Taylor & Francis
Taylor & Francis Group

IIISE Transactions on Healthcare Systems Engineering

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/uhse21

A sociotechnical framework for integration of telehealth into clinical workflow

Samuel Bonet Olivencia & Farzan Sasangohar

To cite this article: Samuel Bonet Olivencia & Farzan Sasangohar (2023) A sociotechnical framework for integration of telehealth into clinical workflow, IISE Transactions on Healthcare Systems Engineering, 13:3, 248-259, DOI: 10.1080/24725579.2023.2211083

To link to this article: https://doi.org/10.1080/24725579.2023.2211083

Published online: 15 May 2023.

Submit your article to this journal

Article views: 60

View related articles

View Crossmark data

Full Terms & Conditions of access and use can be found at
https://www.tandfonline.com/action/journalInformation?journalCode=uhse21

IISE TRANSACTIONS ON HEALTHCARE SYSTEMS ENGINEERING
2023, VOL. 13, NO. 3, 248–259
https://doi.org/10.1080/24725579.2023.2211083

Taylor & Francis
Taylor & Francis Group

Check for updates

A sociotechnical framework for integration of telehealth into clinical workflow

Samuel Bonet Olivencia[a] and Farzan Sasangohar[b]

[a]Industrial Engineering, University of Puerto Rico, Mayaguez, PR, USA; [b]Industrial and Systems Engineering, Texas A&M University College Station, College Station, TX, USA

ABSTRACT

Telehealth has received attention in recent years for improving access to healthcare and for supporting integrated care for chronic diseases. Considering that telehealth integration into clinical workflow can alter healthcare providers' practice patterns, impacting efficiency, quality of care, and patient safety, it is timely to identify and account for system-level variables and considerations to improve the efficiency of telehealth integrations in healthcare settings. Despite the growth of telehealth, and isolated efforts to identify such considerations, a comprehensive conceptual framework for telehealth clinical integration is largely absent. To address this gap, this research effort applied a mixed methods approach to develop a sociotechnical framework to serve as a roadmap for clinics, hospitals, and other healthcare settings regarding the components that must be considered when developing and implementing a telehealth system. The developed framework, System Adoption and Integration of New Telehealth Systems (SAINTS), is grounded in literature and insights from three telehealth case studies in healthcare settings, is influenced by well-grounded sociotechnical models with application in complex healthcare systems, incorporates model-based systems engineering language for the development of structural models, and has been structured considering three temporal stages: system preparation, patient enrollment, and system implementation.

KEYWORDS

Telehealth; telemedicine; workflow modeling; sociotechnical framework; technology adoption; implementation science; process improvement

1. Introduction

Telehealth, which involves the use of electronic information and telecommunication technologies to provide remote care, has been found to improve access to healthcare (Hjelm, 2005; Liu, 2007) and support integrated care for chronic diseases (Wootton, 2012). Despite the recent increase in utilization of telehealth, widespread adoption by healthcare providers faces several major barriers including concerns about: (1) licensing and credentialing (LeRouge & Garfield, 2013; Menachemi et al., 2004; Uscher-Pines & Kahn, 2014), (2) costs and reimbursement (Grigsby et al., 2007; Koopman et al., 2014; Whitten & Mackert, 2005), (3) privacy and confidentiality (Cherney & van Vuuren, 2012; Molfenter et al., 2015; Petersen & DeMuro, 2015), (4) malpractice and liability (Fish et al., 2011; LeRouge & Garfield, 2013; Whitten & Mackert, 2005), and of special interest to this research (5) the integration into clinical workflows (Koopman et al., 2014; Menachemi et al., 2004; Uscher-Pines & Kahn, 2014). While these barriers are still relevant, it is important to emphasize that the constraints of the COVID-19 pandemic on in-person care nevertheless propelled telehealth adoption rates by health providers forward. The rapid and in some cases forced transition to telehealth during the pandemic has resulted in significant changes to well-established clinical workflows which, if not well addressed, can create dissatisfaction and disruption. Understanding the impact of telehealth systems on clinical workflows is vital since integration can alter healthcare providers' practice patterns, impacting efficiency, quality of care, and patient safety (Jarvis-Selinger et al., 2008; Zheng et al., 2010). To ensure efficiency and scalability of future telehealth systems, it is essential to design systems that integrate efficiently into healthcare providers' workflow.

While work has been done to understand workflows in healthcare (see Unertl et al.'s [2010] seminal framework for studying workflows), integration of telehealth into workflows has not been well-studied. Kaufman et al. (2009) proposed three dimensions of telehealth integration that need to be investigated in terms of impact on workflow: (1) system resources, (2) flow of communication, and (3) time on task (Kaufman et al., 2009). However, published literature on telehealth integration tends to focus only on the third dimension by conducting time studies (Cronin et al., 2012; Facchin et al., 2016; Lopetegui et al., 2014; Ricci et al., 2014) and time-motion studies (Cady et al., 2010; Cady & Finkelstein, 2013, 2014; Kaufman et al., 2009; Lopetegui et al., 2014; Tang et al., 2007; Yen et al., 2016) to assess the success of the telehealth implementation. Other studies have used a systems lens to provided more insights on environmental, technological, and organizational factors by identifying barriers and facilitators to telehealth integration in clinical workflow from the perspective of physicians and nurses (Armstrong et al., 2012; Cady & Finkelstein, 2013,

CONTACT Farzan Sasangohar sasangohar@tamu.edu Industrial and Systems Engineering, Texas A&M University College Station, College Station, TX, USA.
© 2023 "IISE"

2014; Fish et al., 2011; Kaufman et al., 2009; Koopman et al., 2014; Ricci et al., 2014; Shaw et al., 2013; Uscher-Pines & Kahn, 2014; Yen et al., 2016). However, most efforts focus on specific telehealth technologies and investigate post-implementation changes. There is a general gap in theoretical frameworks to guide the integration of a wide range of telehealth technologies throughout their lifecycles proactively. An evidence-based theoretical framework may inform implementation and evaluation efforts ensuring usability, sustainability, and scalability of such newly acquired technologies.

Sociotechnical and systems-theoretic models and frameworks that emphasize understanding both the social and the technical aspects of the system, in addition to their interdependencies, have been successful in characterizing key conceptual variables for the design of work systems and the integration of health information technologies (HIT) into clinical workflows while assuring patient safety (e.g. Carayon et al., 2006, Holden et al., 2013; Salwei et al., 2021; Sittig & Singh, 2010). For example, the Systems Engineering Initiative for Patient Safety (SEIPS) model (Carayon et al., 2006) provides the foundation to analyze complex sociotechnical systems in the context of five main dimensions: (1) people, (2) tasks, (3) tools and technologies, (4) physical environment, and (5) organizational conditions. Sittig and Singh's (2010) sociotechnical model for studying HIT in complex adaptive healthcare systems provides the foundation to understand the challenges in the implementation of HIT in the context of eight interdependent and interrelated dimensions: hardware and software, clinical content, human-computer interface, people, workflow, internal organizational features, external rules and regulations, and measurement and monitoring. These models provide useful theoretical foundation to understand complex sociotechnical systems, and to integrate specific technological and measurement dimensions of HIT with other sociotechnical dimensions. However, practical and evidence-based frameworks for telehealth integration that build on this theoretical foundation are a general gap.

The objective of this research is to integrate and synthesize knowledge from various case studies examining different types of telehealth integration including (1) factors contributing to the adoption and utilization of these platforms, (2) healthcare providers' perspectives about challenges and barriers for telehealth integration, and (3) constraints that may lead to inefficiencies and disruptions imposed on healthcare providers' workflow to develop an evidence-based framework that characterizes the structure of the integration of telehealth into clinical workflow.

