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A multi-site study of clinician perspectives in the lifecycle of an algorithmic risk prediction tool

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Abstract

Recent advancements in the performative capacities of artificial intelligence (AI), machine learning (ML), and algorithmic-based tools open up numerous applications in modern medicine. There are, however, few studies that track the whole lifecycle of a digital healthcare tool as it evolves from conception, to design, and deployment in real world settings—especially with a focus on the social dynamics amongst the end-users of the tool: clinicians. In this paper, we present data from a multi-site, 5-year study focused on the development and deployment of an algorithmic risk calculator (HeartMate 3 Risk Score) into a validated and efficacy tested clinical decision support system (CDSS) for patients and clinicians engaging in shared decision making about left ventricular assist device (LVAD) therapy for advanced heart failure. We conducted a total of 76 interviews with 20 advanced heart failure cardiologists and 14 nurse coordinators with LVAD expertise (n=34) across different timepoints during the lifecycle of this digital healthcare tool. Results from Thematic Analysis revealed an array of social factors at play at each stage of the tool's development and implementation, from finding social consensus around risk messaging in the conception and design phases, to various social contingencies that served as facilitators and barriers to the successful integration of the tool in its later stages. Our findings confirm many previously raised issues with introducing new medical and digital healthcare tools into clinical care, and highlight new issues specific to the rapidly advancing technology in CDSS.

Keywords

Digital healthcare tool; Clinical decision support; Risk communication; Social factors; Team dynamics

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

CRediT authorship contribution statement

Rita Dexter: Writing – review & editing, Writing – original draft, Formal analysis, Data curation, Conceptualization. **Kristin Kostick-Quenet:** Writing – review & editing, Supervision, Methodology, Investigation, Formal analysis, Conceptualization. **Jennifer Blumenthal-Barby:** Writing – review & editing, Supervision, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ssmqr.2025.100562.

1. Introduction

Recent advancements in the performative capacities of artificial intelligence (AI), machine learning (ML), and algorithmic-based tools open up numerous applications in modern medicine with the potential to significantly impact patient care (Bohr & Memarzadeh, 2020). The COVID-19 pandemic also served as an accelerator for research focused on the merging of digital technologies and healthcare (Wang et al., 2021). Developers of clinical decision support systems (CDSS) have started to incorporate these novel technologies to amplify their utility in complex medical decision-making (Sutton et al., 2020). However, the risks and benefits of digital healthcare tools in patient care has long been a topic of debate across the fields of medicine, sociology, medical ethics, and nursing (Lupton, 2014; Maeckelberghe et al., 2023; Navarro Martínez et al., 2023; Perakslis & Ginsburg, 2020). One example, the electronic health record (EHR), generated concerns around poor physician acceptance, high costs, and data entry errors which emerged with early iterations in the 1980s (Evans, 2016). Later when CDSS tools began being integrated into the EHR, new concerns emerged around provider alert fatigue, poor-quality training datasets, lack of interoperability, and lack of user acceptance and subsequent workflow integration (Alexiuk et al., 2024; Sutton et al., 2020). Despite these initial hesitancies, EHRs have been widely adopted across the US healthcare system and the world, demonstrating the inevitability of novel technology integration in clinical care.

Given the abundance of utilities in algorithmic-based digital healthcare tools, many researchers, developers, and clinicians choose to prioritize those that directly impact patient care. With the shift towards shared decision-making (Brody, 1980) in the 1970s and patient-focused care (Irwin & Richardson, 2006) at the turn of the century, digital healthcare tools that support and enhance patient understanding of risk and therapeutic options have an immediacy attached to them in the context of high stakes clinical decision-making. The rise in popularity of risk prediction prognostic tools, also termed prognostic prediction tools (PPTs), is a result of a surge in performative computational methodologies and increasing demand for accurate, digestible risk information in patient care (Hallen et al., 2015). In recent years, appreciation for the procedure and complexity involved in bringing a digital healthcare tool from the concept phase to real-world, responsible deployment has captured the attention of researchers working at the intersection of technology and health (Duffy et al., 2022). This is especially true for digital tools that offer prognostic information about risk where there is high susceptibility to variation in patient understanding.

Effective risk communication has been a long-standing topic of interest for medical sociologists in the context of medical decision-making (Birchley et al., 2024; Fagerlin et al., 2011; Kunneman et al., 2015; Reed et al., 2021; Siermann et al., 2024). During the conceptual phase, researchers have called for participatory and “value-sensitive” design in the development of risk communication and digital healthcare tools (Friedman et al., 2013; Schuler & Namioka, 1993), as well as increased attention to implementation in real-world settings (Gerke et al., 2020). Digital healthcare tools are inherently interactional, both by the users (healthcare providers) and recipients (patients) of the technology. Therefore, it is crucial to engage key stakeholders’ perspectives and informational needs in the development and later in the feasibility testing stages of these tools. Examining the concerns and

