are summarized in Table 2. The results in Table 2, except for those related to digital use, were previously reported [26].

**Table 2.** Participant characteristics.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Total sample (N=25)</th>
<th>Hospital A (n=12)</th>
<th>Hospital B (n=13)</th>
<th>P value&lt;sup&gt;a&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years), median (IQR)</td>
<td>81 (72-88)</td>
<td>82 (73-90)</td>
<td>81 (70-88)</td>
<td>.55</td>
</tr>
<tr>
<td>Sex (female), n (%)</td>
<td>13 (52)</td>
<td>5 (42)</td>
<td>8 (62)</td>
<td>.32</td>
</tr>
<tr>
<td>Civil status; living alone, n (%)</td>
<td>13 (52)</td>
<td>6 (50)</td>
<td>7 (54)</td>
<td>.85</td>
</tr>
<tr>
<td>Digital use; use of ICT&lt;sup&gt;b&lt;/sup&gt;, n (%)</td>
<td>16 (64)</td>
<td>9 (75)</td>
<td>7 (54)</td>
<td>.27</td>
</tr>
<tr>
<td>School level, n (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>≤7 years</td>
<td>8 (32)</td>
<td>2 (17)</td>
<td>6 (46)</td>
<td>.40</td>
</tr>
<tr>
<td>8-9 years</td>
<td>6 (24)</td>
<td>3 (25)</td>
<td>3 (23)</td>
<td></td>
</tr>
<tr>
<td>10-11 years</td>
<td>9 (36)</td>
<td>6 (50)</td>
<td>3 (23)</td>
<td></td>
</tr>
<tr>
<td>Upper Secondary School Leaving Examination</td>
<td>2 (8)</td>
<td>1 (8)</td>
<td>1 (7)</td>
<td></td>
</tr>
<tr>
<td>Education level, n (%)</td>
<td></td>
<td></td>
<td></td>
<td>.25</td>
</tr>
<tr>
<td>Comprehensive&lt;sup&gt;c&lt;/sup&gt;</td>
<td>6 (24)</td>
<td>2 (17)</td>
<td>4 (31)</td>
<td></td>
</tr>
<tr>
<td>Short education&lt;sup&gt;d&lt;/sup&gt;</td>
<td>11 (44)</td>
<td>4 (33)</td>
<td>7 (54)</td>
<td></td>
</tr>
<tr>
<td>Medium education&lt;sup&gt;e&lt;/sup&gt;</td>
<td>6 (24)</td>
<td>4 (33)</td>
<td>2 (16)</td>
<td></td>
</tr>
<tr>
<td>Long education&lt;sup&gt;f&lt;/sup&gt;</td>
<td>2 (8)</td>
<td>2 (17)</td>
<td>0 (0)</td>
<td></td>
</tr>
</tbody>
</table>

<sup>a</sup>Pearson χ<sup>2</sup> test was used for categorical variables and Mann-Whitney U test was used for continuous variables.

<sup>b</sup>ICT: information and communication technology.

<sup>c</sup>Corresponding to International Standard Classification of Education-2011 levels 1 and 2.

<sup>d</sup>Corresponding to International Standard Classification of Education-2011 levels 3, 4, and 5.

<sup>e</sup>Corresponding to International Standard Classification of Education-2011 level 6.

<sup>f</sup>Corresponding to International Standard Classification of Education-2011 levels 7 and 8.

**Quantitative Analysis**

The informants were interviewed on the third day after admission. No significant differences in informants’ characteristics between Hospital A and Hospital B were found. The informants’ scores from the READHY instrument are summarized in Table 3. The informants from Hospital A had a higher score on 11 out of 13 scales. However, only significantly higher scores were found for two scales: “Self-monitoring and insight” and “Feeling understood and supported by health care providers.” Informants who used ICT had a significantly higher score than nonusers on 5 out of 7 scales within the eHealth literacy dimensions (Table 4).
<table>
<thead>
<tr>
<th>READHY dimensions</th>
<th>Total sample (N=25), median (range)</th>
<th>Hospital A (n=12), median (range)</th>
<th>Hospital B (n=13), median (range)</th>
<th>P value(^b)</th>
</tr>
</thead>
<tbody>
<tr>
<td>heiQ3: self-monitoring and insight</td>
<td>2.8 (2.0-4.0)</td>
<td>3.2 (2.0-4.0)</td>
<td>2.7 (2.2-3.2)</td>
<td>.007</td>
</tr>
<tr>
<td>heiQ4: constructive attitudes and approaches</td>
<td>3.2 (1.0-3.8)</td>
<td>3.2 (2.5-3.8)</td>
<td>3.2 (1.0-3.8)</td>
<td>.44</td>
</tr>
<tr>
<td>heiQ5: skills and technique acquisition</td>
<td>3.0 (1.3-4.0)</td>
<td>3.0 (2.0-3.8)</td>
<td>2.8 (1.3-4.0)</td>
<td>.35</td>
</tr>
<tr>
<td>heiQ8: emotional distress(^d)</td>
<td>2.5 (1.2-3.5)</td>
<td>2.6 (1.2-3.5)</td>
<td>2.5 (1.8-3.5)</td>
<td>.51</td>
</tr>
<tr>
<td>HLQ1: feeling understood and supported by health care providers</td>
<td>3.0 (1.0-4.0)</td>
<td>3.8 (2.0-4.0)</td>
<td>2.8 (1.0-4.0)</td>
<td>.004</td>
</tr>
<tr>
<td>HLQ4: social support for health</td>
<td>3.4 (1.0-4.0)</td>
<td>3.8 (2.2-4.0)</td>
<td>3.0 (1.0-4.0)</td>
<td>.14</td>
</tr>
<tr>
<td>eHLQ1: ability to process information</td>
<td>1.8 (1.0-4.0)</td>
<td>1.9 (1.0-3.2)</td>
<td>1.8 (1.0-4.0)</td>
<td>.76</td>
</tr>
<tr>
<td>eHLQ2: understanding of health concepts and language</td>
<td>2.8 (1.0-3.6)</td>
<td>3.0 (2.4-3.6)</td>
<td>2.6 (1.0-3.6)</td>
<td>.054</td>
</tr>
<tr>
<td>eHLQ3: ability to actively engage with digital services</td>
<td>2.0 (1.0-3.4)</td>
<td>1.9 (1.0-3.2)</td>
<td>2.2 (1.0-3.4)</td>
<td>.79</td>
</tr>
<tr>
<td>eHLQ4: feel safe and in control</td>
<td>3.0 (1.8-4.0)</td>
<td>3.0 (2.2-4.0)</td>
<td>2.8 (1.8-3.2)</td>
<td>.07</td>
</tr>
<tr>
<td>eHLQ5: motivated to engage with digital services</td>
<td>2.4 (1.0-3.6)</td>
<td>2.5 (1.0-3.0)</td>
<td>1.8 (1.0-3.6)</td>
<td>.25</td>
</tr>
<tr>
<td>eHLQ6: access to digital services that work</td>
<td>2.0 (1.0-3.0)</td>
<td>2.5 (1.0-3.0)</td>
<td>2.0 (1.3-2.8)</td>
<td>.78</td>
</tr>
<tr>
<td>eHLQ7: digital services that suit individual needs</td>
<td>1.5 (1.0-3.3)</td>
<td>1.6 (1.0-3.3)</td>
<td>1.5 (1.0-3.0)</td>
<td>.68</td>
</tr>
</tbody>
</table>

\(^a\)The dimension scores are based on following response categories: 1, strongly disagree; 2, disagree; 3, agree; and 4, strongly agree. A high score is a more desirable trait. The heiQ3, heiQ4, heiQ5, heiQ8, HLQ1, HLQ4, and eHLQ2 scores have been reported previously [26].

\(^b\)Mann-Whitney U test.

\(^c\)heiQ: Health Education Impact Questionnaire.

\(^d\)Reverse score; a high score means a low level of distress.

\(^e\)HLQ: Health Literacy Questionnaire.

\(^f\)eHLQ: eHealth Literacy Questionnaire.
Table 4. Readiness and Enablement Index for Health Technology (READHY) scores for information and communications technology (ICT) users versus nonusers.

<table>
<thead>
<tr>
<th>READHY dimensions</th>
<th>ICT users (n=16), median (range)</th>
<th>ICT nonusers (n=9), median (range)</th>
<th>P value&lt;sup&gt;b&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>heiQ&lt;sup&gt;c&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>heiQ3: self-monitoring and insight</td>
<td>2.9 (2.0-3.7)</td>
<td>2.8 (2.2-4.0)</td>
<td>.95</td>
</tr>
<tr>
<td>heiQ4: constructive attitudes and approaches</td>
<td>3.0 (1.0-3.8)</td>
<td>3.2 (2.6-3.8)</td>
<td>.33</td>
</tr>
<tr>
<td>heiQ5: skills and technique acquisition</td>
<td>3.0 (1.3-4.0)</td>
<td>3.0 (2.0-3.8)</td>
<td>.49</td>
</tr>
<tr>
<td>heiQ8: emotional distress&lt;sup&gt;d&lt;/sup&gt;</td>
<td>2.5 (1.2-3.3)</td>
<td>3.2 (1.8-3.5)</td>
<td>.20</td>
</tr>
<tr>
<td>HLQ&lt;sup&gt;e&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HLQ1: feeling understood and supported by health care providers</td>
<td>3.3 (1.0-4.0)</td>
<td>3.0 (1.8-4.0)</td>
<td>.84</td>
</tr>
<tr>
<td>HLQ4: social support for health</td>
<td>3.1 (1.0-4.0)</td>
<td>3.6 (2.4-4.0)</td>
<td>.30</td>
</tr>
<tr>
<td>eHLQ&lt;sup&gt;f&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>eHLQ1: ability to process information</td>
<td>2.4 (1.0-4.0)</td>
<td>1.2 (1.0-1.8)</td>
<td>.004</td>
</tr>
<tr>
<td>eHLQ2: understanding of health concepts and language</td>
<td>2.8 (1.0-3.4)</td>
<td>3.0 (2.2-3.6)</td>
<td>.09</td>
</tr>
<tr>
<td>eHLQ3: ability to actively engage with digital services</td>
<td>2.5 (1.0-3.4)</td>
<td>1.4 (1.0-1.6)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>eHLQ4: feel safe and in control</td>
<td>2.9 (1.8-3.6)</td>
<td>3.0 (2.0-4.0)</td>
<td>.69</td>
</tr>
<tr>
<td>eHLQ5: motivated to engage with digital services</td>
<td>2.7 (1.0-3.6)</td>
<td>1.8 (1.0-2.4)</td>
<td>.02</td>
</tr>
<tr>
<td>eHLQ6: access to digital services that work</td>
<td>2.7 (1.0-3.0)</td>
<td>1.5 (1.3-2.0)</td>
<td>.02</td>
</tr>
<tr>
<td>eHLQ7: digital services that suit individual needs</td>
<td>2.0 (1.0-3.3)</td>
<td>1.0 (1.0-2.0)</td>
<td>.01</td>
</tr>
</tbody>
</table>

<sup>a</sup>The dimension scores are based on following response categories: 1, strongly disagree; 2, disagree; 3, agree; and 4, strongly agree. A high score is a more desirable trait. The heiQ3, heiQ4, heiQ5, heiQ8, HLQ1, HLQ4, and eHLQ2 scores have been reported previously [26].