2. Materials and methods

A mixed-methods approach was used to synthesize findings from various case studies to design the System Adoption and Integration of New Telehealth Systems (SAINTS) (Figure 1). Insights and lessons learned from three specific case studies that covered different levels of telehealth integration and different telehealth modalities, in addition to findings from the literature, were synthesized to characterize the integration of telehealth into existing workflows. Two widely used sociotechnical models of health systems, namely Carayon et al.'s (2006) SEIPS and Sittig and Singh's (2010) 8-dimentional HIT model, influenced the composition of the framework. Model Based Systems Engineering (MBSE) concepts, using the Systems Modeling Language (SysML), were applied as a common language to model the relationships in the structure of complex systems. Specifically, the SysML block definition diagram was used as a reference to define the components of the telehealth system integration in terms of their features and their structural relationships with other components.

The SAINTS framework was developed in two phases. First, the components in the framework and their respective relationships were derived from the case studies (described below) and were grounded in the literature iteratively. Second, subject matter experts (SMEs) reviewed the framework. Professionals with experience with telehealth were asked to review the framework, provide their feedback, and suggest changes to improve the quality of the final product. The feedback received from the expert-based review was analyzed and integrated into the final version of the framework.

2.1. Case study 1 – evaluation of a recently implemented telehealth system with low adoption

The first case study explored a real-time telemedicine video platform for post-surgical visits, a prevalent modality of telehealth. The study was conducted in the surgical department of a large hospital in the Southwestern United States that had recently integrated the platform for use as an alternative to clinical post-surgical visits. The platform suffered from low adoption at the time of the study. The study population consisted of 9 surgeons: 1 user and 8 non-users of the available telemedicine platform. Mixed methods were used including a pre-exposure readiness survey, a mock interaction with telemedicine, post-exposure usability and technology acceptance surveys, and a short post-exposure interview. The post-exposure interview provided insights about the participants' thoughts and feelings toward the use of telemedicine, awareness of the telemedicine platform, their willingness to adopt, and their perception about barriers and facilitators to adoption of the telemedicine platform. A detailed description of this case study can be found in Bonet, Sultana, et al. (2022).

2.2. Case study 2 – development of a new telehealth system

The second case study involved the collection of stakeholders' perspectives about a novel remote patient monitoring (RPM) technology, which is an emerging modality of telehealth. This study applied a user-centered approach and administered a nation-wide survey instrument to elicit perspectives from healthcare providers, mainly represented by executives and managers at clinics and healthcare settings,

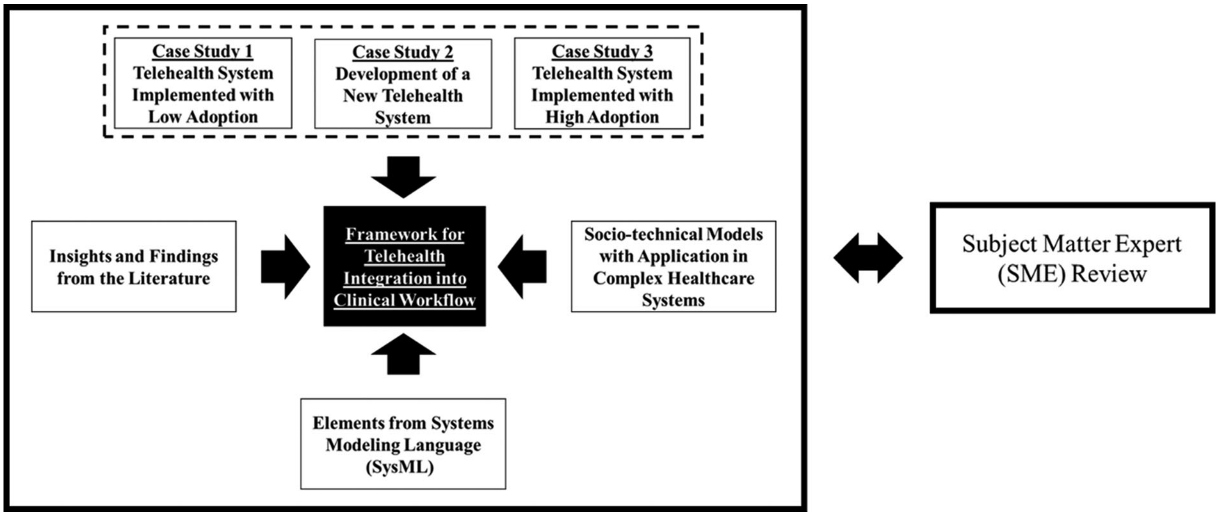

Figure 1. Methodology for developing the system adoption and integration of new telehealth systems (SAINTS) framework.

on enablers and barriers for adopting and integrating RPM technology in underserved communities. This survey elicited perspectives and knowledge about the use of RPM to manage chronic diseases, ease of adoption and workflow disruption, the relationship between patients and physicians, costs and financial benefits, time allocation for data review, and aspects of data communication and visualization. A detailed description of this case study can be found in Bonet, Zahed, et al. (2022).

2.3. Case study 3 – evaluation of a recently implemented telehealth system with high adoption

The third case study explores a well-established home telemonitoring service operating in different regions of Texas since 2015. The service provides hardware, software, and services (e.g. deployment, monitoring assistance, and equipment management) to physicians and providers who then prescribe telemonitoring services to their eligible patients to monitor patients' blood pressure and blood sugar levels. To understand how telemonitoring systems have been integrated into clinics located in underserved communities in Texas, a mixed-methods qualitative study consisting of observational studies and contextual inquiry was conducted with five clinics that have adopted the telemonitoring system. The objective of the study was to understand the context in which the remote health information is used by clinicians so that we could identify the constraints (barriers and facilitators) that lead to inefficiencies and disruptions imposed on clinicians' workflow by the integration of the telemonitoring system. A detailed description of this case study can be found in Park et al. (2019).

2.4. Subject matter expert (SME) review of the SAINTS framework

Expert review of the framework consisted of two rounds of structured interviews, conducted virtually using Zoom and WebEx, with 17 professionals with telehealth experience. The first round included 11 clinicians or clinical personnel involved in the use, support, or maintenance of a virtual intensive care unit (vICU) platform to provide continuous intensivist coverage for acute patients in a hospital in the state of Texas. The participants in the first round included four virtual nurses (vRNs), three vICU and bedside managers and directors, one bedside registered nurse (RN), one physician (MD), one respiratory care coordinator, and one IT personnel. The second round included 6 stakeholders involved in the design, development, and management of telehealth interventions. Three of these stakeholders were founders and managers of a remote patient monitoring company in the state of Texas, which bridges patients to providers by facilitating telemonitoring services to patients with chronic conditions such as diabetes and hypertension. One of the participants was a clinical research assistant professor and director of a telebehavioral health intervention program. Another participant was a clinical research assistant professor and forensic nurse involved in the development of a telehealth sexual assault nurse examiner program. The last participant was a licensed psychologist in the state of Texas, with about 6.5 years of experience in providing counseling services using a virtual video visit telemedicine platform.

During each session (30–60 min), the interviewer used the platforms' screen sharing functions to show the participants a visual representation of the framework. The interviewer provided the participants with a walkthrough of the framework, with detailed explanations of the components and their respective relationships. After discussing the framework in detail, the interviewer asked the participants to provide feedback and specify changes to the components and their respective relationships to improve the quality and representativeness of the framework for various telehealth modalities. Additionally, the participants were asked to specify the practical benefits and challenges of using a systems-theoretic framework to guide the integration of a new telehealth system or to evaluate the integration of a telehealth system that has been already implemented.

The sessions were audio recorded. A deductive thematic analysis of the audio recordings was conducted following a set of established phases (Braun & Clarke, 2006), focusing on identifying participants' suggested changes to the framework and understanding their perception of the benefits and challenges of utilizing the developed framework to guide the integration of telehealth in clinical workflow. Changes were made to the framework in an iterative process that included several rounds of discussion. The final version of the framework is discussed next.