challenges expressed by the end-users of the digital healthcare tool, clinicians, allows researchers and developers to anticipate barriers to implementation and respond accordingly. Notably, implementation science literature has highlighted the value of ethnographic approaches in identifying the sociocultural elements of real-world healthcare environments for which these tools are intended (Gertner et al., 2021). Through ethnography, researchers can observe and understand how different sites and user groups with varying characteristics (e.g. patient volume, organizational structure and flow, etc.) interact with the tool. This is a necessary first step—understanding the variation in use and contextual factors—prior to solidifying "best practices" of said tool, which would otherwise be premature. Looking back at the barriers to adoption of new computerized tools highlighted in the literature, there have been accounts of clinicians' negative attitudes toward digital health care tools, concerns around reduced quality of care, and changes or disruptions to traditional roles and workplace habits (Ammenwerth et al., 2003; André et al., 2008; Ash et al., 2000; Mikulich et al., 2001). There are, however, few studies that track the whole life cycle of a digital healthcare tool, such as an algorithmic risk predictor, as it evolves from conception, to design, and finally deployment in real world settings—especially with a focus on the social factors at play. We aim to fill this gap in the literature using the case study of an algorithmic-risk predictor calculator to outline how the social dynamics amongst clinicians contribute to each of the unique phases in the lifecycle of a digital healthcare tool.

In this paper, we present data from a multi-site, 5-year study focused on the development and deployment of an algorithmic risk calculator into a validated and efficacy tested clinical decision support system (CDSS) for patients and clinicians engaging in shared decision making about left ventricular assist device (LVAD) therapy for advanced heart failure. More specifically, we examine clinician stakeholder views and practices and how they evolved throughout the lifecycle of this digital tool (from conception to design to deployment). We explore the important social factors at play at each stage, from finding social consensus around risk messaging in the conception and design phases, to various social contingencies that served as facilitators and barriers to the successful deployment and integration of the tool in its later stages.

2. Methods

2.1. Research setting

This paper presents findings from a 5-year Agency for Healthcare Research and Quality (AHRQ) funded study on the integration of a personalized risk calculator (Heart Mate 3 Risk Score – HM3RS) into existing patient education materials for LVAD therapy. This project builds on our team's previously published work in the design and efficacy testing of a clinical decision support (CDS) tool for LVAD therapy (see 'Deciding Together' Decision Aid (Kostick et al., 2016, 2018)) in partnership with six clinical sites from diverse geographic regions in the United States that are leading centers for advanced heart failure care. Most are situated in large, urban medical centers. This previous work with partnering sites provided an established infrastructure to integrate an algorithmic personalized risk predictor into the CDS tool. The authors (KK-Q, JB-B) are part of the research group that developed the clinical decision support system.

2.2. Study design

Between 2020–2024, we conducted a total of 76 interviews with 20 advanced heart failure cardiologists and 14 nurse coordinators with LVAD expertise, for a total of 34 unique clinician perspectives. Interviews spanned different timepoints across the development, design, and implementation phases of this digital healthcare tool's lifecycle. For the first three years of the tool's lifecycle, during the design and user-testing phases, interviews occurred approximately once per year. Once the tool was launched into clinical flow, interviews increased in frequency to approximately once per quarter. These interviews were designed to explore clinician attitudes and perspectives throughout the conception, design, and implementation of a patient-facing algorithmic survival estimator for a high-stakes medical decision (LVAD therapy for advanced heart failure). The risk calculator output provides patients with their personalized survival estimates at 1- and 2-years both with and without LVAD using icon arrays to illustrate survivability (see Supplement 1) as well as aggregate risk percentages for potential complications post-implant and other quality of life and functional status benefits of the therapy. The interviews were also intended to engage clinician stakeholders in the theoretical, developmental, and implementation life phases of this tool, incorporating their feedback at each step of the way. Due to the longitudinal nature of our study, some of our clinicians were interviewed more than once. For more information regarding the number of times clinicians were interviewed by participant type, see Table A.

Our semi-structured interview guides were collaboratively developed by our team of bioethicists, including a medical anthropologist and a decision scientist, to identify and track key ethical and practical concerns related to the generation and communication of personalized risk (PR) communication based on the literature as well as our teams' nearly 10 years of experience working with clinicians on the development and dissemination of an efficacy-tested decision aid for patients considering LVAD therapy (Bruce et al., 2015; Buchberg et al., 2019; Kaplan et al., 2025; K. Kostick-Quenet et al., 2024b; K. M. Kostick-Quenet et al., 2024a; Maeckelberghe et al., 2023; Shanmugaratnam & Edwards, 2016). Interview guides for physicians and nurse coordinators were similar but not identical given the difference in roles related to the tool's conception, design, and deployment. Many of our questions for the physicians were conceptual, focused on perceived accuracy, trust, and utility of the calculator in clinical decision-making. While questions for the nurse coordinators included some conceptual questions around the same constructs previously mentioned, we primarily focused our time with nurse coordinators on the tracking the practical use of the tool in the clinic with patients—how patients respond emotionally to their survival estimates, challenges when integrating the tool into clinical flow, how often the tool was being used with patients at their site, etc. Our interview team (RD, MH) was trained in qualitative interviewing and analysis by a medical anthropologist and qualitative/mix methods expert (K-KQ). Questions explored clinicians' views on PR utility for decision-making, degree of reliance, clinician trust, patient emotional reactions, as well as impact on clinical flow, quality of patient communication, bias reduction, and more.