<sup>b</sup>Mann-Whitney U test.

<sup>c</sup>heiQ: Health Education Impact Questionnaire.

<sup>d</sup>Reverse score; a high score means a low level of distress.

<sup>e</sup>HLQ: Health Literacy Questionnaire.

<sup>f</sup>eHLQ: eHealth Literacy Questionnaire.

Qualitative Analysis

Main Themes

From the qualitative analysis, one main theme emerged: To be or not to be a user of technology. There were three subthemes identified: (1) An indispensable tool or a useless gadget: experiences of ICT; (2) A foreign element: barriers and promotors for usage; and (3) I might be too old: ageism (Figure 1). The qualitative findings showed a noteworthy diversity in the informants’ attitude, use, and experience with ICT. The findings revealed how the use and nonuse of ICT was related to the informants’ expectations of derived benefits and their own competence.
Figure 1. Main theme, subthemes, and subordinate themes. ICT: information and communication technology

An Indispensable Tool or a Useless Gadget: Experience of ICT

Theme Overview

This theme covers the diversity of the informants in their experiences and attitudes toward ICT. The informants' experiences of ICT spread over a spectrum. One side of the spectrum included patients that used ICT on a daily basis and experienced it as an indispensable tool in their lives. The other side of the spectrum included informants who never used ICT and regarded it as irrelevant; some found it intimidating and some even considered it to be a threat to their usual way of living. In general, the nonuse of ICT was not a sign of rejection by the informants, but rather an expression of them feeling that they were not a target group for this technology.

Usage of ICT

Most of the informants used ICT at home on a daily basis, and several had various computer devices, including a personal computer, tablet, and smartphone. They used ICT for different purposes such as information seeking, communication with friends and family via email, managing finances, and entertainment. Use of social media such as Facebook was also mentioned. Notably, many of the nonusers of ICT had been introduced to ICT earlier in life, such as through personal computer training in the local residents club or seniors club. However, the skills acquired at such training events had been forgotten, despite their initial interest:

*I am member of a senior citizens club through HK (a trade union)...Yes, it is more than 10 years ago we got the chance to try a computer, and it was quite exciting.* [Informant A; 87 years]

When asked directly, the informant could not explain why she was not using ICT currently, except that she was managing just fine without it. The informants most frequently explained their nonuse of ICT as lack of need or interest. When asked if they would like to learn to use ICT, one informant responded:

*Well, um, in a way, yes, but on the other hand: what would I use it for?* [Informant B; 81 years]

Usage of Health-Related ICT

Use of ICT in relation to health and well-being was common, primarily to look up health information. The search engine Google was used by many, but others also mentioned the national health portal (sundhed.dk), which after logging in with a national personal identifier provides access to various health services, including the electronic health record, prescribed drugs, and paraclinical data. This portal also provides information about health services and resources, and on different conditions and how they are treated using a so-called patient “handbook” without needing to log in. The informants were mainly searching for information on diseases, treatments, and medicine. Beyond information seeking, some informants mentioned how they used digital services of their general practitioners (GPs) for booking appointments or renewal of drug prescriptions. The informants also used access to their electronic health record for information about their treatment. In general, the informants had limited experience with using ICT for monitoring their health conditions. One exception was a patient who used an app on his smartphone for monitoring physical activity (ie, the distance moved in a day). This informant differed from the others as he was younger. Health-related use of ICT was mainly focused on treatment and prevention of complications of an existing disease and, to a limited extent, on health promotion.

Daily use of ICT did not always encompass purposes related to health and well-being. For instance, several informants explained that they did not take advantage of the digital health services offered by the GP. This was not due to worries about digital safety. In general, ICT users trusted the security in the digital systems when sharing their data, and data security did not seem to be a concern among nonusers. For some informants, the use of health-related ICT was perceived as a risk of being a substitute for personal contact with the health care professionals (eg, their GP). Several informants explained how the information was generally better and more easily understood when received in person, and some expressed concerns about misunderstandings. Other reasons mentioned for not using ICT for health-related purposes was lack of knowledge, user competence, and interest. The latter was often an expression of
lack of knowledge of the opportunities made available by the technology.

**Attitudes Toward ICT**

In general, the ICT users had a positive attitude toward ICT. Their narratives revealed how their attitudes were associated with their experiences of various ICT benefits in their everyday lives. Access to all kinds of information on the internet was especially appreciated:

*I basically find a computer an indispensable tool. If you want to know something, well, ask the computer.*

[Informant C; 91 years]

Some informants expressed how ICT helped them manage the challenges of living with a chronic condition, such as by providing information about illness and treatment. Easy access to information on the internet helped prepare them for more qualified conversations with health care professionals:

...It probably means that you are better prepared for at least some of the doctor’s consultations...I mean, in reality, it is all about asking the right questions.

[Informant D; 73 years]

Other informants described how using the GP’s digital services made appointment booking and renewing prescriptions easier, and therefore making interactions less dependent on the GP’s telephone hours. The analysis further revealed examples as to how ICT had a positive influence on compliance with medication, such as the timely ordering of medication by digital renewal of prescriptions and correct administration of medication due to easy access to information.

Not all informants considered ICT to be an indispensable tool. In general, the nonusers lacked interest in using ICT, as they did not consider it relevant. A negative attitude was not common, but was observed. One informant rejected digital communication from public authorities but still used ICT for email with friends and family.

**But now, when you are being pushed, I feel genuinely annoyed over...um...digital pressure from society, from the municipalities. I feel it isn’t right (...) I have applied to be, what do they call it, not-digitalized, and I got approved**[Informant E; 88 years]

ICT was experienced as something new and unfamiliar, influencing their attitudes toward using it. For some, this attitude was a barrier for using ICT, whereas others embraced this challenge and embarked on learning new skills to overcome the difficulties.

*I want to learn, he (son) shouldn’t tell me what to do, he should be teaching me how to, so I can do it myself; otherwise I will have a gigantic problem on my hands as soon as he is out of the door* [Informant F; 76 years]

Despite the challenges experienced, these were not always a hindrance to using the technology. Generally, the informants accepted the occasional challenges and the fact that they sometimes needed assistance with completing the task they were engaged in. Technical challenges such as an inaccessible system or difficulties operating the system were met with patience and confidence. An acceptance attitude was apparent, acknowledging that things may take time and it was sometimes a matter of waiting, either for the system to work again or for the necessary support to be available.

**But sometimes it’s a real mess (laughing).**

**RT: What is it that’s a mess?**

**It’s all of it, isn’t it? I mean, (...) then I wait a bit, then I try again (...) then it usually ends up working**[Informant G; 70 years]

It became apparent in the informants’ narratives that the nonuse of ICT could not necessarily be explained by being technology-averse in general, as some of the nonusers handled other technological devices without problems, such as for monitoring their blood sugar.

**A Foreign Element: Barriers and Promotors for Usage**

**Theme Overview**

Personal attributes such as health-related challenges and limited digital literacy among the informants were barriers for their use of ICT. The informants generally indicated an acceptance of the barriers experienced, and they acknowledged that they often depend on support that is mainly provided by their children.

**Digital Literacy**

A consistent theme was that the informants felt unfamiliar with the language and concepts of the digital systems and had a hard time understanding them. Some emphasized that this was not due to cognitive limitations, as they felt they had good linguistic skills, but rather to their introduction to ICT late in life:

*It’s not like I am linguistically challenged but there have been some instructions where I was thinking: what in the world are you talking about?* [Informant H; 81 years]

The informants mentioned examples of how they encountered new words that made no sense to them, which complicated navigating the system. Age was often considered the prime reason for these linguistic challenges. The informants were older, and technology had entailed estranged procedures and language for which they had no prior experiences to cope with. Time was experienced as passing fast, particularly with regard to the digital age, introducing swift changes in functions as well as language and expressions in relation to technology.

**Because when I was 18-20 years old, nobody said anything about digital files, we didn’t say “stand-by” either, we said “stop.” (…) there are so many new words and things in the systems, and you can’t keep up, also because time passes so quickly for us**[Informant C; 91 years]

One informant used ICT to stay in touch with friends and family by email, but she found it challenging, as she sometimes forgot which button to press. This informant labeled herself as suffering from technological illiteracy.

**Health-Related Barriers**

Various health-related barriers such as arthritis in the fingers or reduced vision were described as making it difficult to operate
certain devices, including when using touchscreens on tablets and smartphones. Informants with impaired vision experienced the use of tablets and phones with small screens challenging. Many preferred the computer as it provides a larger screen. Previously, some of the nonusers had used a personal computer, but had experienced increasing problems over time, which they related to a decline in their cognitive skills such as difficulties with learning and memory. Thus, the informants experienced challenges making the use of both hardware and software either difficult or impossible. Mostly, the obstacles experienced using ICT were related to personal barriers and not to a lack of functionality of the ICT systems.

But then they introduced new systems, and I have a Windows10, which for me is more complicated. And so, I find it harder to learn now. (…) there is no doubt I am having a hard time figuring things out. This is also because I cannot see things properly. It is a terrible show-stopper that I cannot see properly. This is my biggest challenge. [Informant I; 93 years]

However, one informant attributed the challenges to the digital system. He was an experienced ICT user and differed from the other informants as he was younger:

You can say, they are different systems … iPad and iPhone are different from PC, right? It doesn’t always work well together. [Informant J; 69 years]

I Might Be Too Old: Ageism

Theme Overview
This theme describes an understanding that appeared to be common both among the informants and also the social network, indicating that increased age was associated with limited competence to benefit from ICT usage. This understanding seemed in itself to be a substantial barrier for not using ICT at all but also prevented ICT users from expanding their use to health-related purposes.

Lack of Confidence in Own Skills
A general lack of confidence in their own skills in ICT use among the informants was apparent throughout the data both among users and nonusers. This was often based on the attitude that age had the upper hand and made it increasingly difficult to use ICT. For some, however, this attitude was based on prejudice and not from real experience with ICT:

I am not so good at this sort of thing. and then I’d rather not do it at all (…) I keep telling myself I can’t and then I’d rather not. [Informant K; 89 years]

Age was the dominant reason given by nonusers of ICT, combined with the assumption that the effort demanded to acquire the necessary skills was too great, and, in view of their remaining years, not worthwhile, particularly since many had no expectations for ICT to benefit them in their present situation and age. Even informants who actually used ICT lacked confidence in their possibilities in acquiring the necessary skills for using ICT for health-managing purposes.

I really don’t have the capacity or skills for such stuff, no, I can’t do that.