3. Results

The System Adoption and Integration of New Telehealth Systems (SAINTS) framework is divided into three main stages to account for the temporal aspect of adopting and integrating a telehealth system. These stages were defined based on insights from the above-mentioned three case studies: (1) System Preparation, (2) Patient Enrollment, and (3) System Implementation (Figure 2). Inspired by SEIPS (Carayon et al., 2006) and Sittig and Singh's (2010) socio-technical model for studying HIT in complex adaptive healthcare systems, SAINTS includes internal and external regulations and policies which oversee the interactions in all three stages and govern the use of telehealth systems, the enrollment of patients in telehealth programs, and the coverage and reimbursement for telehealth services. Additionally, the three stages draw from the system resources component (limited human and technological resources), as relevant in the analysis of clinical workflow in the context of telehealth (Kaufman et al., 2009). A key consideration in this framework is the stakeholder involvement component which overlays all three stages, emphasizing the importance of engaging key stakeholders before, during, and after implementation of the technology, ensuring a participatory ergonomics approach (Burgess-Limerick, 2018). According to one of the expert review participants, "*stakeholders that are directly affected the most should be incorporated earlier on in the implementation of the program or the system preparation*" to ensure successful integration of the technology into clinical workflow. This is in line with previous research documenting the benefits and complexities that result from involving stakeholders in health technology implementation and assessment (Brereton et al., 2017; Nilsen et al., 2020).

The connection between components within and across stages of SAINTS represents the type of relationships among the components and how the components within one integration stage may influence components in other stages. The following subsections provide more details regarding the components within each of the defined stages of telehealth integration, the breakdown of those components into detailed elements, and the relationships between components within and across stages.

3.1. System preparation

The first stage accounts for five components that should be considered before the implementation of a telehealth system: roll out plan, training, standard operating protocols, workflow definition, and artifacts.

3.1.1. Roll out plan

Integrating telehealth technologies into clinical workflow requires multiple stakeholders to be involved at the sharp end (e.g. patients, providers) and blunt end (e.g. managers, IT personnel, vendors, government) of the healthcare system. At the sharp end, clinics face organizational challenges

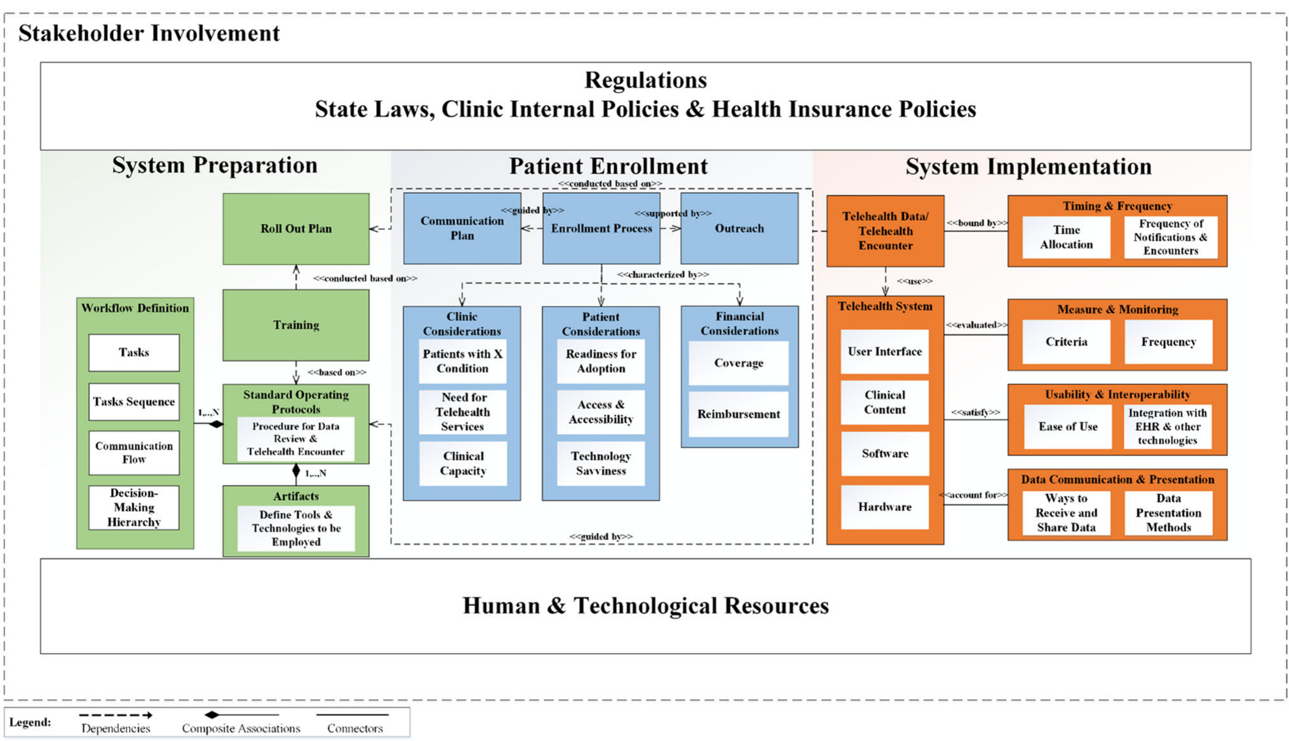

Figure 2. System adoption and integration of new telehealth systems (SAINTS) framework.

posed by coordinating various providers and patients involved in virtual care while managing the in-person care (Jarvis-Selinger et al., 2008). For example, results from case study 1 (Bonet, Sultana, et al., 2022) revealed that for televisits, physicians have concerns regarding the potential lack of effective schedules to balance the in-person visits and the telehealth encounters. To address this issue, the roll out plan may account for effective schedules to avoid unbalanced workloads that could lead to provider sedentarism in some cases, and burnout in other cases. The roll out plan component should define the sequence of clinical events that specify the timeline of implementation and operational activities necessary for the roll out.

3.1.2. Training

The training component highlights the need for improving the stakeholders' knowledge and skills necessary for performing activities related to the telehealth system. Administration of proper training has been identified as one of the main principles that influence the successful development of a telehealth system (Yellowlees, 2005). Findings from case study 3 (Park et al., 2019) revealed that participants, specifically the medical staff, perceived the lack of training as an element that led to inefficiencies in the clinical workflow. The importance of having tiered training was highlighted by one of the SME participants, who mentioned that training should "*come out in stages, so the healthcare team have time to learn, and to adapt, and make changes.*"

3.1.3. Standard operating protocols (SOPs)

The SOPs component accounts for the specific procedures that should be followed to review the telehealth data (e.g. for RPM) or to conduct a telehealth encounter within each defined workflow. These procedures must also include clear instructions related to operational aspects associated with supporting patient engagement in the telehealth intervention, such as education, onboarding, virtual rooming, and technical support, among other aspects. The need to develop efficient workflow protocols has been found to be an emergent theme in telehealth integration (Fish et al., 2011) and critical for maximized success (Jarvis-Selinger et al., 2008). Effective SOPs require predefined workflow and artifact components.

3.1.4. Workflow definition

The workflow definition component accounts for the sequence of tasks that must be executed before, during, and after a telehealth encounter or a telehealth data review activity. First, it includes the definition of the tasks to be accomplished and their sequence, which is essential not only for having organized processes that ensure patient safety, but also to optimize task frequency and duration (Cady & Finkelstein, 2013, 2014; Tang et al., 2007; Yen et al., 2016). Another element of importance is the definition of the flow of communication (Kaufman et al., 2009), which specifies the means of communication and the exchange of information across the system resources. Relatedly, workflow definition also includes establishment of a decision-making hierarchy among the personnel involved, and their granted authorization to make decisions regarding patients' health (i.e. treatment) based on the output from the telehealth encounter or the telehealth data review activities. The decision-making hierarchy may vary per clinic based on the telehealth modality used and the credentials of the personnel for authorized decision-making. In some cases, the telehealth service is provided by registered nurses who have the authorization for decision-making about changes in patient treatment (Cady & Finkelstein, 2013, 2014; Kaufman et al., 2009). In other cases (such as case study 3; Park et al., 2019) even when medical assistants and staff are involved in the telehealth activities, the treatment decisions are made solely by the physician. Due to such variability, it is essential for the decision-making hierarchy to be established prior to the implementation of the telehealth system. Conceptual mapping of the workflows (e.g. Carayon et al., 2006; Salwei et al., 2021) may serve as a "big picture" view of the system and could help stakeholders characterize each of the elements included in this component.