In addition to the formal interviews with clinicians, our team kept ethnographic notes throughout the project documenting our observations of social dynamics amongst clinicians throughout the various phases of the tool's development and implementation in clinical

settings. We draw upon these ethnographic notes in the results section to present findings our team observed over time that did not appear in the formal interviews.

The study was approved by the Institutional Review Board at Baylor College of Medicine (H-48537). All respondents offered verbal informed consent to participate, consistent with the IRB's approved waiver of documented written consent.

2.3. Participant sampling

Clinicians from our six partnering sites were asked to participate in regular interviews as part of their agreement to serve as physician champions or nurse coordinator panelists on the advisory board. Our primary criteria for recruiting champion physicians and nurse coordinator panelists were that they be actively involved in providing care and/or patient education for patients considering LVAD therapy or who were referred for an LVAD consult. Given the longitudinal nature of this study, some clinician partners left their roles throughout the course of the project and were replaced by new clinicians. Champion physicians often identified other physicians and nurse coordinators on their teams who may be interested in joining the project. Interviews lasted on average 36.4 min (standard deviation of ± 14.9) and were conducted either via telephone or videoconference (Zoom) by three members of the research team (RD, MH, KK-Q). Nurse coordinators were compensated for their role on the advisory panel. Physician champions were not compensated.

2.4. Data analysis

Interviews were recorded, transcribed verbatim, and analyzed using Thematic Analysis (Boyatzis, 1998), using a combined inductive and deductive approach to develop codes and identify themes, sub-domains, and domains. We drew upon our teams' extensive knowledge working with this stakeholder group (deductive) while also allowing for emergent themes to surface (inductive). Team members (RD, KK-Q, JB-B) developed a codebook to identify key considerations for the use and acceptability of a new tool from the clinician perspective across the three phases of the project. A trained research assistant (RD) and medical anthropologist (KK-Q) worked closely on applying the codebook to the first several transcripts, comparing coding application and frequencies to ensure intercoder reliability. We then inductively identified themes by iteratively abstracting relevant quotes, whereby the research assistant read each quotation tagged for a theme, paraphrased the quotation (primary abstraction) and identified the underlying construct addressed by said quotation (secondary abstraction). Abstractions were grouped conceptually to identify themes and subthemes. The research team (RD, KK-Q, JB-B) met to discuss emerging themes at multiple stages of this process, contributing to the validity and reliability of the findings. In rare cases where there was disagreement in abstraction interpretation, team members met to reach consensus.

3. Results

Through a combination of clinician interviews and our observations in the field, we identified various social factors contributing to the use and successful integration of the survival estimation tool. We present the first layer of our findings across interview

transcripts and our ethnographic notes (primary analysis) as ‘themes,’ then ‘sub-domains’ (secondary analysis), and finally the three main ‘domains’ of clinician social factors observed throughout the conception, design, and deployment of the HM3RS tool. For a visual depiction of our findings, see Fig. 1. Central to the conception and design phase was identifying social consensus among clinicians about the “right” risk message to deliver to patients which embodied what the tool was meant to achieve. Achieving such consensus proved to be critical during the implementation phase for the sustained life of the tool.

3.1. Deciding on the “right” risk framing

In early conceptual phase interviews, we found that clinicians were in agreement that patients would benefit from receiving the personalized survival and risk estimates offered by the tool; however we observed variance in physician preferences about how the risk information should be organized and presented to patients in the output page of the calculator. This raised questions regarding the “right” framing and which key takeaways patients should have about the risks associated with refusing LVAD. Some senior advanced heart failure cardiologists told us that the general outpatient cardiology community often overemphasizes the risks of LVAD therapy rather than the benefits, sometimes resulting in an overly negative patient outlook towards LVAD by the time they come in for their appointment with the advanced practice cardiologists. Many of these physicians said that they feel compelled to counter these potentially negative impressions by emphasizing the established survival benefits of LVAD over medical management of heart failure with a tool like the HM3RS calculator. For example, one physician expressed the view that early iterations of the calculator’s output lacked a balanced view of the clinical benefits of the therapy alongside the potential risks, potentially leading to biased decision making:

> “So I think … **you should make these more positive,** and then they [the patient] can circle whatever they want so that they actually should want to talk about these things with their clinician. **But just make sure the nomenclature and the terminology is not tilting one way or another.**”
>
> (Ph_03)

Another physician supported a balanced view, arguing that providing unbiasing risk aligns with their approach to providing care:

> “My personal practice is to not recommend an LVAD to anybody. **My practice style is to provide patients unbiased information and let them make an informed decision.** LVAD in particular, it’s such a personal decision, because they really are trading off quality of life and potential for some adverse effects for … increased life expectancy. But some people don’t want to do that. And so I rarely tell somebody that ‘you need an LVAD,’ … I say, ‘we have a therapy. These are the potential benefits to you. These are the potential risks.’ [HM3RS] is very helpful to have that discussion.”
>
> (Ph_02)

