How to Overcome Barriers for the Implementation of New Information Technologies in Intensive Care Medicine

Akira-Sebastian Poncette[2,3], Christian Meske[1,2], Lina Mosch[3], and Felix Balzer[2,3](✉)

[1] Freie Universität Berlin, Garystr. 21, 14195 Berlin, Germany
[2] Einstein Center Digital Future, Wilhelmstraße 67, 10117 Berlin, Germany
felix.balzer@charite.de
[3] Department of Anesthesiology and Intensive Care Medicine, Charité – Universitätsmedizin Berlin (corporate member of Freie Universität Berlin, Humboldt-Universität zu Berlin, and Berlin Institute of Health), Berlin, Germany

Abstract. In highly technical environments, as for instance, the intensive care unit (ICU) in hospitals, developments in digital health are promising for bringing benefits for both the patient and hospital by increasing patient safety and reducing healthcare expenses. However, the digital transformation of ICUs remains slow, and healthcare organisations hesitate to implement new technologies. With this qualitative study, we have aimed to identify potential barriers to the implementation of new information technology in the ICU. Data collection was conducted through ethnography in form of field research. In subsequent focus groups, the Consolidated Framework for Implementation Research (CFIR) was utilised to assess and evaluate the implementation process. For the outer setting, the complex and time-consuming privacy and legal issues were identified; for the inner setting, the ICU as a stressful environment with high patient turnover and staff fluctuation leading to a negative implementation climate was described. Engagement from the ICU staff in regard to embracing the possibilities of digital innovation was found to be limited, and the usage of the new technology was hindered by low perceived usability. To the best of our knowledge, this is the first evaluation of barriers for the implementation of digital health technologies in the ICU. Identified barriers underline that for a digital transformation, not only technological advancements are necessary. End-user involvement and contribution for the conceptualisation and training in digital literacy are more needed than ever before.

Keywords: Healthcare · Hospital · Patient monitoring · IT adoption · Implementation barriers · Intensive care medicine · User-centered design · Digital literacy

A. S. Poncette, L. Mosch, F. Balzer—Department of Anesthesiology and Intensive Care Medicine, Charité – Universitätsmedizin Berlin.

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1 Introduction

1.1 Digital Transformation of the ICU

"Digital transformation of health services encompasses the instrumented effort to meaningfully introduce new digital information and communication technologies and corresponding new processes and stakeholder behaviour into the health sector" [1]. In intensive care medicine, technology always has played an essential role. Monitoring of patients' vital parameters, replacing organ functions through machines (respirator, extracorporeal membrane oxygenation, dialysis) and documenting patients' health status in the patient data management systems (PDMS) are essential parts of the intensive care unit (ICU).

Developments in the field of information and communication technologies and their application in healthcare are promising further improvement of patients' health. In intensive care medicine telemedicine and digital health are mirrored in remote patient monitoring with mobile devices such as tablets or even in entire tele-intensive care units (tele-ICUs), where intensive care is performed by non-specialised healthcare personnel who are supervised and supported by a remote intensivist physician through modern digital communication technologies and high speed data transmission [2]. These developments promise a benefit for both the patient and hospital [3, 4]. Generally speaking, expectations for the digital transformation of ICUs include the increase of patient safety through highly sensitive, specific and at the same time less invasive measurement of vital parameters [2]. Improved visualization of monitoring parameters and clinical decision support systems on an as-needed basis have been found to reduce reaction time (e.g. time to diagnosis) of ICU staff [5, 6]. And with the Internet of Things (IoT), digitalisation in healthcare will become pervasive.

However, the digital transformation of intensive care medicine remains slow and healthcare organisations hesitate to introduce new technologies [7, 8]. So, what are the reasons for this hesitancy and the lagging implementation of digital health into healthcare organisations? What keeps hospitals and healthcare providers from introducing new digital tools? Identifying barriers that impede the implementation of digital health technologies on the ICU is a key aspect if we want to advance the effective and meaningful digital transformation of intensive care medicine.