3.1.5. Artifacts

The artifacts component, which is part of the systems resources dimension for the analysis of workflow in the context of telehealth systems (Kaufman et al., 2009), includes elements related to the definition of the tools and technologies to employ for telehealth activities and the establishment of the technology purchases and updates that should be completed before the implementation of the system. The artifacts component also includes other supportive documentation for the overall workflow of the telehealth activities, such as resource guides, educational material for patients, instructions for technology use, and guidelines for emergency management (Ellimoottil et al., 2018; Puskin et al., 2010).

3.2. Patient enrollment

The second stage includes six main components: enrollment process, communication plan, outreach, clinic considerations, patient considerations, and financial considerations.

3.2.1. Enrollment process

This component defines the process of recruiting and enrolling patients to participate in the telehealth program. This process is in part governed by internal and external policies on how to determine a patient's suitability and eligibility to participate in telehealth, based on several factors that may include the patient's health condition and insurance coverage and reimbursement, which may vary by state, by telehealth modality, and by health insurance company.

3.2.2. Communication plan

The communication plan component defines how the clinic will streamline communication, so the right information gets to the right stakeholders involved in the patient enrollment process at the right time. It is essential to define the sequence of events that must happen, the technologies that will be used, the type of information that must be communicated, how the communication will flow, and what stakeholders must be involved. According to one of the SME reviewers, the developed plan must be shared "*well in advance, so people have time to understand it, prepare, and ask questions.*"

3.2.3. Outreach

The outreach component encompasses initiatives to educate patients about the availability of the telehealth intervention and its benefits, an aspect that has been emphasized as a key factor in improving telehealth infrastructure in health systems (Francke et al., 2022). This is especially important for patients in rural and underserved communities, in which social determinants (Luo et al., 2021) and structural barriers (Cortelyou-Ward et al., 2020), have slowed adoption of telehealth. One participant of the expert review highlighted that "*… patients in underserved areas … are less likely to participate in something like this and they are the one that needed the most. So, there has to be a type of outreach component in this patient enrollment.*" This is supported by findings from a study with patients in underserved Hispanic border communities who lacked knowledge about telehealth, which showed that once participants were oriented to the concept of telehealth, they exhibited positive attitudes toward it, increasing their likelihood to use telehealth services (Ghaddar et al., 2020).

3.2.4. Clinic considerations

Patient enrollment in the telehealth system is influenced by two elements: (1) the clinical capacity, which determines the number of patients a health provider could manage using a telehealth system depending on the human and technological resources available in the clinic; and (2) the need for telehealth in the patient population. Findings from case study 3 (Park et al., 2019), revealed that while physicians understand the benefit and convenience of using a telehealth system (in this case an RPM), they recognize that the system should be employed for those patients whose health outcomes necessitate more frequent monitoring (e.g. patients with chronic conditions such as diabetes and heart disease). Findings from case study 1 (Bonet, Sultana, et al., 2022), in the context of televisits, showed that patients who prefer in-person visits may reject telemedicine due to apprehensions regarding the perceived impact in the quality of the physician-patient relationship (Brewster et al., 2014).

3.2.5. Patient considerations

The enrollment process must be characterized by an understanding of patient considerations to increase the likelihood of patient adoption and compliance with a telehealth intervention. One element to consider is patients' readiness to adopt a telehealth intervention, which could be assessed through qualitative approaches such as interviews and focus groups (e.g. Jennett et al., 2003) or survey instruments such as the technology readiness index (TRI; Parasuraman, 2000). Access to technology is another element to consider. Many patients do not have access to technology (i.e. smartphones and computers) and adequate broadband internet (Health Resources & Services Administration, 2022), particularly those living in rural and underserved areas (Cortelyou-Ward et al., 2020). Additionally, patients with disabilities, language barriers and literacy limitations will encounter accessibility issues which may result in a barrier to using telehealth. Therefore, accessible features such as live captions, access to interpreters, and an interface in multiple languages designed to match the literacy levels of the patient population should be considered (Bonet Olivencia et al., 2021; Health Resources & Services Administration, 2022). Patients' previous experience with technology can also affect adoption, particularly for the older adult population. This is supported by findings from case study 1 (Bonet, Sultana, et al., 2022) and the literature (Kruse et al., 2020; Triana et al., 2020) which emphasize technical literacy as a common barrier preventing the use of telehealth among older adults. This barrier leads to the need for additional workarounds, such as having the assistance from a caregiver. However, sometimes those resources are not available to the patients, as highlighted in findings from case study 1 (Bonet, Sultana, et al., 2022) and the literature (Kalicki et al., 2021).

3.2.6. Financial considerations

Economic factors influence patient eligibility for telehealth enrollment. Concerns regarding costs and reimbursement have been identified as a major barrier for healthcare providers' adoption of telehealth (e.g. Gajarawala & Pelkowski, 2021; Koopman et al., 2014). For example, results from case study 2 (Bonet, Zahed, et al., 2022) revealed that healthcare providers have less optimism regarding the financial benefits they would receive from adopting an RPM telehealth system; providers seem to support private medical insurance as a reimbursement method in addition to public payer alternatives such as Medicare and Medicaid. In the case of Medicaid, as of April 2022, all 50 states and Washington, DC, provided coverage and reimbursement for live video telemedicine, 25 states provided coverage and reimbursement for store-and-forward telehealth, and 30 state Medicaid programs provided coverage and reimbursement for RPM (Center for Connected Health Policy [CCHP], 2022). In the case of private insurers, 43 states and Washington, DC, had laws that govern private payer telehealth reimbursement policy, but only 21 states have explicit payment parity (CCHP, 2022). However, further changes in telehealth coverage and reimbursement policies are expected due to the abrupt and rapid increase effect that the COVID-19 pandemic has had in the utilization of telehealth services (CCHP, 2022).

3.3. System implementation

The third stage accounts for six components to consider while implementing, using, and maintaining a telehealth system: telehealth data/telehealth encounter, timing and frequency, telehealth system, usability and interoperability, data communication and presentation, and measure and monitoring.

3.3.1. Telehealth data/telehealth encounter

The telehealth data/telehealth encounter component defines the interaction between the patient and the healthcare provider, which can be synchronous (e.g. live video telemedicine) or asynchronous through the remote transmission of patient data directly to the healthcare provider (e.g. RPM). This component is guided by the protocols established in the System Preparation stage and must consider aspects of timing and frequency.

3.3.2. Timing and frequency

The timing and frequency component includes elements such as time allocation and frequency of encounters and notifications. Time allocation expectations impact clinic schedules and the estimation of workforce necessary to manage the clinical workload, since medical staff and assistants' work can also be affected by their involvement in processing and transcribing the medical data (Park et al., 2018). Establishing the frequency of encounters is also essential to avoid interruptions and data overload at inconvenient times (Bonet, Zahed, et al., 2022).

3.3.3. Telehealth system

The telehealth system component defines the telecommunication technologies being used for the distribution of remote and virtual health-related services. Grounded in Sittig and Singh's (2010) framework, a telehealth system involves four main elements: hardware, software, clinical content, and user interface. The hardware element encompasses physical devices used to access clinical applications required to run the telehealth system, while the software element accounts for programs and other operating information used. The clinical content includes all the telehealth data on the data-information-knowledge continuum that is stored in or received through the telehealth system. The user interface defines how the user interacts with the telehealth system to access the clinical content.

3.3.4. Usability and interoperability

The usability and interoperability component defines how well the healthcare personnel interact with the telehealth system, and how well the telehealth system integrates with other HIT in the clinic. Ease of use has been identified as one of the main principles for the successful development of a telehealth system (Davidson et al., 2013; Yellowlees, 2005) and interoperability has been identified as one of the major challenges to scale up telehealth systems (Leon et al., 2012). Findings from case study 3 (Park et al., 2019) revealed that healthcare providers consider telehealth interoperability with electronic health records (EHRs) a critical consideration for enhancing data processing activities and for time-saving purposes. A study regarding the allocation of physician time in ambulatory practice identified that physicians spend half of their time on EHR tasks and desk work (Sinsky et al., 2016); therefore, adding more tasks of a similar nature could be perceived as overwhelming. To address interoperability issues, healthcare providers have suggested the need for guidelines to summarize and present data in a way that seamlessly integrates with clinicians' current routine processes for managing data flows (Davidson et al., 2013). While EHRs are one of the most common HITs in healthcare, the interoperability component must account for the integration of the telehealth system with other HIT platforms such as picture archiving communications systems and patient portals.