In previous iterations of the HM3RS calculator output, our team crafted language framing percentages in terms of mortality—’What is the likelihood the patient will die in one

year with or without LVAD?' Physicians we spoke with recommended reframing the risk message from mortality to survival estimates in the icon arrays (see Supplement 1) to encourage a discussion around the likelihood the patient would survive to a year with or without the therapy, as opposed to the likelihood they would not. They also recommended rearranging the order of survival estimates to give the risk "without" LVAD first, then the risk "with" LVAD, so patients can see how their survival improves with the therapy. Some physicians wanted a scale with high, medium, and low tertiles depicted with red in the high-risk category, yellow in medium risk, and green in low risk. Others felt the colors could be too biasing, causing patients to associate high-risk (red) with notions of "danger" or the impulse to "stop."

3.1.1. Social consensus on the key takeaways: In response to questions during user testing about key takeaway messages for patients, clinicians shared that they want the HM3RS to help patients understand how sick they are, and that getting an LVAD is likely to them survive longer than they would without it. As one physician put it succinctly:

> "I think that [patients] need to **understand they're very sick**, they have a **better survival with the device** and that there are **some challenges**. "
>
> (Ph_08)

Another physician similarly emphasized the message above, specifically mentioning communicating to patients why they are sick:

> "What do we want? **We want patients to know that their underlying heart disease is a driver for them for being sick** when they have an end stage heart failure or advanced heart failure. **We want 'em to understand that they're not going to do well without the VAD likely, and they may do better with an LVAD.**"
>
> (Ph_05)

Finally, this physician felt very strongly the calculator output should emphasize the benefits of the therapy, including survival benefits as well as significant improvements on quality of life and functional status:

> "I want patients to know that even if you are in a tough trajectory, if you're in tertile three, there is still **meaningful prolongation of survival** from where you are now. Yes, you'll have a really tough course and your hospitalization will be difficult and things could happen, **but that pain is well worth the benefit,** number one. Number two, if you pass through and you leave the hospital with very few adverse effects … that **you have a wonderful and meaningful prolongation in life** out to five years… Number three, **you have a doubling in your ability to walk and you have a 75% improvement in your quality of life** by measured tools of quality of life."
>
> (Ph_03)

After much deliberation and iterative modifications to the calculator output page the champion physicians reached consensus, and our team moved to the usability and acceptability (U/A) testing stage.

3.2. Clinician adaptivity to new tools

In the conceptual stage of the risk and survival prediction tool's development, we asked clinicians to reflect on the necessary criteria for the acceptance and successful integration of the tool into their clinical flow. Physicians expressed some initial resistance and raised concerns related to existing healthcare challenges faced by clinicians such as time constraints, illustrated by physician 11 when they said:

> "**I don't see many physicians having the time to input any of these data.** It'd be very different if the coordinator who's helping us work up the patient is one-by-one fitting in things into this and at the time of [medical review], let's say, presents the score, that might be very helpful. But … **I don't know how much time we have.** Because for me, I'm doing this and I'm an interventional cardiologist, so it's like, "**Do I sleep for two hours a day or do I do risk models?**"
>
> (Ph_11)

Other physicians were skeptical about accuracy and relevance of the tool despite statistical validation, citing concerns related to the quality and size of the database used to develop the risk predictor:

> "**I don't know that the INTERMACS data set is granular enough** nowadays to make predictions that are better than what I can learn from a clinical trial … And you have such a relatively small data set. You only have a few thousand a year."
>
> (Ph_08)

When asked about their holdout for endorsing the accuracy of the tool, physician 2 responded, "*it's the first iteration of it. I need to see* ***revalidation*** *multiple times. It's a great start."* (Ph_02) Similarly, physician 16 mentioned "***refinement and updating might be [critical] …*** *because … medical therapy for heart failure has changed radically in the last five or six years with some of the new treatments*." (Ph_16)

Physician 8 pointed out the limitations of survival estimates in general, as there are some events that are impossible to predict in the course of a hospitalization or surgery:

> "There are so many factors that happen possibly intraoperatively, like an injury to the heart, at which point, all bets are off. Maybe a cannulation didn't go well … **so many things that can happen that a calculator would not be able to account for."**
>
> (Ph_08)

Another questioned the overall novelty compared to physician expertise:

> "So I think there's nothing particularly novel in the tool. It's not like a black box in which it's gathering data and then all of a sudden spitting out outcomes that are quite surprising because **the factors that go into the risk prediction are well known to the clinicians taking care of the patients.**"
>
> (Ph_14)

Many of these impressions were gathered at the beginning of the implementation period before clinicians had much familiarity with using the risk calculator in practice, revealing a hesitancy based on assumption rather than experience with the tool. Despite initial hesitations and skepticism, we found that most physicians became more comfortable with the tool over time. In fact, when we followed up after HM3RS had been in use for several months, the majority of physicians expressed that they felt the calculator's predictions were accurate, as exemplified by physician 13 who said, "… *it's accurate. I think sometimes it's just having one extra tool and one extra thing is cumbersome for clinicians to use, but I think it's definitely useful*." (Ph_13)