But then they introduced new systems, and I have a Windows10, which for me is more complicated. And so, I find it harder to learn now. (…) there is no doubt I am having a hard time figuring things out. This is also because I cannot see things properly. It is a terrible show-stopper that I cannot see properly. This is my biggest challenge. [Informant I; 93 years]

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Principal Findings
The aim of this study was to explore older patients’ competencies, preferences, and attitudes toward use of ICT, and to gain an understanding of both the barriers and facilitators for their motivation to engage with eHealth. Our findings contradict the perception that older patients cannot or will not use ICT. The qualitative and quantitative data revealed that older patients were indeed users of ICT, but their competence, ability, and preferences may differ from those of younger people. A main finding of this study was the large diversity in the informants’ experiences with the use of ICT. This spanned from daily use to no use at all. The majority of the informants used ICT on a daily basis, which was in alignment with former studies [15,21,32] as well as with data from Statistics Denmark, showing that 51% of the 65–74 year olds and 26% of the 75–89
A prevailing finding was the informants’ lack of confidence in their own competence in using ICT, and how it affected their usage. Theoretically, lack of confidence in one’s own competence relates to the concept of self-efficacy, which is defined as “people’s beliefs in their capabilities to produce given attainments” [34]. Self-efficacy influences individuals’ health behavior intentions, and in this case engagement with an eHealth solution [34,35]. The informants’ low score within the READHY dimension “Ability to actively engage with digital services” (eHLQ3) [29] supports the qualitative finding of low confidence in using ICT. The nonusers’ score was significantly lower than that of the ICT users, and was also lower compared with that reported in other studies using the same instrument [36,37]. Several other studies have found that older patients’ level of self-efficacy influences their use of eHealth. In a Dutch survey study (N=1014), de Veer et al [15] reported self-efficacy to be significantly correlated to older patients’ intention to use eHealth applications. In another study based on data from a questionnaire (N=256) and interviews (N=15), Van Houwelingen et al [21] reported that self-efficacy predicted older patients’ effort expectancy (ie, their belief in how hard or easy it is to use the technology), which was positively associated with their intention to use telehealth.

In future interventions, when introducing older patients to eHealth, it will be important to be aware of and increase their self-efficacy with use of technology. According to social cognitive theory, an individual’s self-efficacy can be improved through mastery experience [34]. Therefore, a key factor in motivating older patients to engage with eHealth is to introduce it in a way that they can perceive the technology as both useful and manageable. Thus, in a hospital setting, when introducing eHealth, it is crucial to provide older patients with sufficient technical support to make them feel confident in using eHealth.

The social context such as feeling understood and having the necessary support from relatives and health care professionals influences an individual’s capability to utilize eHealth [24]. The informants in our study experienced having the necessary support, including technology support from their relatives, in most cases their adult children. Moreover, they generally felt understood and supported by the health care professionals. The above qualitative findings were also reflected in the results from READHY scores, as the total sample had a high median score (above 3) on scales within the dimensions measuring their feelings of being understood and supported by health care professionals and their relatives (HLQ1 and HLQ4). It is noteworthy that the informants with a median age of 81 years had scores in the above-mentioned two scales similar to those reported in the Danish validation study covering the general population with a mean age of 53 years [38].

A lower level of health literacy among older patients has been reported [39]. This study indicated that older patients, even those with acute and chronic illness, often have health literacy resources in terms of support from their social network and trust in the health care system. However, it seems that these resources may not enable or motivate engagement with ICT. As described above, the informants lacked knowledge of the possibilities and benefits of using eHealth, despite their frequent contact with the health care system. Hence, these patients were seemingly
not informed and motivated to use ICT for health-related purposes by the health care professionals they met. This may be explained by a general perception of health care professionals that older patients are not motivated for and able to utilize eHealth [13,14]. Paradoxically, the social network appeared for some to become an obstacle to the use of ICT. In accordance with other studies [15,16], we found that helpful relatives risked taking over the tasks and thus reduced the older person’s need to use ICT. Furthermore, the informants’ lack of confidence in their own ICT competence was also shared by their relatives. A prevailing theme in the qualitative data was ageism, defined as “the stereotyping, prejudice, and discrimination against people on the basis of their age” [40]. The informants’ perception that they, due to their high age, lacked ICT competence was in some cases confirmed by their relatives. Nevertheless, in accordance with other studies [16,21], this study showed how the informants valued the support and guidance from relatives, indicating that it is important to involve relatives when introducing eHealth to older patients. The relatives must perceive the older patients to potentially be capable of using and benefiting from eHealth. Subsequently, the educative intervention must target both patients and relatives.

An important finding in this study was the informants’ perception of ICT usage leading to less personal contact with health care professionals. Consistent with other studies [33,41], the informants in our study preferred personal contact when communicating with health care professionals. The nonuse of health-related ICT was neither due to mistrust in security nor sharing data in digital systems but rather to the perception of digital communication detracting from the personal interaction with the health care professionals. Thus, older patients should be introduced to eHealth as a tool adjunct to the personal guidance and feedback from the health care professionals, enabling them to participate in their own health care. Moreover, we found that older patients may have some preferences for choice of computer devices due to health-related barriers (eg, a bigger screen due to reduced vision or a computer with a keyboard instead of a tablet due to obstacles with touch). These aspects must be considered when planning the implementation of eHealth solutions in a hospital setting to ensure older patients’ successful involvement.

We found demographic differences in the samples from the two hospitals (ie, lower educational level), corresponding with differences in their READHY scores. In accordance with other studies [41], this underlines that patients with a lower educational level may need more and individualized support to utilize eHealth.

**Strengths and Limitations**

One important strength of this study is that the themes appeared across the sample regardless of differences in gender, age, and socioeconomic background. The sample size was small, but nevertheless heterogeneous in terms of the older patients’ gender, age, use of ICT, and educational attainment. In a small sample, heterogeneity may add strength as a pattern across variation highlights central aspects of the phenomenon [42]. Another important strength was the use of READHY as a theoretical framework, which ensured that we captured relevant perspectives in relation to competence for ICT usage. The use of a qualitative design allowed for additional perspectives to emerge. By combining the qualitative and quantitative results, we achieved a nuanced understanding of this group of patients. Furthermore, READHY is a multidimensional instrument encompassing the many aspects influencing individuals’ abilities to engage with eHealth, and allows for gaining a broader understanding of older patients’ resources and barriers to be addressed in an educative intervention. This study also has some limitations. The sample consisted of 25 patients, and 60 of the 85 eligible patients were excluded due to cognitive impairment, either permanent or acute, which negatively affects the transferability of the findings. Furthermore, the informants’ narratives might have been affected by their situation when they were interviewed (ie, being acutely ill and hospitalized).

**Conclusions**

This study indicates that a large group of older patients are potential users of ICT, but their usage showed wide variation, which was also reflected in their competencies, preferences, and attitudes toward the use of ICT. This group of patients has competencies and resources related to self-management and social support that should be utilized when introducing them to eHealth in a hospital setting. An important facilitator for motivating older patients to engage with eHealth is knowledge of the benefits derived from eHealth, and how this may assist them in managing health-related challenges. When introducing health technology to patients, health care professionals should be aware of how both their own assumptions and attitudes and those of relatives may cause a barrier, as well as an insufficient level of patients’ knowledge, skills, motivation, and confidence.

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**Authors’ Contributions**

RT performed the data collection. RT and TL performed the qualitative analysis, which was discussed continually with LK. RT performed the statistical analysis and wrote the first draft of the manuscript, which was critically reviewed by the other authors.
Conflicts of Interest

None declared.

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Abbreviations

**eHLQ**: eHealth Literacy Questionnaire  
**GP**: general practitioner  
**heiQ**: Health Education Impact Questionnaire  
**HLQ**: Health Literacy Questionnaire  
**ICT**: information and communication technology  
**READHY**: Readiness and Enablement Index for Health Technology
Identifying Barriers to and Opportunities for Telehealth Implementation Amidst the COVID-19 Pandemic by Using a Human Factors Approach: A Leap Into the Future of Health Care Delivery?

Tianyi Zhang, MSc; Jarrod Mosier, MD, FCCM; Vignesh Subbian, PhD

Department of Systems and Industrial Engineering, College of Engineering, The University of Arizona, Tucson, AZ, United States
Department of Biomedical Engineering, The University of Arizona, Tucson, AZ, United States
Department of Medicine, Division of Pulmonary, Allergy, Critical Care and Sleep, University of Arizona College of Medicine, Tucson, AZ, United States
Adult ECMO Service, Banner - University Medical Center Tucson, Tucson, AZ, United States

*all authors contributed equally

Corresponding Author:
Tianyi Zhang, MSc
Department of Systems and Industrial Engineering
College of Engineering
The University of Arizona
1127 E James E Rogers Way
Tucson, AZ, 85721-0020
United States
Phone: 1 6088863936
Email: tianyi@email.arizona.edu

Abstract

The extensive uptake of telehealth has considerably transformed health care delivery since the beginning of the COVID-19 pandemic and has imposed tremendous challenges to its large-scale implementation and adaptation. Given the shift in paradigm from telehealth as an alternative mechanism of care delivery to telehealth as an integral part of the health system, it is imperative to take a systematic approach to identifying barriers to, opportunities for, and the overall impact of telehealth implementation amidst the current pandemic. In this work, we apply a human factors framework, the Systems Engineering Initiative for Patient Safety model, to guide our holistic analysis and discussion of telehealth implementation, encompassing the health care work system, care processes, and outcomes.

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KEYWORDS

telehealth; healthcare system; COVID-19; human factors; implementation; SEIPS

Introduction

COVID-19, caused by the novel coronavirus SARS-CoV-2, has swept across the globe since its emergence in late 2019. The rapid spread of SARS-CoV-2 imposed an excessive burden on health care systems, with nearly 326.7 per 100,000 people in the USA requiring hospitalization through the end of 2020 [1]. The extensive adoption of telehealth approaches, as part of protective measures and to promote the overall safety of patients and health care workers, has manifested in various essential components of care delivery. The surge in the adoption of telehealth, however, imposes significant challenges to the health care system, as it has disrupted the balance of the health care work system, thus highlighting the importance of exploring the barriers to and impact of the pandemic-driven, large-scale uptake of telehealth technologies.

The health care system is particularly vulnerable to novel and highly infectious agents such as SARS-CoV-2 because of the exponentially increased demand of health care resources [2], including ventilators and personal protective equipment (PPE), and the high risk of infection among care providers through aerosol transmission during clinical care [3], especially by asymptomatic carriers. The most widely adopted strategy among...
the general public to lengthen the doubling time of the virus and reduce the basic reproduction number, $R_0$, involved social distancing to attenuate the proximity and duration of contact with potentially infected individuals. In clinical settings, telehealth solutions have emerged as an effective tool for health care systems to deliver care to patients while minimizing safety risks to both patients and providers by maintaining social distancing.

The Systems Engineering Initiative for Patient Safety (SEIPS) model [4,5] provides a useful framework for analyzing the widespread adoption of telehealth in response to the COVID-19 crisis. This model allows for a comprehensive and proactive assessment of telehealth implementation in the longer term, beyond the pandemic [6]. Previous studies [7-9] discussing barriers to or the impact of telehealth implementation either overlooked patients’ perspectives or focused more on certain components of the health care system. Here, we demonstrate the application of the SEIPS model to guide the assessment of the barriers to and impact of telehealth on health care systems, processes, and outcomes during the ongoing crisis. According to the SEIPS model, the health care work system includes the following components: person, technologies, environment, tasks, and organization.