3.3.5. Data communication and presentation

The data communication and presentation component encompasses methods used to present, communicate, and share patient health data. While the literature has shown that providers have expressed the desire for telehealth platforms to include a feature to share information with patients and referring physicians (Bonet, Sultana, et al., 2022) and a strong preference for viewing summarized telemonitoring data instead of receiving raw data (Davidson et al., 2013; Koopman et al., 2014), there is no clear evidence regarding their preferences about the communication method to receive and send telehealth data and the form of presenting such data.

3.3.6. Measure and monitoring

The measurement and monitoring component defines the criteria to be used to measure the status and success of the integration of the telehealth system, in addition to how frequently the telehealth system must be monitored. As identified by Sittig and Singh (2010), HIT must be measured and monitored on a regular basis, something that has been found absent in previous models for HIT integration. Sittig and Singh (2010) identified four key elements to measuring and monitoring in HIT which are applicable for telehealth: the availability of key features and functions ready to use, how those features and functions are being used by the clinicians, the system effectiveness to achieve the anticipated patient health outcomes, and identification and documentation of any unintended consequences of using the system.

3.4. Component relationships

The connections between SAINTS components within a stage and across stages are notated using the SysML language that specifies relationships in structural diagrams (Friedenthal et al., 2014). SysML language is usually used for the abstraction of mechanical systems; adaptations have been made to apply this common systems engineering tool to represent relationships in a sociotechnical system. Three types of relationships are showcased in the SAINTS framework.

The first and most predominant type of relationship presented is *dependency*. This type of relationship is showcased with a dashed arrow, where the component at the part end (the client) depends on the component at the arrowhead end (the supplier). When the supplier component changes, the client component may have to change accordingly. The framework showcases dependencies between components within a stage. For example, at the System Preparation stage, the Training component has a dependency relationship with the Roll Out Plan component and the SOPs component. A change in the roll out plan may imply changes in the training deployment, and the content included in the Training component is based on the defined procedures in the SOPs component. Similarly, the framework highlights dependency relationships at the Patient Enrollment stage. The framework also showcases dependencies between components across stages, such as the dependency relationship of the Telehealth Data/Telehealth Encounter component with the Telehealth System component, the Roll Out Plan component, and the SOPs component.

The second, and less prevalent, type of relationship presented is the *composite association* (indicated by an arrow with a black diamond head). The composite association conveys a structural decomposition, indicating that an instance of the component at the composite end (black diamond) is made up of instances of the components at the part end. This type of relationship characterizes the composition of the SOPs component, which is composed of instances of the Workflow Definition component and the Artifacts components. The multiplicities at the composite end indicate that the standard operating protocols can include one to many defined workflows and artifacts.

The third type of relationship presented is the *connector* (straight black line). The connectors are used to showcase underspecified relationships between elements. For example, while the Telehealth System component is neither dependent on, nor composed of, the Measure and Monitoring component, the Usability and Interoperability component, and the Data Communications and Presentation component, its effective integration must account for elements within them.

3.5. SME evaluation of the SAINTS framework

All SME participants found a systems-theoretic framework, such as the SAINTS framework, useful in guiding the adoption and integration of telehealth systems into clinical workflows. Several benefits and challenges related to usage of the SAINTS framework were mentioned.

3.5.1. Perceived benefits of using the SAINTS framework

The expert review participants suggested two main utilities of the SAINT framework: the system-level representation and helping build a shared mental model among stakeholders.

3.5.1.1 System-level representation. More than half of the participants [9/17, 53%] expressed that the SAINTS framework provides a comprehensive representation of the integration of telehealth into clinical workflow. For example, two participants expressed that the SAINTS framework provides a "*nice roadmap*" of the major components and their respective relationships. Another participant highlighted that the framework is comprehensive enough to be used as "*… a checklist to ensure that we thought about X, Y, and Z, and not going off of memory … and accidently forgetting something.*" Two participants commended the structure of the framework, expressing that they like how each component was represented as a box that could be unpacked into further details. One participant pointed out the flexibility of SAINTS as useful both to develop new telehealth initiatives and to implement existing ones. That participant expressed "*If I'm building it, I would go from right to left. If I'm implementing it, I would go left to right.*" Two other participants supported the efficacy of the SAINTS framework to be used as an evaluation tool to identify barriers and facilitators in telehealth integration.

3.5.1.2. Building shared mental model between stakeholders. Participants highlighted that stakeholder involvement is vital for the successful implementation of a telehealth system. The majority of participants [9/17, 53%] expressed that a holistic visual framework would be beneficial to create a shared mental model between all the stakeholders involved in the initiative. One of the participants expressed, "*… if they understand the higher end intricacies of everything, it gives them more of a reason behind why we do things a certain way. Showing them the framework will help them understand what they are doing better.*" Two participants highlighted how the SAINTS framework could work as a visual aid for stakeholder involvement. One of the participants mentioned, "*… because it is visual, it would be much easier to plan and involve stakeholders because they can see it rather than just saying that telehealth is being implemented with no plan that they can visualize.*"

3.5.2. Perceived challenges of using the SAINTS framework

Some participants found the SAINTS framework too broad to be used as a tool effectively, and raised issues related to its complexity and generalizability to a wide range of telehealth integrations.

3.5.2.1. Abstraction. While the participants recognized the value of SAINTS as a good representation of the structure of telehealth integration, some [3/17, 18%] pointed out that the scope of the framework is broad and suggested that further exploration of the internal complexities and intricacies of each of the components is required to ensure the successful integration of telehealth into clinical workflow.

3.5.2.2. Generalizability. Some participants [3/17, 18%] expressed that while SAINTS provides a good starting point for understanding the structure of telehealth integration, there will be generalizability challenges due to the inherent differences between healthcare settings. Therefore, achieving a one-size-fits-all framework for telehealth integration may be complicated, not to say impossible.

3.5.2.3. Complexity. While SAINTS provides a simplified visual representation of the complex structure of telehealth integration, some participants [5/17, 29%] expressed that at first glance the framework may be "*overwhelming*" or "*intimidating*" especially for stakeholders who may not be familiar with telehealth or technology implementation. As one of the participants mentioned, those stakeholders "*… could be overwhelmed by it. It is a lot of information to digest. But I still think there is a benefit to it regardless of those challenges, to let people know how things work on a bigger scale.*" Additionally, while the participants considered SAINTS as self-explanatory, a few participants pointed out that the terminology used may add complexity since there may be a disconnect in language and its interpretation between healthcare settings and across stakeholders, and further definitions and details are required.

4. Discussion

In this paper, we presented a novel framework that may serve as a descriptive model of telehealth workflow integration using a systems approach. The development of SAINTS, as a sociotechnical framework, provides a holistic overview of the emergent components that characterize the structure of components necessary for a successful integration of telehealth system and the inter-relationships between such components. While previous work with application in HIT has contributed to modeling integration at the workflow analyses level (Carayon et al., 2011; Salwei et al., 2021), to our knowledge, this is the first evidence-based model that focuses on the end-to-end process of integration for various telehealth systems. An important contribution of this research is the use of SysML block diagrams as a reference to define the structure of the framework and define relationships between components. MBSE methods such as SysML have been shown to provide an appropriate level of abstraction to manage perceived complexity of large systems and an extremely valuable tool to bridge the communications gaps that exist between engineers, non-engineers, and the various stakeholders involved in a system (Rainey & Tolk, 2014).

While the evaluation of SAINTS presented in this paper is by no means comprehensive, the expert review conducted showed preliminary support for the efficacy and practicality of SAINTS in capturing key components of telehealth integration. The analysis showed that SAINTS may be used as (1) a roadmap for the identification of barriers and facilitators, (2) a way to contrast different temporal stages, (3) a list of the relevant components within the different temporal stages, (4) a description of the relationships between the components within and across the temporal stages, and (5) a starting point for the future development of guidelines for the integration of telehealth systems with existing workflows.