As analytic observers, our team tracked several considerations contributing to clinician acceptance of and adaptation to the new tool over time. First, physicians wanted to ensure the accuracy of the tool and were only convinced of that after review of empirical evidence demonstrating the tool's performance, peer/expert endorsement, and their own personal experience with the tool itself. The tool's first validation study was published in 2022 (Mehra et al., 2022a) in a well-respected, peer-reviewed cardiology journal alone was not sufficient to assuage physicians' concerns about accuracy. However, our observations reveal that after attending conferences and hearing endorsement from respected colleagues, many of the physicians we spoke with were more and more willing to start using the tool in their clinic. Once their teams had been using the tool for several months, concerns surrounding accuracy diminished even further, as physicians were able to interact with the tool themselves and judge its performance. This combination of empirical evidence, relational trust through peer-endorsement, and hands-on experience with the tool permitted physicians to begin to accept it.

Second, as mentioned earlier, there was an existing infrastructure of a clinical decision support system (CDSSS) in place at our partnering sites, which included a patient facing element (decision aid) that was used during LVAD education sessions. These factors allowed for more seamless integration of the risk and survival prediction tool, reducing disruption to the team dynamics and clinical flow. Without our research team's established relationships with nurse coordinators, especially those who participated in the previous decision aid trial (Kostick et al., 2018), introducing a survival predictor output to the existing education may have felt disjointed or awkward. Their previous experience integrating the decision aid into their education sessions provided the necessary entry point to supplement the existing education with the tool's output. Having the framework already in place allowed for the clinical teams to start adapting to the tool in their workflows.

We asked nurse coordinators how burdensome the transition of adding another piece of information to their education sessions had been, and by and large they reported a minimal lift. Nurse coordinator 12 said, *"for me*, ***my flow's the same***. *I just add [HM3RS] at the end. It only takes maybe about two, three minutes and afterwards, and to be honest*, ***not much change at all***. *The same process."* (Co_12) Another nurse coordinator thought of the risk calculator as a small addition, saying *"I think it's [HM3RS]* ***added in***. *It's one more additional [piece of] information of what you've given them [the patient] to help with that decision making they're trying to do."* (Co_10) A third nurse coordinator described the integration of the tool into their flow as *"****actually pretty easy*** *because like I said, we've*

kind of fallen away from comparing to MOMENTUM data. And it's like, no, for you we're talking about for you. Instead of, oh, we did a study with the perfect candidates and however many people survived," (Co_06) highlighting the increased relevance of a personalized risk calculator as opposed to population averages for patients weighing a decision like LVAD.

Finally, an important component contributing to successful acceptance and adaptation of the tool at each partnering site was autonomy. Our team provided partnering clinicians with instructions and best practice guidelines for use of the tool (see Supplement 2) to start out with, but ultimately each site was given the freedom to decide how best they would incorporate the tool into their clinical flow. This flexibility was crucial in ensuring the teams at each respective site could insert the tool where it made the most sense for their LVAD candidacy and education processes.

3.3. Social dynamics: roles and delegation

Social power and healthcare hierarchies have been well established in medicine (Essex et al., 2023; Vanstone & Grierson, 2022). How these dynamics manifest in the implementation of a new tool in the clinical space effect successful integration. Quickly, factors related to the social dynamics of the six clinical teams revealed how the new tool would be incorporated into their existing clinical flow. Stemming from the social dynamics, certain elements of healthcare system hierarchy came to light in the implementation phase of a tool as certain tasks are delegated to certain roles.

Many physicians initially expressed that they wanted to be the primary messenger of the calculator output to patients. When following up about physicians' preferences for the delivery of the HM3RS, we asked if there had been any shift throughout the implementation process:

> "Interviewer: And you still feel strongly about you [the physician] being the one administering the output results?
>
> Ph_02: *Correct*."

Interestingly, physician 2 was one of the few physicians who continued to feel strongly that a physician be the messenger of the calculator output results despite challenges encountered related to bandwidth and time constraints. For the majority of the physicians in our study, over time we observed a 'loosening of the reigns' where physicians started to delegate this task to non-physician team members:

> "I was just thinking to myself, just the way I practice. I was thinking to myself the first 10 times I probably want to see it [HM3RS] and then I'm going to tell 'em [nurse coordinators/clinical team] I don't need to see it just **because it's something new and I want to make sure that I see it**. But I'm very good at delegating…"
>
> (Ph_08)

Once physician 8 felt comfortable enough with the performance and accuracy of the tool, then they would start to allow others on their clinical team to calculate and explain the risk score to patients. The authority of the physician as it relates to the introduction of a new tool speaks to their role on the clinical team. It is their job to ensure the tool is clinically relevant

and accurate, and once that has been established, other non-physician team members who have the time and bandwidth to use the tool will be permitted to use it with patients.