1.2 Barriers to Implementation

Barriers to implementation of digital health applications into healthcare systems can be clustered in (1) poor usability, (2) limited knowledge and awareness and (3) lack of resources [10–14]:

Poor Usability. Healthcare technologies have always been lagging behind in terms of usability and user-friendly design [9, 15, 16]. This provokes adverse effects like the emergence of additional work, relative disapproval of technologies and also increases the probability of medical errors [9, 10]. Poor usability often results from high complexity of technologies associated with non-existent interoperability [11]. Unfortunately, this characterizes many digital health technologies and contributes to implementation failure [12].

Limited Knowledge and Awareness. A study by Moeckli et al. found that the lack of healthcare professionals' understanding of technologies implemented in a tele-ICU was a major barrier to implementation, as was the lack of demand for respective innovations [13]. Moreover, missing the advantages of digital health technologies over conservative practices poses a barrier to implementation [14].

Lack of Resources. Further main barriers to digital health implementation are a shortage of dedicated resources. For example, financial investments and protected time for staff members are seldom approved when installing a novel technology [11].

The limited engagement of those responsible for driving health innovations in authorities (leadership engagement) is designated to hinder the successful completion of the implementation [15, 16].

1.3 Research Goal

With this qualitative study, we aimed to identify barriers to the implementation of novel technology, focusing on the particularities of the intensive care setting and to discuss strategies to overcome these. Developed strategies may inspire future research, product development and healthcare provision for a more rapid and sustainable move towards digital transformation in healthcare.

2 Methods

2.1 Setting

We conducted this study at an intensive care unit of a large German university hospital between February 2016 and December 2018 shortly after the implementation of the Vital Sync™ Virtual Patient Monitoring Platform 2.4 developed by Medtronic plc as a remote patient monitoring using tablet computers. Participants of the study included the ICU staff team (nurses, physicians, respiratory therapists) as well as coordinators of the ICU (senior physician, nursing management). Prior to the study, all participants gave their consent to participate, and the local ethics committee provided ethical approval for this study (EA1/031/18).

2.2 Research Team and Study Design

The research team consisted of a physician with background in anesthesiology, intensive care medicine, geriatrics and digital health (AP), a senior medical student with a focus on digital health (LM), a professor of digital health, who is a computer scientist and anesthesiologist (FB), and a professor of information systems and digital transformation (CM). We chose an exploratory qualitative research approach using ethnography, a field research with subsequent focus groups was conducted as previously described [17].

2.3 Data Collection and Analysis

For optimal ethnographic research conditions, we chose to immerse with the ICU staff in a four weeks field study. This way, we aimed to observe ICU routine and interaction with the ICU staff. After the field study, regular visits during the whole study period followed. Field notes were subsequently discussed and summarised in focus groups with the authors and the head of the ICU staff. First conclusions were iteratively challenged by the interdisciplinary research team. For data analysis, the Consolidated Framework for Implementation Research (CFIR) was used [12, 15]. The CFIR is a well-used framework that was chosen to provide the possibility to holistically evaluate the implementation process of a digital health technology [11–13]. Additionally, login frequencies of ICU staff were retrieved from the tablet computers.

2.4 Technical Setup

Implementation of the Vital Sync™ was conducted on a ten bed Post Anesthesia Care Unit (PACU), an ICU mainly for postoperative patients that need a short term (24 h) intensive care treatment and monitoring. The primary patient monitoring device used at the time of the study was the Philips IntelliVue patient monitoring system (MX800 software version M.00.03; MMS X2 software version H.15.41-M.00.04). All parameters including the electrocardiogram (ECG), blood pressure, temperature, or ventilator parameters of mechanically ventilated patients were displayed through the Philips IntelliVue patient monitoring system on stationary touchscreen displays at the bedside and on a monitor at the central nurse station.

The Vital Sync™ Virtual Patient Monitoring Platform was used as secondary monitoring and received vital parameters (1 Hz) from five out of a total of ten ICU beds. Transmitted vital parameters included peripheral capillary oxygen saturation (SpO_2), pulse rate (PR), end-tidal carbon dioxide level ($etCO_2$) and respiratory rate (RR), and were retrievable from six tablet computers (two large iPads, two iPad minis, two Microsoft Surfaces) and one stationary monitor at the central nurse station. In addition, the integrated pulmonary index (IPI), a respiratory score, was automatically calculated from the above-mentioned parameters and displayed on all devices [18]. These five parameters were retrievable after logging into an iPad (six-digit code) or a Surface (username and password) and further logging into a Vital Sync™ website (iPad) or software (Surface) with another username and password. The Vital Sync™ software was web-based and with the specific URL retrievable from any computer connected to the hospital's intranet. The installation of the new system did not interfere with the ICU routine.