Despite the initial evidence of efficacy presented in this paper to support the SAINTS framework, there are several limitations that affect the generalizability and practicality of this framework. Most importantly, the framework was developed based on case studies capturing two modalities of telehealth namely the televisits and remote patient monitoring. Work is needed to validate the applicability of the framework to other telehealth modalities such as store-and-forward and mobile health. In addition, despite the positive perceptions of SMEs regarding the applicability of SAINTS to a wide range of systems, the large variability in the adoption and implementation of telehealth across various health systems, geographic areas, and cultural differences in usage of such technologies warrants more work to evaluate and update the framework using more case studies. While SAINTS is unique in providing a sociotechnical framework in the context of telehealth, our collective experience shows that one-size-fits-all frameworks are rarely achievable without other context-specific considerations. Therefore, not all components in the SAINTS framework may be relevant or there may be components missing in the framework, depending on the structure of the healthcare system, the specific considerations related to the health conditions for which the technology is being used, and the telehealth modality being implemented. Taking this into consideration, a prospective study is required in the future to test the efficacy of the SAINTS framework in guiding the implementation of single- and multi-modality telehealth interventions in healthcare systems of different sizes, located in different geographic areas, at different levels of technology adoption, and with a variety of stakeholders involved in the process.

In addition, SAINTS provides a macro view of the main components to consider in the integration of these technologies, and future research is needed to add more specificity by employing a micro perspective to explore system components individually and further model their internal complexities and intricacies. Based on the feedback received from the participants, while the visual representation of the framework is self-explanatory, it should be accompanied by detailed definitions for each component to avoid any confusion with the terminology used and support those with little to no experience with telehealth and with these types of contextual frameworks.

It is recognized that aspects preceding the implementation of telehealth systems, such as identifying the clinical need for a telehealth-based intervention (DeGaetano & Shore, 2015); defining the desired outcomes (Ellimoottil et al., 2018); selecting the telehealth modality most suited to address the clinical needs (Haque & Hayden, 2022); determining the practical, legal, and financial implications (Dart et al., 2016); and considering if the intervention must be designed and developed in-house or if it must be outsourced, among other aspects, are important and require detailed consideration. However, these aspects are out of the scope of the body of work developed in this research effort. The SAINTS framework was developed to guide the implementation of telehealth once a healthcare setting had defined the telehealth platform to adopt after considering all the mentioned aspects that precede the telehealth integration. These aspects may be integrated in a new stage in future version of the SAINTS framework, after further research is done in this area.

Despite these limitations, we believe the SAINTS framework can help providers and healthcare administrators in effective and sustainable implementation efforts for existing and emerging telehealth technologies. While the constraints imposed by COVID-19 increased the adoption of telehealth technologies across the U.S., utilization of these technologies has not reached its full potential and it is expected to grow at an accelerated rate. Consequently, tools and methods that support healthcare settings of varying sizes in the long-term implementation of these technologies are timely. SAINTS proactively creates a shared mental model of the structure of telehealth implementation among providers and healthcare administrators to guide the implementation process, aid in the identification of gaps in implementation, and support better and more meaningful decisions.

Acknowledgments

The authors thank Jacob M. Kolman, MA, ISMPP CMPP™, senior technologist at Texas A&M University and senior scientific writer at Houston Methodist Academic Institute, for critical and linguistic review of this manuscript.

Consent and approval

This study received approval by a local institutional review board (IRB). Informed consent was obtained from each subject who participated in the study.

Disclosure statement

The authors report no conflict of interest.

Funding

This research was partly funded by the National Science Foundation Engineering Research Center Precise Advanced Technologies and Health Systems for Underserved Populations (PATHS-UP).

ORCID

Farzan Sasangohar http://orcid.org/0000-0001-9962-5470

References

Armstrong, A. W., Kwong, M. W., Chase, E. P., Ledo, L., Nesbitt, T. S., & Shewry, S. L. (2012). Teledermatology operational considerations, challenges, and benefits: The referring providers' perspective. *Telemedicine Journal and e-Health: The Official Journal of the American Telemedicine Association*, *18*(8), 580–584. https://doi.org/10.1089/tmj.2011.0241

Bonet Olivencia, S., Rao, A. H., Smith, A., & Sasangohar, F. (2021). Eliciting requirements for a diabetes self-management application for underserved populations: A multi-stakeholder analysis. *International Journal of Environmental Research and Public Health*, *19*(1), 127. https://doi.org/10.3390/ijerph19010127

Bonet, S., Sultana, I., Larsen, E., Zheng, F., & Sasangohar, F. (2022). Adoption of telemedicine to support postoperative visits: Mixed methods study of technological readiness and attitudes among surgeons. *JMIR Preprints*, 39514. https://doi.org/10.2196/preprints.39514

Bonet, S., Zahed, K., Sasangohar, F., Dvir, R., & Vedlitz, A. (2022). Integration of remote patient monitoring systems into physicians work in underserved communities: Survey of healthcare provider perspectives. ACELAB preprints. https://acelab.tamu.edu/wp-content/uploads/sites/23/2022/06/Bonet-et-al._RPMIntegrationSurvey-1.pdf

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, *3*(2), 77–101. https://doi.org/10.1191/1478088706qp063oa

Brereton, L., Wahlster, P., Mozygemba, K., Lysdahl, K. B., Burns, J., Polus, S., Tummers, S., Refolo, P., Sacchini, D., Leppert, W., Chilcott, J., Ingleton, C., Gardiner, S., & Goyder, E. (2017). Stakeholder involvement throughout health technology assessment: An example from palliative care. *International Journal of Technology Assessment in Health Care*, *33*(5), 552–561. https://doi.org/10.1017/S026646231700068X

Brewster, L., Mountain, G., Wessels, B., Kelly, C., & Hawley, M. (2014). Factors affecting front line staff acceptance of telehealth technologies: A mixed-method systematic review. *Journal of Advanced Nursing*, *70*(1), 21–33. https://doi.org/10.1111/jan.12196

Burgess-Limerick, R. (2018). Participatory ergonomics: Evidence and implementation lessons. *Applied Ergonomics*, *68*, 289–293. https://doi.org/10.1016/j.apergo.2017.12.009

Cady, R. G., & Finkelstein, S. M. (2013). Mixed-methods approach for measuring the impact of video telehealth on outpatient clinic triage nurse workflow. *Computers, Informatics, Nursing: CIN*, *31*(9), 439–449. https://doi.org/10.1097/01.NCN.0000432126.99644.6c

Cady, R. G., & Finkelstein, S. M. (2014). Task-technology fit of video telehealth for nurses in an outpatient clinic setting. *Telemedicine Journal and e-Health: The Official Journal of the American Telemedicine Association*, *20*(7), 633–639. https://doi.org/10.1089/tmj.2013.0242

Cady, R., Finkelstein, S., Lindgren, B., Robiner, W., Lindquist, R., VanWormer, A., & Harrington, K. (2010). Exploring the translational impact of a home telemonitoring intervention using time-motion study. *Telemedicine Journal and e-Health: The Official Journal of the American Telemedicine Association*, *16*(5), 576–584. https://doi.org/10.1089/tmj.2009.0148

Carayon, P., Cartmill, R., Hoonakker, P., Hundt, A. S., Karsh, B. T., Krueger, D., Snellman, M., Thuemling, T., & Wetterneck, T. B. (2011). Human factors analysis of workflow in health information technology implementation. In P. Carayon (Ed.), *Handbook of human factors and ergonomics in health care and patient safety* (pp. 536–551). CRC Press.