- The **person** component considers education, knowledge, motivation, and physical and psychological characteristics, as it relates to both patients and health care providers.
- The **technologies** component involves all devices and information systems that are used to deliver care.
- The **environment** component consists of the workstation design, layout, noise, and any existential environmental factors.
- The **tasks** component discusses the content, participation, and demands of the job.
- Finally, the **organization** component emphasizes teamwork, coordination, collaboration, communication, and organizational culture [4].

The SEIPS model also emphasizes that the analysis of processes and outcomes should be based at both the individual level (ie, patients and health care workers) and the organizational level. For example, telehealth can reduce the burden of environment infection due to COVID-19, which is an essential process to health care organizations but not necessarily a direct part of patients’ care processes. In this work, we use the SEIPS model to discuss barriers related to and impacts of telehealth implementation amidst the COVID-19 pandemic (Table 1).

Given that there are few measures to assess outcomes of telehealth during the pandemic, we will also discuss and propose measures that could be helpful in guiding the assessment as well as future scalability and efficacy studies.
Table 1. Assessment of barriers related to and impact of telehealth implementation during the COVID-19 pandemic by using the Systems Engineering Initiative for Patient Safety (SEIPS) model.

<table>
<thead>
<tr>
<th>Domain and components</th>
<th>Impact</th>
<th>Issues</th>
</tr>
</thead>
<tbody>
<tr>
<td>Telehealth-enabled work system</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Person as patients</td>
<td>• Increased acceptance of telehealth due to convenience</td>
<td>• Insufficient and variable levels of digital literacy among the patient population • Widening of health care disparities [10-12]</td>
</tr>
<tr>
<td>Person as providers</td>
<td>• Increased motivation</td>
<td>• Mental or physical challenges due to the imperative and wide adoption of telehealth</td>
</tr>
<tr>
<td>Technologies and tools</td>
<td>• Enhanced patient and health care worker safety</td>
<td>• Telehealth may be disruptive and not user-friendly</td>
</tr>
<tr>
<td>Environment</td>
<td>• Highlighted the suboptimal and complex environment for telehealth uptake</td>
<td>• Insufficient communication infrastructure • The environment where patients interact with telehealth technology may be suboptimal</td>
</tr>
<tr>
<td>Tasks for patients</td>
<td>• Safer and potentially quicker access to care</td>
<td>• Systemic, informational, procedural gap that patients need to fill in</td>
</tr>
<tr>
<td>Tasks for providers</td>
<td>• Clinical and nonclinical services can be safely continued via telehealth</td>
<td>• Challenges in adapting to changes in job content and demands</td>
</tr>
<tr>
<td>Organization</td>
<td>• Formulation of new teams • Maximizing the utilization of existing resources to deal with the pandemic</td>
<td>• Dynamic changes to teamwork • Reallocation of accountability and responsibility • Redistribution of labor, equipment, information, and funding resources</td>
</tr>
<tr>
<td>Telehealth-enabled processes</td>
<td></td>
<td></td>
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<tr>
<td>Care Processes</td>
<td>• Wide application of forward-atrie, tele-intake, and tele-ICU&lt;sup&gt;b&lt;/sup&gt;</td>
<td>• Time management is more challenging (eg, a busy lobby makes it easier to accept the physician being late as opposed to being at home waiting alone in the virtual lobby) • Telehealth may not lead to a shorter overall time spent in the care system</td>
</tr>
<tr>
<td>Other processes</td>
<td>• Reduced demand of other processes that support care processes (eg, reduced environment disinfection needs due to the fewer in-person visits)</td>
<td>• Information flow may be more fragmented</td>
</tr>
<tr>
<td>Telehealth outcomes</td>
<td></td>
<td></td>
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<tr>
<td>Patients’ outcomes</td>
<td>Unclear</td>
<td>• Lack of measures for patient safety and quality of care evaluation</td>
</tr>
<tr>
<td>Care providers’ and organizational outcomes</td>
<td>Unclear</td>
<td>• Lack of measures for assessing care providers’ mental and physical health affected by the surging use of telehealth during the COVID-19 pandemic • Organizational outcome related to the pandemic-driven, large-scale uptake of telehealth needs more attention</td>
</tr>
</tbody>
</table>

<sup>a</sup>PPE: personal protective equipment.  
<sup>b</sup>ICU: intensive care unit.

### Discussion

#### Person

During various stages of the COVID-19 pandemic, many health care providers were quarantined after potential exposure to or confirmed infection with the virus, resulting in a limited workforce and a reduced health care system capacity. Telehealth can facilitate the rearrangement and reassignment of the workforce and maintain the capacity by allowing quarantined health care providers to continue their work without compromising the health care system’s safety. Moreover, care facilities that lack telemedicine programs can outsource part of their services to entities with well-established telemedicine programs to meet these goals [13].
Despite the claimed benefits of efficiency and convenience offered by telehealth, not all health care providers have been satisfied with the telehealth options available, even before the COVID-19 pandemic. Preliminary reports from the early phases of the pandemic [8] suggests that health care providers’ unwillingness is one of the barriers to telehealth implementation in practice. However, this position does not fully consider latent factors such as technological and administrative issues that lead to the active failure (ie, care providers’ unwillingness). Furthermore, there is significant variability in telehealth education and training among clinicians, leading to varying levels of acceptance and uptake. The surging health care demands during the pandemic has forced health care workers to adopt telehealth predominantly for safety reasons. Further research is needed to better understand how the adoption of telehealth demanded by new care delivery protocols may affect health care providers’ physical and mental workload.

Patients, on the other hand, are also profoundly influenced by the imperative uptake of telehealth since the beginning of the pandemic. Recent studies have shown that telehealth approaches such as remote video visits in a variety of care delivery contexts is acceptable to patients [14,15]. For example, some patients perceive primary care video visits as convenient and efficient because they can stay in their home environments while seeing care providers; however, they are still concerned about privacy issues [14]. A 2009 systematic review [16] and a recent study [17] have both identified that factors such as human-technology interaction (ie, user experience and usefulness), environment (ie, the context where patients would use telehealth), and patient demographics (ie, socioeconomic status) could influence their acceptance of telehealth. Although the pandemic may have potentially increased patients’ subjective acceptance of telehealth, objective barriers still hinder a higher acceptance among patients. For instance, some patients may not have access to technology that enables telehealth, have poor internet connectivity, or face technical challenges in navigating telehealth systems [14,18]. These barriers are particularly encountered by vulnerable populations that need most medical attention during the COVID-19 pandemic. In general, although the public health crisis may improve the overall uptake, penetration, and implementation of telehealth among all populations, it may also intensify health inequities [10-12].

Technologies and Tools

Prior to the COVID-19 pandemic, telehealth was regarded as an alternative form of care delivery to in-person care. It was considered ancillary because telehealth was not widely possible until the widespread prevalence of smartphones [19,20]. Today, telehealth can be realized through a variety of communication modalities depending on institutional and regulatory guidance, such as phone calls, text messaging, email, patient portal, or licensed third-party software, and most of them can be accomplished via smartphones.

A recent study pointed out that the adoption of telehealth can conserve PPE and extend the time to peak capacity. Even high-volume emergency departments can preserve PPE and safety by performing medical screening exams remotely for patients with suspected COVID-19 [21].

Despite the benefits of telehealth uptake, we cannot assume it would work well within the current health care system. In fact, the telehealth system is deemed as disruptive and not user-friendly by many clinicians [8]. For instance, in large health systems in urban Southwest Arizona, telehealth tools were made available during the pandemic, yet many were impractical or nonviable solutions. Contrary to the report that claimed clinicians’ unwillingness of adopting telehealth [8], clinicians were positive about telehealth and eager for its uptake to continue serving their patients during statewide mandatory stay-at-home orders, but they were also frustrated at the obstacles to its implementation. We believe that a redesign of the telehealth system is urgently required and is fundamental to higher levels of acceptance and satisfaction among users, including both patients and providers.

Environment

Despite the convenience that telehealth can provide, the lack of infrastructure and insufficient technical capability may limit providers’ and patients’ use and acceptance of telehealth. Although the majority of the United States has access to 4G or faster networks, many remote and rural regions still lag behind in terms of internet coverage. A report from the American Hospital Association shows that 34 million Americans do not have access to satisfactory broadband [22]. The existing Federal Communication Commission program that supports the expansion of broadband is criticized as cumbersome and insufficient to fill the financial gap of increasing broadband access in rural areas [22]. Previous studies have found that telehealth is an effective tool to treat a large group of patients in disaster response [23] and that Wi-Fi and cellular service are key to the successful implementation of telemedicine [19]. The poor coverage may limit, for example, the quality of video conferences between patients and health care workers, or even between health care workers from remote areas. Even in developed health care facilities or regions, the communication demands during the COVID-19 pandemic may still impose a heavy load on the hospitals’ network, thus hindering telehealth capabilities and requiring immediate technical attention. One solution to improve telehealth use could be to deliver some data using 4G as well as 2G and 3G networks [24], which could ease the burden on the network.

The COVID-19 pandemic may have also changed the environment wherein the patient usually uses telehealth. The environment in which patients interact with telehealth technology may be suboptimal. The shelter-in-place orders compelled people to stay in their residential living spaces. The lighting, noise level, and airflow in residential living spaces may not be ideal for medical consultation via telemedicine. For example, childcare and at-home responsibilities may interfere with the interaction with providers via telemedicine, especially regarding sensitive issues. Such environmental factors are less often explored by studies but are still demanded important for satisfactory telehealth use [16].
Tasks
Telehealth can facilitate the delivery of clinical and nonclinical services [25], both of which are essential during the COVID-19 pandemic. Telehealth-enabled clinical services usually consist of live, video-based patient visits, store-and-forward consultations (eg, patients measure their body temperature at home and care providers evaluate the information in the remote setting), remote monitoring (eg, electronic intensive care unit [e-ICU] [13]), messages sent through phone or a patient portal, and phone calls [25,26].

The widespread adoption of telehealth to deliver care during the COVID-19 pandemic has changed the care delivery protocols [27]. Patients are expected to collaboratively fill systemic (eg, navigating an unfamiliar method of accessing care), informational (eg, primary care physicians cannot visually examine the patients if the consultation is realized via messages or phone calls, and their diagnosis would only be based on verbal descriptions, which is filled in by patients), or procedural (eg, recording their own vital signs prior to video consultation or store-and-forward consultation) gaps. As patients are required to take more responsibility with telehealth, they could feel overwhelmed and disoriented about navigating the rapidly changing system of care. Thus, it is vital to ensure the design of a telehealth-mediated health care system is centered on patients’ needs and experiences.