Another role physicians we saw play out is that of a 'point of reference'—someone to whom other team members can turn with questions related to the new tool:

> "I actually don't talk to the patients about the HeartMate Three Risk Score. **I always talk to the fellows and to the surgeons and to the teams outside to help them understand** that, hey, look, this patient's score is X. This would actually give him or her a two-year outcome that is as good or better than heart transplant. "
>
> (Ph_03)

This physician offering their expertise as it relates to the tool allows clinicians or trainees who may not otherwise have the context to interpret the risk scores they are calculating. Additionally, their role as a division chief commands a certain level of respect within the social circle of the hospital and even the larger LVAD community, and therefore their time spent training and convincing colleagues of the worth and utility of the tool only increases the likelihood of the tool's uptake.

Physician influence did not go unnoticed by the nurse coordinators beginning to implement the tool at their sites. One nurse coordinator commented that the message might have a greater impact if a physician also brought up the risk score in their conversations with the patient:

> "Yeah, and I think this is where **the physician needs to come in and because they really need to emphasize how sick they are**. "
>
> (Co_12)

The reasoning many physicians gave behind why they initially felt they should be delivering risk information to patients was that they wanted to be available to answer questions patients may have related to their survival and risk. Interestingly, nurse coordinator 12 sees the physicians' role less as an information source and more as a means of getting patients to appreciate the gravity of the situations in which they find themselves. Time constraints for physicians in medicine are not novel (Prasad et al., 2020; Sinsky et al., 2016). However, when the tool is passed to the non-physician team members who often (in this context) have more time to have longer patient education and decision-making discussions, those team members must feel comfortable having risk conversations. This was not always the case.

One nurse coordinator shared "*it would not be within our practice to share that number [HM3RS] with the patient. I would defer that to the primary team."* (Co_03) Speaking more generally about the consult vs primary team dynamic at their institution, this coordinator points to another level of roles within the healthcare system. Many of the LVAD nurse coordinators we spoke with have advanced practice degrees such as ANP, NP, or MSN and many years of experience working in cardiology. Still, the training differs both in breadth and depth when comparing advanced heart failure cardiologists and advanced practitioners. What is in a clinicians' 'scope of practice' is often highly related to the training they received, and nurse coordinator 3 clearly felt explaining personalized survival estimates

would not be in their scope as an LVAD coordinator. But due to their physician counterpart not only initiating the use of a new tool in the clinic, but also passing the task off to their nurse coordinators, this coordinator felt they were being asked to do something they felt is outside of their scope of practice. In this case, the coordinator declined to do so, halting the implementation of the tool at that site. However, other nurse coordinators may not feel empowered enough to do the same when asked by their physician counterparts to use a new tool with which they do not feel comfortable.

4. Discussion

Our findings offer a window into the contextual social factors that occur amongst clinicians when launching a new digital healthcare tool into the clinical space. The three domains we presented (consensus around the "right" risk message, clinician adaptivity to new tools, and role of social dynamics) highlight social factors which either help or hinder clinician acceptance and adoption of a new digital healthcare tool. Particularly when the tool offers statistical messages surrounding risk, diverging views with regards to how the risk message should be framed to patients came to light through our conversations with physicians. There has been longstanding concern surrounding how to present accessible risk information to a patient population that can struggle with numeracy, health, and statistical literacy (Gigerenzer et al., 2007). The clinicians we spoke with agreed unanimously that patients should receive educational material with regards to the risks and benefits of LVAD, but *how* exactly to present risk information to patients is where we started to see diverging views amongst clinicians.

The way risk information is presented to patients has significant impacts on decision-making (Mentrup et al., 2020). For example, studies have shown that when patients are presented with absolute risk as opposed to relative risk, patients will often overestimate risks and benefits (Malenka et al., 1993). Framing the calculator outputs in terms of "survival" as opposed to "mortality" primes the patient differently, and perhaps more positively towards the intervention (LVAD in this case) (Blumenthal-Barby, 2021). When we probed as to why the physicians felt so strongly about survival framing, they explained that in the larger cardiology community and perhaps in medicine in general, LVAD is often portrayed or thought of in an overly negative light. Physicians are not alone in this. Intensive care nurses who care for patients following LVAD implantation have also been shown to have negative attitudes towards the therapy (Combs et al., 2021). Remembering that the physicians we spoke with are leading advanced heart failure cardiologists in the field, they posited that other cardiologists with less LVAD expertise are not aware of the recent advancements in the therapy and therefore fail to both recognize themselves and convey to patients the significant survival benefits the device can offer. Due to this atmosphere, the physicians we spoke with felt it was important to convey that patients are more at risk without the LVAD than with (this is objectively true regarding the survival benefits) (Mehra et al., 2022b; Mehra & Gustafsson, 2021; Mehra et al., 2023).