2.5 Software

When a new patient arrives on the ICU, the patient is virtually added to the Vital Sync™ Monitoring Software at the bedside in a 7 step process as described on the product homepage [19]. All four vital parameters, SpO_2 = peripheral capillary oxygen saturation, PR = pulse rate, RR = respiratory rate, $EtCO_2$ = end-tidal carbon dioxide and the IPI (=Integrated Pulmonary Index) score are displayed in the patient-specific view. At the bottom of the display, the CO_2 Waveform is displayed (see Fig. 1).

Fig. 1. Screenshot of the patient view of the Vital Sync™ Virtual Patient Monitoring Platform 2.4; all four vital parameters (SpO_2 = peripheral capillary oxygen saturation, PR = pulse rate, RR = respiratory rate, $EtCO_2$ = end-tidal carbon dioxide) and the IPI (= Integrated Pulmonary Index) score are displayed [19]

Fig. 2. Screenshot of the patient tile view of the Vital Sync™ Virtual Patient Monitoring Platform 2.4; all four vital parameters (SpO_2, PR, RR, $EtCO_2$) [19]

When the home button on the top right is pressed, the patient tile view (all patients of the ward) is shown. In this view, a configurable selection of numeric parameters (i.e. SpO_2, $etCO_2$, PR, and RR) without waveforms of all connected patients is presented (see Fig. 2).

2.6 Installation and ICU Staff Training

The on-site setup of the devices was finished in May 2018. Usage of the system began in the same month after instruction into the device of the ICU staff (physician, nurses and respiratory therapists) over a period of one month. Additionally, two workshops were offered to explain further technical backgrounds and for hands-on training with the new technology. ICU staff training was continued on an as-needed basis.

2.7 Mapping of CFIR Domains to Study-Specific Areas

The Consolidated Framework for Implementation Research provides a guideline for the assessment and evaluation of an implementation process and helped us to contextualise the given data. We mapped the CFIR domains to the respective study-specific areas (see Table 1). The special characteristics of our study setting comprised the PACU with its high patient turnover personnel (from external and internal staff pools) and patients, a multidisciplinary team (physicians, nurses, respiratory therapists using Vital Sync™) that was responsible for several ICUs [15].

Table 1. Mapping of CFIR domains to study-specific areas [11, 15]

CFIR domain	Study-specific areas
Intervention characteristics	Remote patient monitoring system with integrated CDSS
Outer setting	Federal and state entities, university hospital
Inner setting (structural characteristics, networks & communications, culture, implementation climate)	PACU (ICU), multidisciplinary team of several ICUs, high patient and personnel fluctuation
Characteristics of individuals	ICU staff: nurses, physicians, respiratory therapists
Process	Implementation of a remote patient monitoring system on an ICU

3 Results

3.1 Usage

Random visits to the installation site indicated that up to this point, the Vital Sync™ was hardly ever used by the ICU staff. This was confirmed by review of the login details of the devices. In consequence, intensified ICU staff training was conducted from May to December 2018, which made no considerable improvements.

3.2 Barriers

As barriers to implementation of the Vital Sync™, all aspects that hindered or delayed the installation and usage of Vital Sync™ were considered (see Fig. 3).