Current telehealth practices have also disrupted care providers’ workflow and work content [28,29]. In a report describing a Veterans Affairs physician’s day of tele-interacting with their patients in the era of the COVID-19 pandemic, the provider was frustrated that telehealth does not allow them to quickly grasp important peripheral information of patients, such as their comportment and facial expressions, which in-person visits allow for [29]. The peripheral information is essential to providers particularly for older patients or those with various underlying health conditions, that is, groups that are the most vulnerable to COVID-19. This is not an isolated example, and there are more care providers affected that need to make the quick switch to telemedicine to be compliant with the new care policies during the COVID-19 pandemic. This introduces extreme stress into the health care system, especially when additional training is often necessary. Above all, telehealth as a protective method for health care workers during the pandemic may be more cost-effective than the traditional ICU setting. The challenges remain in terms of how remote clinicians communicate, collaborate, and coordinate with onsite health care workers to deliver timely and necessary care to patients that are compliant with the safety standards. The overall management and organization of ICU may require further analysis as to who should be accountable for patient safety.

In addition to the numerous changes telehealth could possibly contribute to the teamwork dynamics, it could also play a role in resource reallocation within the system. Resources in health systems usually include labor resources (ie, a variety of care providers and administrative staff), equipment resources (ie, ventilator, PPE, and computers), information resources (ie, patient information), and funding resources (ie, payment and reimbursement).

Telehealth can conserve valuable labor resources and maximize the use of available human resources by (1) protecting health care providers from potential exposure to COVID-19; (2) allowing health care providers with suspected exposure to COVID-19 to continue working, who may otherwise have to be self-isolated [13]; (3) integrating labor resources across different systems (eg, e-ICU can reduce the onsite labor resource requirement by using centralized patient monitoring [13]). Ideally, telemedicine can help out-of-state providers to fill in the local shortage of health care workforce economically and promptly [19]; however, state-based physician licensure can hinder the use of telemedicine to coordinate the cross-state response to a natural disaster such as COVID-19 pandemic [26]. Fortunately, the pandemic has effected changes to several policies, as the federal and state governments have modified or waived certain policies to facilitate the broad application of telehealth [30].

Telehealth use was mostly restricted to patients living in remote areas or staying in the health care facilities [22]; therefore, most patients, even if they wanted telehealth services, did not have many options to do so, given the billing and insurance coverage concerns associated with its use. One report listed reimbursement problems as one of the barriers to the use of telehealth [8]. In the United States, a recent survey revealed that the District of Columbia and 42 out of 50 states have enacted some telehealth commercial insurance coverage policy [32], and only 35 states together with the District of Columbia have some sort of parity law [22], which direct insurance providers to cover telehealth services the same way as they would cover in-person care services. However, in many states, the details of reimbursement policy of telehealth are still vague as payment parity is unclear as well. The payment parity means that facilities, published by individual states, urges all health care facilities to assemble a committee that is designated to review and implement guidance during the COVID-19 crisis [31]. Such new teams and committees would change the teamwork dynamic within their health care system.
telehealth services should be reimbursed to the same extent as how traditional in-person services are reimbursed. Given the special circumstances of the COVID-19 pandemic, wherein many fees are subsidized or waived, parity payment is not a significant concern at this stage but telehealth insurance coverage is still a dominating issue. As urban dwellers are more in need of telehealth due to the higher likelihood of spread of the virus within areas of relatively higher population density [30], the traditional telehealth reimbursement policies would pose as a barrier to applying telehealth during the COVID-19 pandemic. In 2018, Duffy and Lee [20] suggested that providers need to actively redesign the care models and that the payment system will evolve along with it. Fortunately, this is no longer the case. Current Medicare coverage in the United States has removed the rural and site limitations and allows patients residing in any location to get covered for their telehealth use [33].

The pandemic-driven telehealth uptake also heightened the information flow problem more than ever before. A COVID-19 care management pathway enabled by telehealth can connect many health care entities for triaging, screening, and treatment through telehealth or onsite outpatient visits, specimen collection (onsite or drive-through), clinical testing laboratories, follow-up with primary care or appropriate care providers, and inpatient care [34]. Information flow among these entities is often fragmented due to a plethora of regulations and laws such as the Health Information Technology for Economic and Clinical Health Act and Health Insurance Portability and Accountability Act (HIPAA) [34]. The multiple overlapping federal and state laws that intentionally protect health information located in different information systems now unsurprisingly also make it onerous for care providers and patients to use telehealth to exchange COVID-19–related information [35]. Therefore, the difficulty of integrating patient health information across entities needs to be addressed for effective telehealth services. Improving interoperability between various information systems and enhancing electronic health record as a one-stop information hub may be one potential solution [34].

**Processes**

The clinical care processes of COVID-19 typically consist of four stages: screening, testing, treatment, and recovery. During the screening stage, forward triage is deemed as an important practice to relieve the intake pressure on the health care facility’s front end [13]. Ideally, forward triage is done through telehealth where initial risk assessment and patient counseling are conducted remotely [34]. This would give patients quicker access to care while keeping low-risk patients away from the overwhelmed health care system and reducing unnecessary exposure for patients and care providers. In addition to the forward triage, tele-intake is also a good approach to reduce exposure risks for some in-person visits if deemed necessary [13]. It is noteworthy that the use of telehealth may not reduce the overall time that patients spend in the health care system, starting from the initial contact with the health care system until their last contact, because telehealth may not address the bottlenecks of the entire treatment management process that cause delays. For example, forward triage can reduce patients’ time of accessing care, but they may still need to wait for a hospital bed during their actual in-person visit. One study found that tele-intake can increase the rate of leaving without treatment completion and that tele-intake only functions best when the health care system capacity levels up accordingly [36].

While telehealth had manifested its potential in allowing patients quicker access to care, it also imposed a higher requirement for care providers’ time management. A traditional busy lobby usually made it easier to accept if the physicians were late to the appointments; however, patients waiting alone on a web-based platform and not being able to see the bustle on the side of care providers could make the care experience less patient-centered. Hence, an ideal telehealth system design would allow care providers to better engage patients and improve their care experience before and after the televisit.

In terms of other processes that support care processes, telehealth may exhibit different effects. For example, with fewer in-person visits, the stress and demand of repetitive environment disinfection could be relatively relieved. However, telehealth could also impose extra challenges of integrating, maintaining, and transferring of patient information.

**Outcomes**

Regulation and policy changes that have come into effect during the pandemic may be perceived as the driving force for the large-scale uptake of telehealth. However, for longer-term sustainability, performance-based outcome metrics are needed to assess the impact of telehealth on health systems. A few studies have made initial attempts to apply existing performance metrics to assess telehealth implementation [36,37]. The outcome measures we propose (Table 2) can help guide future work in optimizing and scaling telehealth implementation.
Table 2. Potential outcome measures of telehealth-enabled care.

<table>
<thead>
<tr>
<th>Outcome level and dimension</th>
<th>Potential outcome measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patient outcome</td>
<td></td>
</tr>
<tr>
<td>Patient safety</td>
<td>• Diagnostic errors (compared to in-person visits)</td>
</tr>
<tr>
<td></td>
<td>• Hospitalization rate</td>
</tr>
<tr>
<td></td>
<td>• ICU(^a) admission rate</td>
</tr>
<tr>
<td></td>
<td>• Intubation rate</td>
</tr>
<tr>
<td></td>
<td>• Mortality rate (general and ICU)</td>
</tr>
<tr>
<td></td>
<td>• Readmission rate</td>
</tr>
<tr>
<td></td>
<td>• Health care–associated infections</td>
</tr>
<tr>
<td>Care quality</td>
<td>• Left without being seen</td>
</tr>
<tr>
<td></td>
<td>• Door-to-provider and door-to-disposition times</td>
</tr>
<tr>
<td></td>
<td>• Left without treatment complete</td>
</tr>
<tr>
<td></td>
<td>• Left against medical advice</td>
</tr>
<tr>
<td></td>
<td>• Left without treatment [36]</td>
</tr>
<tr>
<td>Employee outcome</td>
<td></td>
</tr>
<tr>
<td>Work safety</td>
<td>• Work-associated infections</td>
</tr>
<tr>
<td></td>
<td>• PPE(^b) sufficiency</td>
</tr>
<tr>
<td>Work quality</td>
<td>• Work stress and clinician burnout</td>
</tr>
<tr>
<td></td>
<td>• Work efficiency</td>
</tr>
<tr>
<td>Organizational outcome</td>
<td>• Staff turnover rate</td>
</tr>
<tr>
<td></td>
<td>• Policy implementation performance</td>
</tr>
<tr>
<td></td>
<td>• Finance health index (before and after the COVID-19 pandemic)</td>
</tr>
</tbody>
</table>

\(^a\)ICU: intensive care unit.  
\(^b\)PPE: personal protective equipment.

Conclusions

The COVID-19 pandemic has thrust telehealth solutions into the front line of health care despite significant barriers to its effective implementation and optimization. There are significant benefits to utilizing telehealth, namely providing enhanced safety options for patients and health care providers during the pandemic and introducing the potential to enhance efficiency and convenience in the future. However, challenges with telehealth implementation arising in different domains of health care work system and processes that potentiate disruption to care delivery, worsen disparities in health care, and provoke changes from different levels within the health care industry, still need to be addressed. Future efforts should therefore address these barriers to implementation by redesigning telehealth solutions via a systematic approach such that health care systems can mitigate the negative effects of telehealth and seamlessly realize the benefits and enhanced safety that telehealth provides.

Acknowledgments

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Conflicts of Interest

None declared.

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31. COVID-19 Implementing Crisis Standards of Care at Short-Term Inpatient Acute Care Facilities Guidance Approved by State Disaster Medical Advisory Committee (SDMAC) - 4/1/2020. Arizona Department of Health Services. URL: https://tinyurl.com/h8sv4nr9 [accessed 2020-06-12]


Abbreviations

e-ICU: electronic intensive care unit
ICU: intensive care unit
PPE: personal protective equipment
SEIPS: Systems Engineering Initiative for Patient Safety Model
Patient Satisfaction and Trust in Telemedicine During the COVID-19 Pandemic: Retrospective Observational Study

Sharon Orrange1*, MD, MHS; Arpna Patel1*, MD; Wendy Jean Mack1*, PhD; Julia Cassetta1*, MD

Keck School of Medicine of USC, University of Southern California, Los Angeles, CA, United States

*all authors contributed equally

Corresponding Author:
Sharon Orrange, MD, MHS
Keck School of Medicine of USC
University of Southern California
1975 Zonal Avenue
Los Angeles, CA, 90033
United States
Phone: 1 323 442 5100
Fax: 1 310 272 8206
Email: sharon.orrange@med.usc.edu

Abstract

Background: Los Angeles County is a hub for COVID-19 cases in the United States. Academic health centers rapidly deployed and leveraged telemedicine to permit uninterrupted care of patients. Telemedicine enjoys high patient satisfaction, yet little is known about the level of satisfaction during a crisis and to what extent patient- or visit-related factors and trust play when in-person visits are eliminated.

Objective: The aim of this study is to examine correlates of patients’ satisfaction with a telemedicine visit.