While we recognize the value and legitimacy of correcting an overly negative view of LVAD, from an ethics perspective it was important to our team to ensure patients receive a balance of both potential risks and benefits they may experience with the therapy. In a

context of overly negative starting assumptions, a slightly positive lean, especially given that some amount of “choice architecture” is inevitable, may be ethically justifiable, towards an overall aim of balance (Abhyankar et al., 2013; Blumenthal-Barby et al., 2013). Our team grappled with how to manage competing preferences from our partnering physicians, an unforeseen obstacle which required careful consideration and navigation. One way we were able to identify agreement amongst the clinicians was through asking them about the key takeaway messages they wanted patients to walk away with after interacting with the tool as we moved into the feasibility testing stage of the project. With some minor language modification, the clinicians came to agreement on these key messages. Initiating collaborative discussions around framing and messaging of the calculator output served as the first step towards the social consensus required to adopt this tool into practice.

Introducing a new tool into health care comes with a unique set of challenges, especially when said tool is computer-based. Artificial intelligence (AI) and machine learning (ML) in particular have been highlighted to have significant applications for health care (Topol, 2019). However, the capacity and utility of any medical tool is entirely dependent on the users’ willingness to wield it. Barriers to adoption of new computerized tools highlighted in the literature include clinicians’ negative attitudes toward digital health care tools, concerns around reduced quality of care, and changes or disruptions to traditional roles and workplace habits (Ammenwerth et al., 2003; André et al., 2008; Ash et al., 2000; Mikulich et al., 2001). Our case study aligns well with the first previously established challenge—negative attitudes towards new digital healthcare tools—in that physicians were initially somewhat hesitant to endorse its predictive accuracy, even when presented with a validation study (Mehra et al., 2022a). Our team’s previous work showed different criteria for clinician trust in an AI-based digital healthcare tool including epistemic considerations like computational nature of algorithms, the quality of training data, differentiating between ‘source’ and ‘functional’ explainability, but also some relational considerations such as personal beliefs and experience and peer-endorsement (Kostick-Quenet et al., 2024b). These relational considerations for trust point to social factors which contribute to physician trust and acceptance of new digital healthcare tools. Physicians who initially resisted the idea that an algorithmic predictor could do a better job than their own clinical gestalt began to shift after using the tool themselves as well as hearing from respected colleagues who were using the tool. Importantly, as more physicians began using the tool in practice, they realized the risk predictor was not meant to replace their clinical intuition but instead serve as another datapoint to weigh in their treatment recommendation. This shift in mindset of the application of the tool combined with collegial endorsement allowed physicians to overcome their initial resistance.

Interestingly, our case study diverges from the literature slightly with regards to the second established barrier to implementing new medical tools—concerns surrounding reduced quality of patient care. In fact, when our team initially considered a randomized clinical trial study design of the impact of the HM3RS calculator on patient decision making, our partnering physicians warned that the HM3RS calculator should already be considered standard of care for patients and therefore it would be unethical to provide personalized risk and survival information to some patients and not others. This highlights their belief that the tool did not reduce quality of care, but instead enhances it. The growing capacities

of AI/ML/algorithmic-based medical tools are quickly integrating into clinical care due to their applications in radiology diagnostics, precision medicine, and risk stratification (Bohr & Memarzadeh, 2020; Johnson et al., 2021; Mun et al., 2021). Though these computerized tools have the potential to significantly improve patient care, there are new challenges with their development and implementation. Concerns around patient safety in novel health information technology have been underscored in the literature (Sittig et al., 2020). Questions around ethical development and use of AI tools in health care are numerous and only growing, many calling for an interdisciplinary approach to work towards solutions (Kim et al., 2023).

Finally, the third challenge—changes or disruptions to traditional roles and workplace habits—was in part observed in our case study, and in part not. Physicians initially expressed desire to be the main users of the tool and to deliver risk information to patients, however, unsurprisingly, time constraints got in the way. Time constraints in primary care have been well documented (Nguyen et al., 2024), and also exist in specialties and in-patient settings (Mansini & Zanotti, 2020). A logical conclusion from the physicians' lack of time is that some less urgent or complex tasks pass to other non-physician members of the clinical team, such as the LVAD nurse coordinator. This hierarchy is consistent with previous analyses of social dynamics in health care in the United States (Liberatore & Nydick, 2008), and therefore appears to contradict the notion that the introduction of a new tool necessarily disrupts or alters traditional roles and workplace habits. In fact, speaking with the nurse coordinators, it seems integrating this tool into their flow was seamless. We think this relatively smooth transition at most sites was in large part due to the existing infrastructure of the CDSS and its role in the nurse coordinators' LVAD education sessions. However, not all nurse coordinators we spoke with were freely accepting of their physician counterpart directing them to use this tool with patients. One nurse coordinator in particular felt it was not within her scope of practice to share personalized risk information with patients, which she may have perceived as disruption of established roles.