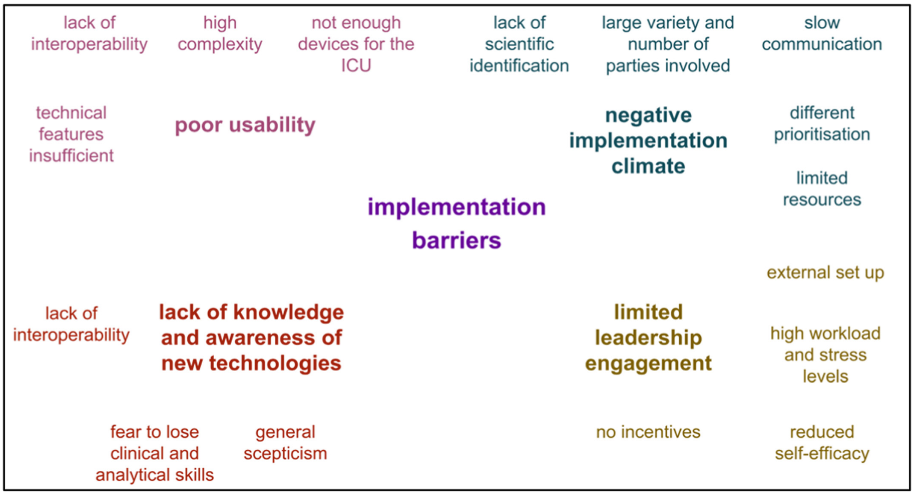

Fig. 3. Identified barriers to implementation of Vital Sync™, a remote patient monitoring device for intensive care medicine

Negative Implementation Climate. A challenge for the implementation of Vital Sync™ was the variety and number of parties involved in the project. Along with slow communication channels (email), time-consuming processes for complicated privacy and legal issues and having different project prioritisation between parties (e.g. ICU project leader of Vital Sync™ versus legal department of hospital) led to delays of installation of more than 6 months.

Negative implementation climate was further influenced by limited available resources such as digital infrastructure (non-existent interoperability of Vital Sync™ with other devices such as a respirator) and lack of time for staff training due to high workload. Because the research team and the intervention itself have been set up and planned mainly without the involvement of internal ICU staff, the ICU personnel was lacking scientific and academic identification with the Vital Sync™ system. Another characteristic of the ICU was the high fluctuation of both ICU personnel and patients which along with missing communication led to a non-usage of the remote patient monitoring system.

Limited Leadership Engagement. The Vital Sync™ implementation was lacking a general leadership engagement and motivation from ICU and implementation stakeholders to promote the usage of Vital Sync™. This limited leadership engagement was due to the fact that the implementation project was developed externally and responsibilities about leadership in the ICU team and implementation team not clearly defined. High workloads and stress levels were the main reasons for the limited leadership engagement regarding Vital Sync™ implementation.

Lack of Knowledge and Awareness of Digital Health Technologies Among ICU Staff. A key factor that hindered the implementation of the Vital Sync™ software was ICU staffs' limited knowledge and awareness of digital health technologies and their potential. We observed a general skepticism towards new digital technologies among the ICU staff, related to the fear to lose clinical and analytical skills when applying digital health. This also contributed to the fact that the relative priority of the project was different among responsible stakeholders (leader of the research team, senior physician on ICU, head of nursing department), impeding the implementation process.

Perceived Limited Usability. The implemented remote patient monitoring system (Vital Sync™) was perceived as hard to set up and complicated to use. The main reason users stated this was the confusing design of the application and the perceived high complexity of features (e.g. Clinical Decision Support System - IPI). Another point of criticism was the lack of interoperability with other devices, e.g. the respiratory machine or blood pressure.

Also, not all patient beds were equipped with Vital Sync™ and not every staff member could get a personal mobile device. In total only 6 tablets were available for a team of one respiratory therapist, three physicians and up to six nurses per shift. Devices had to be returned to the docking station after usage and were not individualised. Furthermore, only four vital parameters were displayed on the remote monitor, which was considered insufficient by healthcare professionals on the ICU.

4 Discussion

4.1 Summary

As part of the installation of the Vital Sync™ Virtual Patient Monitoring, we conducted this study at an ICU through means of ethnography and focus groups. The results show multilayered implementation barriers in all domains of the CFIR. For the outer setting, the complex and time-consuming privacy issues were identified, whereas, for the inner setting, the ICU as a generally stressful environment with a high patient and staff fluctuation lead to a negative implementation climate. Regarding the characteristics of the individuals, engagement from the ICU staff in regard to embracing the possibilities of digital innovation was lacking. And the process itself was hindered by limited perceived usability. In Fig. 4, strategies to overcome these perceived barriers to implementation are proposed by applying the CFIR as a structure.