Methods: In this retrospective observational study conducted in our single-institution, urban, academic medical center in Los Angeles, internal medicine patients aged ≥18 years who completed a telemedicine visit between March 10th and April 17th, 2020, were invited for a survey (n=1624). Measures included patient demographics, degree of interpersonal trust in patient-physician relationships (using the Trust in Physician Scale), and visit-related concerns. Statistical analysis used descriptive statistics, Spearman rank-order correlation, and linear and ordinal logistic regression.

Results: Of 1624 telemedicine visits conducted during this period, 368 (22.7%) patients participated in the survey. Across the study, respondents were very satisfied (173/365, 47.4%) or satisfied (n=129, 35.3%) with their telemedicine visit. Higher physician trust was associated with higher patient satisfaction (Spearman correlation \( r=0.51, P<.001 \)). Visit-related factors with statistically significant correlation with Trust in Physician score were technical issues with the telemedicine visit (\( r=-0.16 \)), concerns about privacy (\( r=-0.19 \)), and amount of time spent (\( r=-0.07 \)). Visit-related factors associated with patients’ satisfaction included fewer technical issues (\( P<.001 \)), less concern about privacy (\( P<.001 \)), and successful face-to-face video (\( P<.001 \)). The only patient variable with a significant positive association was income and level of trust in physician (\( r=0.18, P<.001 \)). Younger age was associated with higher satisfaction with the telemedicine visit (\( P<.005 \)).

Conclusions: There have been calls for redesigning primary care after the COVID-19 pandemic and for the widespread adoption of telemedicine. Patients’ satisfaction with telemedicine during the COVID-19 pandemic is high. Their satisfaction is shaped by the degree of trust in physician and visit-related factors more so than patient factors. This has widespread implications for outpatient practices and further research into visit-related factors and the patient-provider connection over telemedicine is needed.

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KEYWORDS

telemedicine; patient satisfaction; COVID-19; health services research; health policy; health care delivery; physicians; medicine
**Introduction**

On March 11, 2020, the World Health Organization declared the COVID-19 outbreak a pandemic; thereafter, telemedicine—particularly video consultation—was promoted and scaled up to reduce the risk of transmission [1,2]. A few months later, Los Angeles became the county with the highest number of COVID-19 cases in the United States [3,4]. To prioritize public health, our academic health center rapidly deployed and leveraged telemedicine in response to the COVID-19 pandemic, permitting uninterrupted care of our patients [5]. We transitioned all clinic encounters as of March 16, 2020, to telemedicine, defined here as synchronous video or telephone visits [6,7].

Studies have shown that telemedicine visits enjoy high patient satisfaction [8,9]. Still, little is known about patient satisfaction with their primary care provider during a pandemic when patients have little choice but to seek remote care. Historically, correlates of patient satisfaction with telemedicine represent patients who have chosen that platform and thus are skewed toward a younger, female, and underinsured or uninsured population [10,11]. Additionally, patient satisfaction with direct-to-consumer telemedicine has been assessed with little or no previous doctor-patient relationship or coordination with the patients’ primary care provider [12]. Patient trust in their provider, an essential foundation for fostering patient satisfaction, has not been well studied in this type of remote care setting [13].

Rapid implementation of telemedicine within practices has been proposed to properly care for patients during the pandemic and beyond [14,15]. With the tremendous advances in telemedicine since COVID-19, determining factors correlated with satisfaction carries widespread implications for outpatient medicine and efforts to establish a framework for satisfying telemedicine visits. These findings are crucial for providers in adopting telemedicine as an element of the patient care continuum.

We captured 6 weeks of telemedicine visits in our primary care practice to explore the relationship between trust and patient satisfaction during a telemedicine visit, which has received little attention [16-18]. We examined whether patient factors, visit-associated factors, and the degree of “trust in provider” contributed to a satisfying telemedicine visit. We hypothesized that patient satisfaction with a telemedicine visit would be positively related to the degree of trust in the provider, patient-specific factors, and ease of use of the telemedicine platform.

**Methods**

Keck Medical Center is a large academic medical center located in Los Angeles. Inpatient services are provided at our institution at Keck Medical Center and USC Verdugo Hills Hospital, while outpatient services are provided at Keck Medical Center Outpatient facilities; both institutions share the same providers.

**Data Source**

Upon providing informed consent, the respondent was invited to complete a questionnaire provided by electronic survey. To explore the degree to which “trust in physician” correlates with satisfaction with telemedicine, we used a previously validated measure, the 11-question Trust in Physician Scale [19], to assess interpersonal trust in patient-physician relationships. Responses were scored on a 5-point Likert scale and higher scores indicated higher levels of trust (scale range 11-55).

Telemedicine visit–related issues and concerns including cost, privacy, convenience, technical issues, and time were assessed using a 5-item Likert scale. Responses ranged from 1-5 and higher scores indicated higher levels of agreement/satisfaction.

Satisfaction with the telemedicine visit was measured using the statements “I look forward to using telehealth in the future” (yes/no) and “To what extent were you satisfied with your visit?” (5-item Likert scale).

Respondents were also asked several questions about their demographics and health status.

**Study Population**

We performed a retrospective study of patients aged 18 years and older who had one or more telemedicine visits with a provider in the internal medicine department at the Keck Medical Center between March 10th and April 17th, 2020. This timing corresponds with a Keck Medical Center mandate to shift the majority of outpatient care from in-person to telemedicine visits. A total of 1744 patients had an encounter with our internal medicine providers during that time, and a link to a survey was successfully emailed to 1624 patients (93%). Data were collected in the fall of 2020. To be eligible to participate, the respondent had to have a telemedicine visit with one of our primary care providers. With a final sample size of 368 responders (22.7%), the attained sample size provided 80% statistical power to detect correlations of 0.14 and higher. All patients during the study period were invited to a video-enabled telehealth visit; of the 368 responders, 284 (77.4%) used video with their telehealth visit and the rest were telephone consultations. The study database in REDCap used the survey feature; all surveys were completed anonymously, and no personal health information or personally identifiable information on survey respondents was collected, in compliance with the Health Insurance Portability and Accountability Act (HIPAA). Nonresponders were similar in gender to responders (60.3% female versus 64.4% female), but responders were older than nonresponders by an average of 4.5 years (P<.001).

**Statistical Analysis**

Descriptive statistics were used to summarize visit-related concerns, patient characteristics, and satisfaction with the telemedicine visit. Variables were summarized as frequency and percentages for categorical variables and median and IQR for continuous variables.

The association of the Likert scale satisfaction item with trust in physician was evaluated with a Spearman rank-order correlation. The median (IQR) Trust in Physician Scale score is presented by level of patient satisfaction.
Associations of patient- and visit-related factors with Trust in Physician score and patient satisfaction used Spearman rank-order correlation, linear regression, and ordinal logistic regression (ordinal patient satisfaction dependent variable). Patient- and visit-related factors found in a linear regression analysis to be associated with the Trust in Physician score were included as independent variables to obtain an estimate and test of the adjusted association of trust with satisfaction with the telemedicine encounter.

**Results**

**Preliminary Analysis**

A link to a survey was emailed to 1624 patients; there were 368 respondents. The characteristics of the sample (N=368) are described in Table 1. The sample was primarily female and White, with a mean age of 55.8 (SD 16.0) years. Respondents evaluated their current health as fair to good.

Across the study, respondents were very satisfied (173/365, 47.4%) or satisfied (n=129, 35.3%) with their telemedicine visit, and 77.3% (279/361) reported that they “look forward to using telehealth in the future.” Table 2 describes the visit characteristics of the sample. Respondents tended not to worry about privacy or the cost of the telemedicine visit. The majority of patients (284/367, 77.4%) used video with their telehealth visit, while the rest were telephone consultations. Face-to-face video rather than telephone alone was preferred by most respondents, with 67.7% (243/359) strongly agreeing/agreeing it was important. Almost one-third of patients (114/365, 31.3%) had technical issues during the visit, yet 63 were resolved during the telemedicine visit. Notably, despite technical challenges, the convenience of telehealth was supported by 55.7% (204/366) and 32.8% (n=120) of patients who strongly agreed and agreed the telehealth visit was convenient, respectively. There was high satisfaction among our respondents with the amount of time spent and 90.1% (327/363) strongly agreed or agreed that the amount of time spent with the provider was adequate. Patients did not appear to have privacy concerns, with 28.8% (105/365) strongly disagreeing and 40% (n=146) disagreeing that they were “concerned about privacy.”

A summary of results from respondents to the 11-point Trust in Physician Scale appears in Table 3. Respondents overwhelmingly agreed with the statement “I trust my doctor’s judgments about my medical care” and that their doctor “is a real expert in taking care of medical problems.”