Carayon, P., Schoofs Hundt, A., Karsh, B. T., Gurses, A. P., Alvarado, C. J., Smith, M., & Flatley Brennan, P. (2006). Work system design for patient safety: The SEIPS model. *Quality in Health Care*, *15*(Suppl 1), i50–i58. https://doi.org/10.1136/qshc.2005.015842

Center for Connected Health Policy. (2022). State Telehealth Laws and Reimbursement Policies Report-Spring 2022. Retrieved May 18, 2022. https://www.cchpca.org/2022/05/Spring2022_ExecutiveSummaryfinal.pdf

Cherney, L. R., & van Vuuren, S. (2012). Telerehabilitation, virtual therapists, and acquired neurologic speech and language disorders. *Seminars in Speech and Language*, *33*(3), 243–257. https://doi.org/10.1055/s-0032-1320044

Cortelyou-Ward, K., Atkins, D. N., Noblin, A., Rotarius, T., White, P., & Carey, C. (2020). Navigating the digital divide: Barriers to telehealth in rural areas. *Journal of Health Care for the Poor and Underserved*, *31*(4), 1546–1556. https://doi.org/10.1353/hpu.2020.0116

Cronin, E. M., Ching, E. A., Varma, N., Martin, D. O., Wilkoff, B. L., & Lindsay, B. D. (2012). Remote monitoring of cardiovascular devices: A time and activity analysis. *Heart Rhythm*, *9*(12), 1947–1951. https://doi.org/10.1016/j.hrthm.2012.08.002

Dart, E. H., Whipple, H. M., Pasqua, J. L., & Furlow, C. M. (2016). Legal, regulatory, and ethical issues in telehealth technology. In J. Luiselli & A. Fischer (Eds.), *Computer-assisted and web-based innovations in psychology, special education, and health* (pp. 339–363). Academic Press.

Davidson, E., Simpson, C. R., Demiris, G., Sheikh, A., & McKinstry, B. (2013). Integrating telehealth care-generated data with the family practice electronic medical record: Qualitative exploration of the views of primary care staff. *Interactive Journal of Medical Research*, *2*(2), e29. https://doi.org/10.2196/ijmr.2820

DeGaetano, N., & Shore, J. (2015). Conducting a telehealth needs assessment. In P. Tuerk & P. Shore (Eds.), *Clinical videoconferencing in telehealth* (pp. 23–54). Springer.

Ellimoottil, C., An, L., Moyer, M., Sossong, S., & Hollander, J. E. (2018). Challenges and opportunities faced by large health systems implementing telehealth. *Health Affairs (Project Hope)*, *37*(12), 1955–1959. https://doi.org/10.1377/hlthaff.2018.05099

Facchin, D., Baccillieri, M. S., Gasparini, G., Zoppo, F., Allocca, G., Brieda, M., Verlato, R., & Proclemer, A. (2016). Findings of an observational investigation of pure remote follow-up of pacemaker patients: Is the in-clinic device check still needed? *International Journal of Cardiology*, *220*, 781–786. https://doi.org/10.1016/j.ijcard.2016.06.162

Fish, A., George, S., Terrien, E., Eccles, A., Baker, R., & Ogunyemi, O. (2011). Workflow concerns and workarounds of readers in an urban safety net teleretinal screening study. *AMIA Annual Symposium Proceedings* (pp. 417–426). AMIA Symposium.

Francke, J. A., Groden, P., Ferrer, C., Bienstock, D., Tepper, D. L., Chen, T. P., Sanky, C., Grogan, T., & Weissman, M. A. (2022). Remote enrollment into a telehealth-delivering patient portal: Barriers faced in an urban population during the COVID-19 pandemic. *Health and Technology*, *12*(1), 227–238. https://doi.org/10.1007/s12553-021-00614-x

Friedenthal, S., Moore, A., & Steiner, R. (2014). *A Practical Guide to SysML: The Systems Modeling Language*. Morgan Kaufmann.

Gajarawala, S. N., & Pelkowski, J. N. (2021). Telehealth benefits and barriers. *The Journal for Nurse Practitioners: JNP*, *17*(2), 218–221. https://doi.org/10.1016/j.nurpra.2020.09.013

Ghaddar, S., Vatcheva, K. P., Alvarado, S. G., & Mykyta, L. (2020). Understanding the intention to use telehealth services in underserved Hispanic border communities: Cross-sectional study. *Journal of Medical Internet Research*, *22*(9), e21012. https://doi.org/10.2196/21012

Grigsby, B., Brega, A. G., Bennett, R. E., Devore, P. A., Paulich, M. J., Talkington, S. G., Floersch, N. R., Barton, P. L., Neal, S., Araya, T. M., Loker, J. L., Krohn, N., & Grigsby, J. (2007). The slow pace of interactive video telemedicine adoption: The perspective of telemedicine program administrators on physician participation. *Telemedicine Journal and E-Health*, *13*(6), 645–656.

Haque, S. N., & Hayden, E. M. (2022). Telehealth. In J. Finnell & B. Dixon (Eds.), *Clinical Informatics Study Guide* (pp. 255–259). Springer.

Health Resources & Services Administration. (2022). *Health Equity in Telehealth*. Retrieved May 18, 2022. https://telehealth.hhs.gov/providers/health-equity-in-telehealth/

Hjelm, N. M. (2005). Benefits and drawbacks of telemedicine. *Journal of Telemedicine and Telecare*, *11*(2), 60–70. https://doi.org/10.1258/1357633053499886

Holden, R. J., Carayon, P., Gurses, A. P., Hoonakker, P., Hundt, A. S., Ozok, A. A., & Rivera-Rodriguez, A. J. (2013). SEIPS 2.0: A human factors framework for studying and improving the work of healthcare professionals and patients. *Ergonomics*, *56*(11), 1669–1686. https://doi.org/10.1080/00140139.2013.838643

Jarvis-Selinger, S., Chan, E., Payne, R., Plohman, K., & Ho, K. (2008). Clinical telehealth across the disciplines: Lessons learned. *Telemedicine Journal and e-Health: The Official Journal of the American Telemedicine Association*, *14*(7), 720–725. https://doi.org/10.1089/tmj.2007.0108

Jennett, P., Jackson, A., Healy, T., Ho, K., Kazanjian, A., Woollard, R., Haydt, S., & Bates, J. (2003). A study of a rural community's readiness for telehealth. *Journal of Telemedicine and Telecare*, *9*(5), 259–263. https://doi.org/10.1258/135763303769211265

Kalicki, A. V., Moody, K. A., Franzosa, E., Gliatto, P. M., & Ornstein, K. A. (2021). Barriers to telehealth access among homebound older adults. *Journal of the American Geriatrics Society*, *69*(9), 2404–2411. https://doi.org/10.1111/jgs.17163

Kaufman, D. R., Pevzner, J., Rodriguez, M., Cimino, J. J., Ebner, S., Fields, L., Moreno, V., McGuiness, C., Weinstock, R. S., Shea, S., & Starren, J. (2009). Understanding workflow in telehealth video visits: Observations from the IDEATel project. *Journal of Biomedical Informatics*, *42*(4), 581–592. https://doi.org/10.1016/j.jbi.2009.03.012

Koopman, R. J., Wakefield, B. J., Johanning, J. L., Keplinger, L. E., Kruse, R. L., Bomar, M., Bernt, B., Wakefield, D. S., & Mehr, D. R. (2014). Implementing home blood glucose and blood pressure telemonitoring in primary care practices for patients with diabetes: Lessons learned. *Telemedicine Journal and e-Health: The Official Journal of the American Telemedicine Association*, *20*(3), 253–260. https://doi.org/10.1089/tmj.2013.0188

Kruse, C., Fohn, J., Wilson, N., Patlan, E. N., Zipp, S., & Mileski, M. (2020). Utilization barriers and medical outcomes commensurate with the use of telehealth among older adults: Systematic review. *JMIR Medical Informatics*, *8*(8), e20359. https://doi.org/10.2196/20359

Leon, N., Schneider, H., & Daviaud, E. (2012). Applying a framework for assessing the health system challenges to scaling up mHealth in South Africa. *BMC Medical Informatics and Decision Making*, *12*, 123. https://doi.org/10.1186/1472-6947-12-123