4.2 Implementation Climate

Leadership involvement and identification with the proposed new technology has found to be vital for a successful implementation. This also applies to the involvement of the end-users (ICU staff) in the conceptualisation, development and implementation of the new technology, which may even be more challenging in rural hospitals

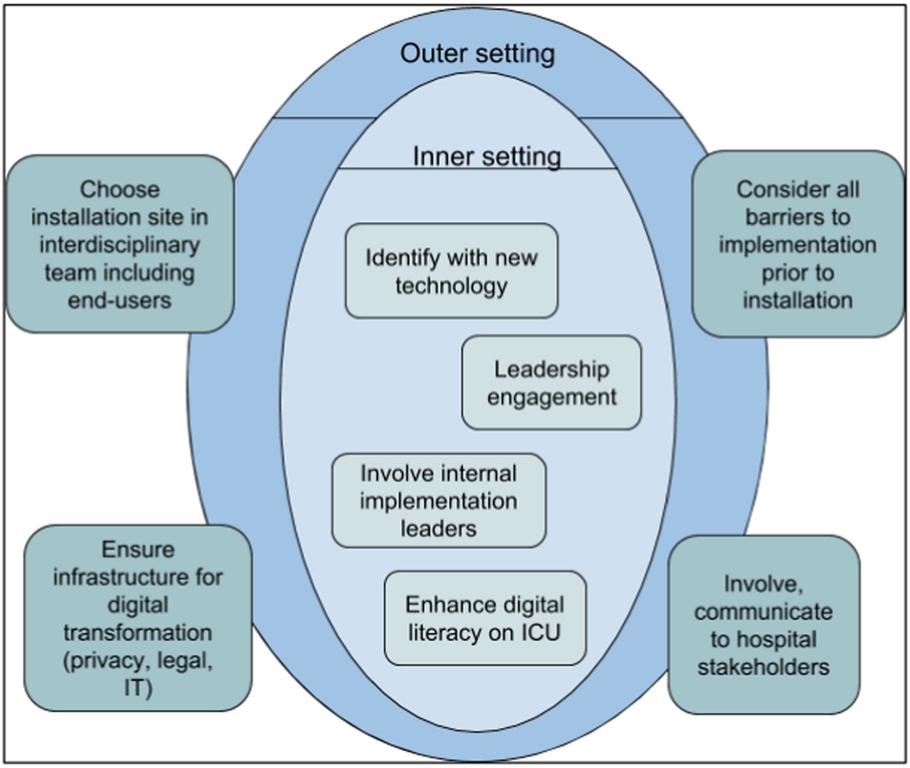

Fig. 4. Strategies to overcome perceived barriers to implementation of a remote patient monitoring device on ICU (divided into outer and inner setting according to the modified CFIR)

compared to the university environment. To overcome this barrier, a formally selected internal implementation leader should be announced, get protected time and made familiar with the responsibilities and roles within the team [11]. If the ICU staff are highly interested in implementing new technology, choosing the right system in an interdisciplinary approach is highly recommended. Since communication over email is known to be slow and potentially induce misunderstandings [24], few but effective meetings in person with an agenda and predetermined roles for all participants might be more sufficient.

In a university hospital environment, early identification of general barriers to the implementation of new technology (e.g. malfunctioning technical infrastructure) may support its application in the single departments and hospital wards. The primary challenge in this context relates to privacy and legal aspects of digital transformation. Although from May 2018, security and privacy requirements for personal health data are set in the General Data Protection Regulation (GDPR), expertise and guidance in regard to digital health applications especially in hospitals are still lacking [2]. In addition, digital transformation comes with an ever-rising number of interconnected and intersectoral health systems. This needs an information technology infrastructure, which is in many healthcare institutions (especially in rural areas) still to be established [25].

Regarding the intensive care unit (in this case the PACU) as the installation and implementation site, careful considerations of possible barriers to implementation have to be taken into account in an interdisciplinary team. In the conceptualization phase, all factors of the installation site have to be rated as a potential barrier or not. In our case, high fluctuations of ICU staff (from external and internal pools) and patients resulted in high workloads for individual staff members. This led to insufficient training with the proposed technology. Another ICU, with less turn-over of patients and staff may have been a better place for the implementation.