https://humanfactors.jmir.org/2021/2/e28589
<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age in years (n=365), median (IQR)</td>
<td>57 (43-68)</td>
</tr>
<tr>
<td>Hispanic (n=366), n (%)</td>
<td>96 (26.2)</td>
</tr>
<tr>
<td><strong>Race (n=348), n (%)</strong></td>
<td></td>
</tr>
<tr>
<td>White</td>
<td>262 (70)</td>
</tr>
<tr>
<td>Black or African American</td>
<td>25 (7.2)</td>
</tr>
<tr>
<td>American Indian or Alaskan Native</td>
<td>7 (2)</td>
</tr>
<tr>
<td>East Asian</td>
<td>28 (8.1)</td>
</tr>
<tr>
<td>Southeast Asian</td>
<td>14 (4)</td>
</tr>
<tr>
<td>Asian Indian</td>
<td>3 (0.9)</td>
</tr>
<tr>
<td>Native Hawaiian or Pacific Islander</td>
<td>3 (0.9)</td>
</tr>
<tr>
<td>Some other race</td>
<td>32 (9.2)</td>
</tr>
<tr>
<td>Female (n=364), n (%)</td>
<td>239 (66)</td>
</tr>
<tr>
<td><strong>Education (n=364), n (%)</strong></td>
<td></td>
</tr>
<tr>
<td>Less than high school</td>
<td>10 (2.8)</td>
</tr>
<tr>
<td>High school degree or equivalent</td>
<td>14 (3.9)</td>
</tr>
<tr>
<td>Some college but not degree</td>
<td>67 (18.4)</td>
</tr>
<tr>
<td>Bachelor’s degree</td>
<td>109 (30)</td>
</tr>
<tr>
<td>Graduate degree</td>
<td>164 (45.1)</td>
</tr>
<tr>
<td><strong>Current health (n=365), n (%)</strong></td>
<td></td>
</tr>
<tr>
<td>Excellent</td>
<td>46 (12.6)</td>
</tr>
<tr>
<td>Good</td>
<td>196 (53.7)</td>
</tr>
<tr>
<td>Fair</td>
<td>98 (26.9)</td>
</tr>
<tr>
<td>Poor</td>
<td>25 (6.9)</td>
</tr>
<tr>
<td><strong>Income in US $ (n=364), n (%)</strong></td>
<td></td>
</tr>
<tr>
<td>0-19,999</td>
<td>29 (8)</td>
</tr>
<tr>
<td>20,000-39,999</td>
<td>17 (4.7)</td>
</tr>
<tr>
<td>40,000-59,999</td>
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<tr>
<td>60,000-79,999</td>
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<td>80,000-99,999</td>
<td>24 (6.6)</td>
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<tr>
<td>100,000-119,999</td>
<td>21 (5.6)</td>
</tr>
<tr>
<td>120,000-139,999</td>
<td>21 (5.6)</td>
</tr>
<tr>
<td>140,000-159,999</td>
<td>21 (5.6)</td>
</tr>
<tr>
<td>160,000-179,999</td>
<td>11 (3)</td>
</tr>
<tr>
<td>180,000-199,999</td>
<td>13 (3.6)</td>
</tr>
<tr>
<td>200,000 or more</td>
<td>78 (21.4)</td>
</tr>
<tr>
<td>Prefer not to answer</td>
<td>70 (19.2)</td>
</tr>
<tr>
<td>Characteristics</td>
<td>Participants, n (%)</td>
</tr>
<tr>
<td>-------------------------------------------------------------------------------</td>
<td>---------------------</td>
</tr>
<tr>
<td>Used video with your telehealth visit (n=367)</td>
<td>284 (77.4)</td>
</tr>
<tr>
<td><strong>Did you experience significant technical issues before or during your visit? (n=365)</strong></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>51 (14)</td>
</tr>
<tr>
<td>Yes, but it was resolved during telehealth visit</td>
<td>63 (17.3)</td>
</tr>
<tr>
<td>No</td>
<td>251 (69)</td>
</tr>
<tr>
<td><strong>What sort of technical issues did you have? (n=110)</strong></td>
<td></td>
</tr>
<tr>
<td>Sound was not working</td>
<td>13 (11.8)</td>
</tr>
<tr>
<td>Video was not working</td>
<td>38 (34.5)</td>
</tr>
<tr>
<td>I was able to connect, but via different telehealth sources</td>
<td>32 (39.1)</td>
</tr>
<tr>
<td>Other issues</td>
<td>27 (24.6)</td>
</tr>
<tr>
<td><strong>The telehealth visit was convenient (n=366)</strong></td>
<td></td>
</tr>
<tr>
<td>Strongly disagree</td>
<td>7 (1.9)</td>
</tr>
<tr>
<td>Disagree</td>
<td>11 (3)</td>
</tr>
<tr>
<td>Neither agree nor disagree</td>
<td>24 (6.6)</td>
</tr>
<tr>
<td>Agree</td>
<td>120 (32.8)</td>
</tr>
<tr>
<td>Strongly agree</td>
<td>204 (55.7)</td>
</tr>
<tr>
<td><strong>The amount of time spent was adequate (n=363)</strong></td>
<td></td>
</tr>
<tr>
<td>Strongly disagree</td>
<td>5 (1.4)</td>
</tr>
<tr>
<td>Disagree</td>
<td>9 (2.5)</td>
</tr>
<tr>
<td>Neither agree nor disagree</td>
<td>22 (6.1)</td>
</tr>
<tr>
<td>Agree</td>
<td>134 (36.9)</td>
</tr>
<tr>
<td>Strongly agree</td>
<td>193 (53.2)</td>
</tr>
<tr>
<td><strong>I was concerned about privacy (n=365)</strong></td>
<td></td>
</tr>
<tr>
<td>Strongly disagree</td>
<td>105 (28.8)</td>
</tr>
<tr>
<td>Disagree</td>
<td>146 (40)</td>
</tr>
<tr>
<td>Neither agree nor disagree</td>
<td>63 (17.3)</td>
</tr>
<tr>
<td>Agree</td>
<td>28 (7.7)</td>
</tr>
<tr>
<td>Strongly agree</td>
<td>23 (6.3)</td>
</tr>
<tr>
<td><strong>Having face-to-face video was important (n=359)</strong></td>
<td></td>
</tr>
<tr>
<td>Strongly disagree</td>
<td>7 (2)</td>
</tr>
<tr>
<td>Disagree</td>
<td>22 (6.1)</td>
</tr>
<tr>
<td>Neither agree nor disagree</td>
<td>87 (24.2)</td>
</tr>
<tr>
<td>Agree</td>
<td>108 (30.1)</td>
</tr>
<tr>
<td>Strongly agree</td>
<td>135 (37.6)</td>
</tr>
<tr>
<td><strong>I was worried how much my telehealth visit would cost (n=363)</strong></td>
<td></td>
</tr>
<tr>
<td>Strongly disagree</td>
<td>83 (22.9)</td>
</tr>
<tr>
<td>Disagree</td>
<td>114 (31.4)</td>
</tr>
<tr>
<td>Neither agree nor disagree</td>
<td>112 (30.9)</td>
</tr>
<tr>
<td>Agree</td>
<td>36 (9.9)</td>
</tr>
<tr>
<td>Strongly agree</td>
<td>18 (4.5)</td>
</tr>
<tr>
<td><strong>I look forward to using telehealth in the future (n=361)</strong></td>
<td>279 (77.3)</td>
</tr>
<tr>
<td><strong>To what extent were you satisfied with your visit (n=365)</strong></td>
<td></td>
</tr>
<tr>
<td>Characteristics</td>
<td>Participants, n (%)</td>
</tr>
<tr>
<td>-----------------------------------------------------</td>
<td>---------------------</td>
</tr>
<tr>
<td>Very unsatisfied</td>
<td>10 (2.7)</td>
</tr>
<tr>
<td>Unsatisfied</td>
<td>14 (3.8)</td>
</tr>
<tr>
<td>Neutral</td>
<td>39 (10.7)</td>
</tr>
<tr>
<td>Satisfied</td>
<td>129 (35.3)</td>
</tr>
<tr>
<td>Very satisfied</td>
<td>173 (47.4)</td>
</tr>
</tbody>
</table>

**Did you recover from your illness? (n=312)**

<table>
<thead>
<tr>
<th>Response</th>
<th>Participants, n (%)</th>
<th>Median (IQR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>12 (3.9)</td>
<td></td>
</tr>
<tr>
<td>Yes, but I required more than one telehealth visit</td>
<td>12 (3.9)</td>
<td></td>
</tr>
<tr>
<td>No, I was seen in an urgent care clinic/emergency room</td>
<td>70 (22.4)</td>
<td></td>
</tr>
<tr>
<td>No, I was sent to the Keck Medical evaluation tent or Evaluation and Treatment Center</td>
<td>218 (69.9)</td>
<td></td>
</tr>
</tbody>
</table>

*N/A: not applicable.*
### Table 3. Trust in Physician Scale responses.

<table>
<thead>
<tr>
<th>Statements</th>
<th>Participants, n (%)</th>
<th>Median (IQR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>I doubt my doctor really cares about me as a person (n=366)</td>
<td></td>
<td>1 (1-2)</td>
</tr>
<tr>
<td>Strongly disagree</td>
<td>202 (55.2)</td>
<td></td>
</tr>
<tr>
<td>Disagree</td>
<td>104 (28.4)</td>
<td></td>
</tr>
<tr>
<td>Neither agree nor disagree</td>
<td>40 (10.9)</td>
<td></td>
</tr>
<tr>
<td>Agree</td>
<td>8 (2.2)</td>
<td></td>
</tr>
<tr>
<td>Strongly agree</td>
<td>12 (3.3)</td>
<td></td>
</tr>
<tr>
<td>My doctor is usually considerate of my needs and puts them first (n=365)</td>
<td></td>
<td>5 (4-5)</td>
</tr>
<tr>
<td>Strongly disagree</td>
<td>7 (1.9)</td>
<td></td>
</tr>
<tr>
<td>Disagree</td>
<td>4 (1.1)</td>
<td></td>
</tr>
<tr>
<td>Neither agree nor disagree</td>
<td>32 (8.8)</td>
<td></td>
</tr>
<tr>
<td>Agree</td>
<td>131 (35.9)</td>
<td></td>
</tr>
<tr>
<td>Strongly agree</td>
<td>191 (52.3)</td>
<td></td>
</tr>
<tr>
<td>I trust my doctor so much I always try to follow his/her advice (n=365)</td>
<td></td>
<td>4 (4-5)</td>
</tr>
<tr>
<td>Strongly disagree</td>
<td>6 (1.6)</td>
<td></td>
</tr>
<tr>
<td>Disagree</td>
<td>2 (0.5)</td>
<td></td>
</tr>
<tr>
<td>Neither agree nor disagree</td>
<td>33 (9)</td>
<td></td>
</tr>
<tr>
<td>Agree</td>
<td>152 (41.6)</td>
<td></td>
</tr>
<tr>
<td>Strongly agree</td>
<td>172 (47.1)</td>
<td></td>
</tr>
<tr>
<td>If my doctor tells me something is so, then it must be true (n=363)</td>
<td></td>
<td>4 (3-4)</td>
</tr>
<tr>
<td>Strongly disagree</td>
<td>8 (2.2)</td>
<td></td>
</tr>
<tr>
<td>Disagree</td>
<td>23 (6.3)</td>
<td></td>
</tr>
<tr>
<td>Neither agree nor disagree</td>
<td>117 (32.2)</td>
<td></td>
</tr>
<tr>
<td>Agree</td>
<td>153 (42.2)</td>
<td></td>
</tr>
<tr>
<td>Strongly agree</td>
<td>62 (17.1)</td>
<td></td>
</tr>
<tr>
<td>I sometime distrust my doctor’s opinion and would like a second one (n=362)</td>
<td></td>
<td>2 (2-3)</td>
</tr>
<tr>
<td>Strongly disagree</td>
<td>82 (22.7)</td>
<td></td>
</tr>
<tr>
<td>Disagree</td>
<td>152 (42)</td>
<td></td>
</tr>
<tr>
<td>Neither agree nor disagree</td>
<td>85 (23.5)</td>
<td></td>
</tr>
<tr>
<td>Agree</td>
<td>35 (9.7)</td>
<td></td>
</tr>
<tr>
<td>Strongly agree</td>
<td>8 (2.2)</td>
<td></td>
</tr>
<tr>
<td>I trust my doctor’s judgements about my medical care (n=362)</td>
<td></td>
<td>4 (4-5)</td>
</tr>
<tr>
<td>Strongly disagree</td>
<td>5 (1.4)</td>
<td></td>
</tr>
<tr>
<td>Disagree</td>
<td>3 (0.8)</td>
<td></td>
</tr>
<tr>
<td>Neither agree nor disagree</td>
<td>25 (6.9)</td>
<td></td>
</tr>
<tr>
<td>Agree</td>
<td>167 (46.1)</td>
<td></td>
</tr>
<tr>
<td>Strongly agree</td>
<td>162 (44.8)</td>
<td></td>
</tr>
<tr>
<td>I feel my doctor does not do everything he/she should for my medical care (n=363)</td>
<td></td>
<td>2 (1-2)</td>
</tr>
<tr>
<td>Strongly disagree</td>
<td>148 (40.7)</td>
<td></td>
</tr>
<tr>
<td>Disagree</td>
<td>137 (37.7)</td>
<td></td>
</tr>
<tr>
<td>Neither agree nor disagree</td>
<td>44 (12.1)</td>
<td></td>
</tr>
<tr>
<td>Agree</td>
<td>24 (6.6)</td>
<td></td>
</tr>
<tr>
<td>Strongly agree</td>
<td>10 (2.8)</td>
<td></td>
</tr>
</tbody>
</table>
## Statements