There were limitations to this study, first and foremost that some clinicians were interviewed on more than one occasion and others were not, due to personnel turnover through the 5-year life of this study. As previously mentioned, we used slightly different interview guides for the physicians and the LVAD nurse coordinators. There are strengths to this tailored approach, such as increasing relevancy of questions to the clinician's experience and positionality in the healthcare institution. However, there are also some limitations, such as a lack of consistency across stakeholders. Sampling bias was also a limitation, as champion physicians were asked to identify members of their team who might be interested in participating in the study. The clinicians we interviewed were specialists in one highly specific medical condition, advanced heart failure, therefore some generalizations may not be appropriate. Additionally, due to the longitudinal nature of the project, we chose to focus our analysis on clinician perspectives of the risk predictor patient-facing interface development, launch, and integration because of longstanding relationships with champion physicians and nurse coordinators throughout the five years of the tool's lifecycle. The logistical difficulty of repeatedly contacting end-stage heart failure patients and caregivers over time, paired with the reality that some patients died as a result of their condition shortly after we spoke with them, made the inclusion of the same patients and caregivers next to

impossible. However, we acknowledge that omitting patients' and caregivers' perspectives on the tool limits analysis of the full scope of the tool's impact on key stake-holders. Finally, though we took meticulous ethnographic notes of our observations of clinicians' attitudes social dynamics throughout the conception, design, and implementation of the tool, there is always the possibility our interpretation is not entirely reflective of reality, especially when four of our six partnering sites are non-local.

5. Conclusion

Our findings confirm many previously raised issues with introducing new medical and digital healthcare tools into clinical care, and highlight new issues specific to the rapidly advancing technology in CDSS. Using the HM3RS as a case study, the clinicians we spoke with revealed competing preferences for risk framing, initial hesitancy but eventual acceptance of the tool for most sites, though not without some friction related to delegation and roles in the deployment phase. As hospital administrators, clinicians, developers, and/or researchers endeavor to implement novel digital healthcare tools, the social innerworkings of partnering clinical teams deserve careful consideration, as these dynamics amongst clinicians ultimately led to the success or failure of one such risk predictor's uptake and use. Future research on key stakeholder perspectives exploring the social contingencies that permit or block these technologies from adoption and acceptance into clinical care is warranted.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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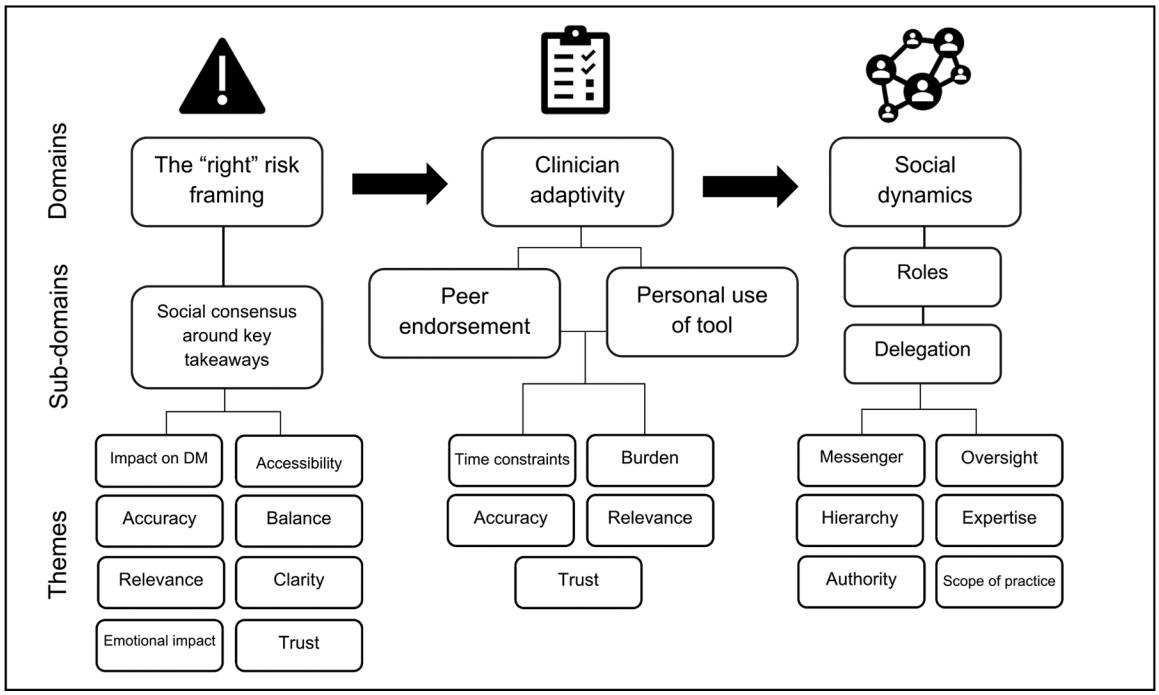

Fig. 1.

Results of Thematic Analysis. Arrows indicate the progressive nature of the project from the tool’s conception and design to deployment in clinical settings, and resultant social factors which facilitated, or prohibited, acceptance and adoption of the tool by clinicians; (DM = decision-making).

Table A

Numbers of interviews over four years by clinician type.

Clinician type	Interviewed once n (%)	Interviewed twice n (%)	Interviewed 3+ n (%)
Physician (20)	10 (50 %)	4 (20 %)	6 (30 %)
Nurse coordinator (14)	7 (50 %)	3 (21 %)	4 (29 %)