LeRouge, C., & Garfield, M. J. (2013). Crossing the telemedicine chasm: Have the US barriers to widespread adoption of telemedicine been significantly reduced? *International Journal of Environmental Research and Public Health*, *10*(12), 6472–6484. https://doi.org/10.3390/ijerph10126472

Liu, J. (2007). Health professional shortage and health status and health care access. *Journal of Health Care for the Poor and Underserved*, *18*(3), 590–598. https://doi.org/10.1353/hpu.2007.0062

Lopetegui, M., Yen, P. Y., Lai, A., Jeffries, J., Embi, P., & Payne, P. (2014). Time motion studies in healthcare: What are we talking about? *Journal of Biomedical Informatics*, *49*, 292–299. https://doi.org/10.1016/j.jbi.2014.02.017

Luo, J., Tong, L., Crotty, B. H., Somai, M., Taylor, B., Osinski, K., & George, B. (2021). Telemedicine adoption during the COVID-19 pandemic: Gaps and inequalities. *Applied Clinical Informatics*, *12*(4), 836–844. https://doi.org/10.1055/s-0041-1733848

Menachemi, N., Burke, D. E., & Ayers, D. J. (2004). Factors affecting the adoption of telemedicine—A multiple adopter perspective. *Journal of Medical Systems*, *28*(6), 617–632. https://doi.org/10.1023/b:Joms.0000044964.49821.df

Molfenter, T., Boyle, M., Holloway, D., & Zwick, J. (2015). Trends in telemedicine use in addiction treatment. *Addiction Science & Clinical Practice*, *10*, 14. https://doi.org/10.1186/s13722-015-0035-4

Nilsen, E. R., Stendal, K., & Gullslett, M. K. (2020). Implementation of eHealth technology in community health care: The complexity of stakeholder involvement. *BMC Health Services Research*, *20*(1), 395. https://doi.org/10.1186/s12913-020-05287-2

Parasuraman, A. (2000). Technology readiness index (TRI): A multiple-item scale to measure readiness to embrace new technologies. *Journal of Service Research*, *2*(4), 307–320. https://doi.org/10.1177/109467050024001

Park, J., Erikson, C., Han, X., & Iyer, P. (2018). Are state telehealth policies associated with the use of telehealth services among underserved populations? *Health Affairs (Project Hope)*, *37*(12), 2060–2068. https://doi.org/10.1377/hlthaff.2018.05101

Park, S., Wagle, N., Hammett, J., Olivencia, S., Lawley, M., Sasangohar, F., & Kum, H.-C. (2019). Telemonitoring in Texas (Report No.: 2019-001–2). Texas A&M University. https://pinformatics.tamhsc.edu/reports/telemonitoring_tamu2019_001v2.pdf

Petersen, C., & DeMuro, P. (2015). Legal and regulatory considerations associated with use of patient-generated health data from social media and mobile health (mHealth) devices. *Applied Clinical*

Informatics, *6*(1), 16–26. https://doi.org/10.4338/ACI-2014-09-R-0082

Puskin, D. S., Cohen, Z., Ferguson, A. S., Krupinski, E., & Spaulding, R. (2010). Implementation and evaluation of telehealth tools and technologies. *Telemedicine Journal and e-Health: The Official Journal of the American Telemedicine Association*, *16*(1), 96–102. https://doi.org/10.1089/tmj.2009.0182

Rainey, L., & Tolk, A. (2014). *Modeling and simulation support for system of systems engineering applications* (1st ed.). John Wiley & Sons.

Ricci, R. P., Morichelli, L., D'Onofrio, A., Calò, L., Vaccari, D., Zanotto, G., Curnis, A., Buja, G., Rovai, N., & Gargaro, A. (2014). Manpower and outpatient clinic workload for remote monitoring of patients with cardiac implantable electronic devices: Data from the HomeGuide Registry. *Journal of Cardiovascular Electrophysiology*, *25*(11), 1216–1223. https://doi.org/10.1111/jce.12482

Salwei, M. E., Carayon, P., Hoonakker, P. L., Hundt, A. S., Wiegmann, D., Pulia, M., & Patterson, B. W. (2021). Workflow integration analysis of a human factors-based clinical decision support in the emergency department. *Applied Ergonomics*, *97*, 103498. https://doi.org/10.1016/j.apergo.2021.103498

Shaw, R. J., Kaufman, M. A., Bosworth, H. B., Weiner, B. J., Zullig, L. L., Lee, S. Y., Kravetz, J. D., Rakley, S. M., Roumie, C. L., Bowen, M. E., Del Monte, P. S., Oddone, E. Z., & Jackson, G. L. (2013). Organizational factors associated with readiness to implement and translate a primary care based telemedicine behavioral program to improve blood pressure control: The HTN-IMPROVE study. *Implementation Science: IS*, *8*, 106. https://doi.org/10.1186/1748-5908-8-106

Sinsky, C., Colligan, L., Li, L., Prgomet, M., Reynolds, S., Goeders, L., Westbrook, J., Tutty, M., & Blike, G. (2016). Allocation of physician time in ambulatory practice: A time and motion study in 4 specialties. *Annals of Internal Medicine*, *165*(11), 753–760. https://doi.org/10.7326/M16-0961

Sittig, D. F., & Singh, H. (2010). A new sociotechnical model for studying health information technology in complex adaptive healthcare systems. *Quality and Safety in Health Care*, *19*(Suppl 3), i68–i74. https://doi.org/10.1136/qshc.2010.042085

Tang, Z., Weavind, L., Mazabob, J., Thomas, E. J., Chu-Weininger, M. Y., & Johnson, T. R. (2007). Workflow in intensive care unit remote monitoring: A time-and-motion study. *Critical Care Medicine*, *35*(9), 2057–2063. https://doi.org/10.1097/01.ccm.0000281516.84767.96

Triana, A. J., Gusdorf, R. E., Shah, K. P., & Horst, S. N. (2020). Technology literacy as a barrier to telehealth during COVID-19. *Telemedicine Journal and e-Health: The Official Journal of the American Telemedicine Association*, *26*(9), 1118–1119. https://doi.org/10.1089/tmj.2020.0155

Unertl, K. M., Novak, L. L., Johnson, K. B., & Lorenzi, N. M. (2010). Traversing the many paths of workflow research: Developing a conceptual framework of workflow terminology through a systematic literature review. *Journal of the American Medical Informatics Association: JAMIA*, *17*(3), 265–273. https://doi.org/10.1136/jamia.2010.004333

Uscher-Pines, L., & Kahn, J. M. (2014). Barriers and facilitators to pediatric emergency telemedicine in the United States. *Telemedicine Journal and e-Health: The Official Journal of the American Telemedicine Association*, *20*(11), 990–996. https://doi.org/10.1089/tmj.2014.0015

Whitten, P. S., & Mackert, M. S. (2005). Addressing telehealth's foremost barrier: Provider as initial gatekeeper. *International Journal of Technology Assessment in Health Care*, *21*(4), 517–521. https://doi.org/10.1017/S0266462305050725

Wootton, R. (2012). Twenty years of telemedicine in chronic disease management–an evidence synthesis. *Journal of Telemedicine and Telecare*, *18*(4), 211–220. https://doi.org/10.1258/jtt.2012.120219

Yellowlees, P. M. (2005). Successfully developing a telemedicine system. *Journal of Telemedicine and Telecare*, *11*(7), 331–335. https://doi.org/10.1177/1357633X0501100707

Yen, P. Y., Lara, B., Lopetegui, M., Bharat, A., Ardoin, S., Johnson, B., Mathur, P., Embi, P. J., & Curtis, J. R. (2016). Usability and workflow evaluation of "RhEumAtic Disease activitY" (READY). A mobile application for rheumatology patients and providers. *Applied Clinical Informatics*, *7*(4), 1007–1024. https://doi.org/10.4338/ACI-2016-03-RA-0036

Zheng, K., Haftel, H. M., Hirschl, R. B., O'Reilly, M., & Hanauer, D. A. (2010). Quantifying the impact of health IT implementations on clinical workflow: A new methodological perspective. *Journal of the American Medical Informatics Association: JAMIA*, *17*(4), 454–461. https://doi.org/10.1136/jamia.2010.004440