<table>
<thead>
<tr>
<th>Statements</th>
<th>Participants, n (%)</th>
<th>Median (IQR)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>I trust my doctor to put my medical needs above all other considerations when treating my medical conditions (n=362)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Strongly disagree</td>
<td>4 (1.1)</td>
<td></td>
</tr>
<tr>
<td>Disagree</td>
<td>8 (2.2)</td>
<td></td>
</tr>
<tr>
<td>Neither agree nor disagree</td>
<td>47 (13)</td>
<td></td>
</tr>
<tr>
<td>Agree</td>
<td>151 (41.7)</td>
<td>4 (4-5)</td>
</tr>
<tr>
<td>Strongly agree</td>
<td>152 (42)</td>
<td></td>
</tr>
<tr>
<td><strong>My doctor is a real expert in taking care of medical problems (n=363)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Strongly disagree</td>
<td>3 (0.8)</td>
<td></td>
</tr>
<tr>
<td>Disagree</td>
<td>4 (1.1)</td>
<td></td>
</tr>
<tr>
<td>Neither agree nor disagree</td>
<td>51 (14)</td>
<td></td>
</tr>
<tr>
<td>Agree</td>
<td>154 (42.2)</td>
<td>4 (4-5)</td>
</tr>
<tr>
<td>Strongly agree</td>
<td>151 (41.6)</td>
<td></td>
</tr>
<tr>
<td><strong>I trust my doctor to let me know if a mistake was made about my treatment (n=362)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Strongly disagree</td>
<td>4 (1.1)</td>
<td></td>
</tr>
<tr>
<td>Disagree</td>
<td>8 (2.2)</td>
<td></td>
</tr>
<tr>
<td>Neither agree nor disagree</td>
<td>54 (14.9)</td>
<td></td>
</tr>
<tr>
<td>Agree</td>
<td>158 (43.7)</td>
<td>4 (4-5)</td>
</tr>
<tr>
<td>Strongly agree</td>
<td>138 (38.1)</td>
<td></td>
</tr>
<tr>
<td><strong>I sometimes worry that my doctor may not keep the information we discuss totally private (n=365)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Strongly disagree</td>
<td>199 (54.5)</td>
<td></td>
</tr>
<tr>
<td>Disagree</td>
<td>115 (31.5)</td>
<td></td>
</tr>
<tr>
<td>Neither agree nor disagree</td>
<td>47 (12.9)</td>
<td></td>
</tr>
<tr>
<td>Agree</td>
<td>3 (0.8)</td>
<td></td>
</tr>
<tr>
<td>Strongly agree</td>
<td>1 (0.3)</td>
<td></td>
</tr>
</tbody>
</table>

Physician trust total score\(^a\) (n=345)

Physician trust total score generated by the sum of 11 items from the physician trust survey. Highest possible score=55; mean 45 (SD 6.5).

### Trust in Physician and Satisfaction With Telemedicine Visit

Higher physician trust was associated with higher patient satisfaction with the telemedicine visit. Results of the Spearman correlation indicated that there was a significant positive association between the degree of patients’ trust in physician and satisfaction with their telemedicine visit (\(r=0.51, P<.001\)).

### Patient Factors and Trust in Physician

Overall, patient factors including age (\(r=-0.01, P=.81\)), level of education (\(r=0.01, P=.99\)), and current health status (\(r=-0.01, P=.78\)) were not significantly correlated with level of trust in their physician. There was, however, a significant positive association between income and level of trust in physician (\(r=0.18, P<.001\)).

### Visit-Related Factors and Trust in Physician

In contrast to patient factors, several visit-related factors showed a significant correlation with Trust in Physician score. Respondents who did not have technical issues (\(r=-0.16, P=.002\)), concerns about privacy (\(r=-0.19, P<.001\)), or concerns about the cost (\(r=-0.23, P<.001\)) had a higher degree of trust in their physician. Those who agreed face-to-face video was important (\(r=0.23, P<.001\)), liked the convenience (\(r=0.41, P<.001\)), and were satisfied with the amount of time spent (\(r=0.47, P<.001\)) also showed a higher degree of trust in their physician.

### Patient Factors and Satisfaction With Telemedicine Visit

Patient factors including gender (\(P=.67\)), education (\(P=.82\)), income (\(P=.14\)), and current health (\(P=.18\)) were not associated with satisfaction with their telemedicine visit. Age was the only significant factor associated with satisfaction, with a younger median age of 54 (IQR 42-64) years among those who were very satisfied compared to a median age of 60 (IQR 50-69) years among those who were unsatisfied or neutral (likelihood ratio \(P=.005\) with ordinal logistic regression).
Visit-Related Factors and Satisfaction With Telemedicine Visit

Evaluated by ordinal logistic regression, all visit-related factors were associated with patient satisfaction with their telemedicine visit. Fewer technical issues (P<0.001), acknowledging the convenience (P<0.001), appreciating the amount of time spent (P<0.001), fewer concerns about privacy (P<0.001) and cost (P=0.2), and successful face-to-face video (P<0.001) were all significantly associated with a satisfying telemedicine visit.

Discussion

The COVID-19 pandemic poses unique challenges to health care delivery, especially for those in primary care. Patient fear surrounding COVID-19 has disrupted patients’ normative expectations toward their doctors (and vice versa), creating more complex trust relationships. Prior studies have shown patients prefer telemedicine with a doctor with whom they have an established relationship [20]. When it comes to specialist referral, trust and confidence in one’s primary care provider are crucial to creating a satisfying experience [21,22].

Telemedicine, particularly video consultation, has been rapidly implemented to reduce the risk of transmission. Before this historic period, studying telemedicine satisfaction would have posed a self-selection bias, which the pandemic mostly eliminated due to institutional and patient health precautions early on. Correlates of patient satisfaction aid to inform and further educate practices adopting telemedicine and the pandemic provides a unique opportunity to evaluate those visits and factors affecting satisfaction.

Patients’ trust in their physician, telemedicine services, and willingness to rely on such a health service for care during a pandemic has not previously been described. Researchers have given little attention to which factors contribute to trust in a telemedicine visit, a unique situation made more difficult during the pandemic. A previously reported study on the use of telehealth visits for anticoagulation management found trust in the technology, trust in health care professionals, and trust in the treatment affected trust in the telemedicine service [23]. The rapid transition to telemedicine requires providers and patients to transition to a new normal that includes communicating via telephone or video. For providers, this means developing skills in building trust, counseling, empathy, “modified” physical exams, and diagnosis using the telemedicine platform. Prior telemedicine studies include a level of self-selection, yet provide some insight into the importance of trust in provider for telemedicine visits. In one study, patients who chose a virtual follow-up over an in-person visit spoke of the importance of an existing doctor-patient relationship and having already had previous consultations with that same person before the follow-up video consultation [24].

Recent suggestions on fostering human connection have focused primarily on telemental health, with tips provided for enhancing virtual connections, such as being “present,” identifying needs, listening, responding with empathy, and sharing information [25]. Empirical evidence in this area is sparse and achieving greater clarity about factors contributing to a satisfying telemedicine visit would help health care providers better anticipate patients’ needs.

Our study provides new insights into the reasons for a satisfying telemedicine visit when an established relationship with the provider or practice exists. Consistent with our hypothesis and using our patients’ experience at the onset of the COVID-19 pandemic, we found that trust in physician, as assessed using the 11-question Trust in Physician Scale, was correlated with higher patient satisfaction in telemedicine visits. Patients who trust their doctor and try to follow his/her advice, trust their doctor’s judgment about medical care, and believe their doctor will let them know if a mistake was made about their treatment were more likely to be satisfied with a telemedicine visit and wanted to use the platform again. These findings suggest a significant role in provider engagement, fostering human connection, and strengthening the patient-physician attachment. Higher physician trust was positively correlated with greater patient satisfaction with telemedicine.

Furthermore, factors related to the visit, including privacy, cost, convenience, and time, were associated with higher satisfaction and higher trust in physicians. Our findings suggest that ease of use with fewer technical issues and video-enabled visits result in higher patient satisfaction and higher trust in physician. At our institution, test calls before initial sessions help evaluate the level of technological support a patient needs for the upcoming telemedicine visit.

Our findings support a role for continued improvement in training and operational issues in telemedicine.

While the study group was mostly White, high-income, and well-educated, our study did not find evidence that patient-related factors in this sample play a significant role in trust in physician or the likelihood of a satisfying telemedicine visit. Patient income was positively associated with level of trust; this association has been reported for in-person care, where lower physician trust is seen with lower income [21]. Our study found higher income correlated with a higher level of trust in physician, which was positively associated with patient satisfaction with telemedicine. Consistent with prior research that shows younger patients, perhaps due to higher eHealth literacy, have higher acceptance of the telemedicine platform [26,27], we also found that younger age correlated with a satisfying telemedicine visit. Our predominantly younger White female population is consistent with prior studies on the acceptance of telemedicine [24,27].

This study has several limitations. First, this was a retrospective study with no comparison to in-person visit satisfaction during the same period or before the pandemic. We did not feel the pandemic’s challenging situation, which did not allow for the option of in-person visits, could be compared to prior visits. As the pandemic lifts, this would be something evaluated in future studies. Previous studies on the acceptability of video consulting show that even among those who would choose that format again, face-to-face consulting was seen as the gold standard and preferred for both provider and patient for emotionally charged or more challenging consultations [24]. Second, the use of a web-based survey prevents us from recruiting patients without an email address (n=113, 7%), potentially leading to bias toward
respondents with higher digital literacy. Third, the response rate to the survey was lower than anticipated (368/1624, 22.7%). We suspect replying to an email survey in the early days of the pandemic presented additional challenges to our patient population who had not necessarily chosen the telemedicine platform. Fourth, respondents were significantly older than our nonresponders (55.8 years versus 51.3 years, P<.001), yet while our findings support older age as a factor correlated with satisfaction with their visit, age was not correlated with trust in physician. Fifth, the Likert-based satisfaction item, although face valid, was not derived from a validated questionnaire. Lastly, as our study population was less ethnically and racially diverse than the overall United States and Los Angeles County population, we could not capture the experiences of underrepresented minorities and underserved communities.

In conclusion, this study suggests most patients are satisfied with telemedicine visits during the COVID-19 pandemic and that trust in physician correlates favorably with patient satisfaction. Trust and satisfaction are shaped by many visit-related factors, including convenience, time spent, and video-enabled encounters, rather than specific patient-related factors. Our study reinforces telemedicine as a new form of health care delivery even in times of uncertainty, supporting our hypothesis that patient satisfaction with a telemedicine visit would be positively related to the degree of trust in the provider and ease of use of the telemedicine platform. Further studies examining patient-physician relationships over telemedicine may better elucidate elements contributing to patients’ trust in their physicians. With calls to promote and scale-up telemedicine in primary care, this will help develop a strategy and operational plans for providers to switch to remote patient care.

**Acknowledgments**

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**Conflicts of Interest**

None declared.

**References**