4.3 Involvement of Leadership Engagement in Implementation

As one of the inner settings of the CFIR, leadership engagement is rated as supportive in all stages of the development and implementation of new technology in an existing environment - e.g. the ICU [12]. In our study, we can confirm that the insufficient involvement of key stakeholders in the implementation of novel technology lead to delayed and unsuccessful implementation. On the one side, key stakeholders of university hospitals are challenged by several tasks such as patient care, research, education and management of staff or procurement at the same time [20]. Pressure can come from application deadlines for a research grant on the one day and an urgent therapy for a critically ill patient on the other. In addition, stress levels in the intensive care environment are generally high through critically ill patients, high turnover of patients, fluctuations of ICU staff, ongoing noise through alarms, and high distraction rates with no fluent workflow [21]. Thus, the priority of the implementation of new technology may be rated as low from day to day. On the other side, prioritization often goes along with interest and motivation in a specific topic. In this multifaceted dilemma, the ‘I don’t have time’ mentality in university hospitals hence may possibly rather be understood as ‘I am not interested enough to prioritize this’. From a person, who is not interested in a specific topic, less support can be expected [21].

The full support and involvement of key stakeholders is an essential element for a successful implementation of new technology in ICU. Key stakeholders should motivate and empower ICU staff, inform and communicate about the expected outcomes and goals of the project, solve problems that may occur, and communicate with the outer setting. Strategies to involve key stakeholders might include the following:

- Find out the *motivations* and *interests* of the key stakeholders
- *Involve* key stakeholders *early* in the conceptualization phase
- Make key stakeholders *identify* with the proposed project
- Explain new technology taking into account their *motivations and interests*
- *Inspire* key stakeholders of the proposed new technology; show its *advantages* over the current system
- Explain key stakeholder *roles and responsibilities*

4.4 Enhancing Digital Literacy of Healthcare Providers

Digital Health does not only achieve a translation from analog to digital processes, but also induces new processes. This is not only limited to the increasing human-computer interaction, but also refers to the fact that in the future humans will have to trust other sources of information that guide clinical decision making, as for instance artificial intelligence systems or remotely located specialists (tele-ICU). Thus, new responsibilities or roles in an ICU structure may change due to digital technology. When addressing digital transformation, it is therefore important to include all end-users. Ensuring the wide-spread digitisation in ICU (e.g. through implementing patient data management systems) and enabling digitalisation in ICU (e.g. through the intramural communication with mobile devices such as tablets and smartphones), only has an impact when healthcare providers are trained to use digital technologies (digital literacy) and their feedback used to jointly create user-centered solutions for patient care. For digital transformation, this final step is crucial. To enhance digital literacy as well as to foster innovation in healthcare, we encourage hospitals to offer trainings in digital health to their staff through expert workshops, simulations or e-learning, also to get them acquainted with current developments in digital health. Another method en vogue is the hackathon concept. A hackathon is a competition event where teams battle against each other usually over 48 h for the best solution to a specific problem. Conducting a healthcare hackathon inside a hospital has an enormous innovation potential just by bringing healthcare providers together with developers and IT designers [22, 23].

4.5 Embrace Usability and Advantage of New Digital Health Solutions

Although the electronic health records (EHR) have been implemented in the US healthcare system over nine years ago, EHR usability (referring to the efficient, effective and safe use of technology) is still not fully optimised for clinical use [26]. Insufficient usability of EHR even reduces patient safety [27]. Usability issues are not only limited to EHR but concern all medical devices. With digital transformation, we want to take advantage of digitalization, including the intuitive use of software and hardware, embracing usability to harmonise human-computer interaction. In a stressful environment as the ICU [20], stress should not be induced through the use of digital applications. Rather, digital applications should calm and focus the user for an efficient, effective and safe work. In usability research various low-cost methods are available [28]. One technique for example includes the user to think-aloud when using the new system. This is a simple and cost-effective way to discover potential usability issues. The key to optimal usability of digital systems and the basis of a usability test are the early involvement of users in the design process and acknowledging their feedback.

5 Conclusion

The successful implementation of novel technologies in an ICU setting requires a thorough assessment of the possible barriers in different settings and a diligent planning of how to overcome those. However, for digital transformation, not only technological advancements are necessary. The early involvement and continuous training of the end-user are more needed than ever before.

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