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Investigating the Heart Pump Implant Decision Process: Opportunities for Decision Support Tools to Help

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Abstract

Clinical decision support tools (DSTs) are computational systems that aid healthcare decision-making. While effective in labs, almost all these systems failed when they moved into clinical practice. Healthcare researchers speculated it is most likely due to a lack of user-centered HCI considerations in the design of these systems. This paper describes a field study investigating how clinicians make a heart pump implant decision with a focus on how to best integrate an intelligent DST into their work process. Our findings reveal a lack of perceived need for and trust of machine intelligence, as well as many barriers to computer use at the point of clinical decision-making. These findings suggest an alternative perspective to the traditional use models, in which clinicians engage with DSTs at the point of making a decision. We identify situations across patients' healthcare trajectories when decision supports would help, and we discuss new forms it might take in these situations.

Author Keywords

Clinical Decision Support Systems; Decision Support Tools; Field Study; Qualitative Methods; Service Design

ACM Classification Keywords

H.4.2. Information Systems Applications: Decision support (e.g., MIS)

INTRODUCTION

The idea of leveraging machine intelligence in healthcare in the form of *decision support tools* (DSTs) has fascinated healthcare and AI researchers for decades. These tools promise improved healthcare quality through complementary insights on patient diagnosis, treatment options, and likely prognosis. In recent years, the adoption of electronic medical records along with advances in big data technologies has created the perfect environment for algorithm-powered DSTs to impact clinical practice.

Interestingly, almost all these tools have failed when migrating from research to clinical practice [15, 24, 25]. In a review of clinically deployed DSTs, healthcare researchers ranked the lack of HCI as the most likely reason of their failure. This includes a lack of consideration for clinicians' workflow and the role AI currently plays in clinical practice [33, 46]. Currently little to no work in the field of HCI has investigated these issues or proposed how intelligent DSTs should be integrated into care environments.

We, HCI researchers and Bioengineering researchers, are collaborating on the design of a DST supporting a heart pump implant decision. The heart pump VAD (ventricular assist device) is an implantable electromechanical device used to partially replace the function of a heart. They were initially used to support heart failure patients until they could get a heart transplant. A few years ago, VADs became approved as a destination therapy: as the last therapeutic treatment for people in end-stage heart failure [19]. VADs implanted for destination therapy were expected to extend patients lives for several years. However, many patients who received VADs died shortly after the implant [7]. Additionally, many patients who might benefit from a VAD did not appear to have been offered this treatment. The decision to implant a VAD seemed a perfect place to apply a DST, as these intelligent systems could mine thousands of patient records, bringing the collective intelligence of many physicians to each implant decision.

Given the previous failures of DST deployment and the wide gap between DST technology and clinical reality, we chose to conduct a field study. We had two goals:

1. To understand the clinical decision process around a VAD implant, including the participants, their work practices, the contexts where the decisions get made, and other critical factors that influence the decision;
2. To identify the key touch points where we might situate a prognostic DST that clinicians would find useful in their practice.

We interviewed and observed clinicians caring for VAD patients at three different implant centers. We then analyzed our data using affinity diagrams and a service blueprint of the decision paths different patients follow. Our findings reveal that for most cases, clinicians do not find the decision process to implant a VAD challenging, and thus would not likely engage with a DST to aid with the decision. However, we did identify situations when decision support would help. Clinicians would value the support for emergent cases, when they have very little data to predict how a critical patient might respond to available therapies. In addition, the implant clinicians would value a DST that worked in upstream clinics and hospitals if it could prevent patients from arriving at an implant center after their window for an implant had closed.

This study makes two contributions. First, our field observations and interviews provide a rare description of how an implant decision is reached across many clinician roles and contexts. It provides a timely answer to healthcare researchers' call for context-focused HCI approach. Second, this work suggests an alternative perspective to the idea of a DST as a system clinicians engage with at the point of making a decision. This work suggests a DST might play a more vital role if it followed clinicians over time and across their care for heart failure patients.

RELATED WORK

Clinical Decision Support Tools (DSTs)

Clinical decision support tools (DSTs) are computational systems that support one of three tasks: diagnosing patients, selecting/recommending treatments, or making prognostic predictions of the likely course of a disease or outcome of a treatment [48].

Most DSTs aim to reduce human errors and help *clinicians* make the right decisions. Others prepare *patients* to make well-informed decisions, where patients' preferences and values play an important role in critical decisions [48]. Integrating the positivistic, doctor perspective and the humanistic patient perspective remains an open challenge in medicine [6]. We found no DST that supports clinician and patient collaboration in making well-informed decisions, and no clinician-facing systems that include social support factors in their prognostic predictions.

Output from DSTs can take several forms: discreet decisions, a set of ranked recommendations, predictions of likely outcomes, alerts of a potential problem, or lists of considerations that should be taken into account before making a decision [48]. The DST for VAD implant decision will be a prognostic DST using data mining to help clinicians make a good destination therapy choice. Like almost all other prognostic DSTs, it currently takes a context-less, prototypical form: It takes in a list of patient condition measures and produces an individualized prediction of patient trajectory, including likely survival and other post-surgical risks [5].

Despite success in labs, the vast majority of DSTs failed when they moved to clinical practice. Clinicians rarely use them [13, 15, 47]. Healthcare researchers have speculated that the lack of HCI consideration in the design of these systems might be the main cause of these failures rather than poor technical performance [38, 40]. These HCI-related issues identified by these researchers include:

- *Poor workflow integration:* Clinicians reported DSTs are disruptive, time-consuming, and conflict with the chaotic nature of clinical work [3, 25, 34, 36, 45, 46]. Some researchers suggested DSTs should be integrated into Electronic Medical Records (EMR) so as to fit into clinician workflow [35].
- *Poor social integration:* Most DSTs have been designed for use by a single user/decision maker; however, many critical healthcare decisions are made by clinician teams [10, 20, 27, 44]. Research also started investigating DST's social influence. A lab experiment shows that physicians are concerned patients would think less of them and their skills if they needed a tool to make medical decisions [37];

- *Poor concern for clinician needs:* Clinicians often lack the motivation to use a DST [22, 40]. They see it as getting in their way and slowing them down. Other clinicians do not trust that the outputs of these systems are informative for the kinds of patients they care for [15, 47]. Finally, some perceive DSTs as infringing on their autonomy and their expertise [45].

Interestingly, drug ordering and preventive care reminder systems are one type of DST that has worked very well in clinical environments. These are rule-based systems. When clinicians enter a prescription that falls outside the standard of care, the DST issues an alert and it requires the clinician to input a rationale for the deviation [26, 41]. These systems prevent human errors, and they collect important information when clinicians should deviate from the standard. They have demonstrated relatively wide use because they have been integrated into the tools clinicians already use, and they only make their presence known to clinicians when an anomaly is detected. This is quite different from the interaction of most prognostic DSTs, which assume clinicians will recognize they need help, walk up to the system, and seek advice for the decision.

Decision Support Tools in HCI

Little HCI research has investigated why DSTs fail in clinical practice or studied the context of healthcare decision making with a focus on how to best integrate and situate a DST. Rather, research has focused on other critical issues including better information presentation and visualization, accuracy of risk communication, trust-worthiness, ease of use for medical information, etc. [39, 43, 48] Few studies that investigated DST in use are lab studies; instead, studies have often substituted undergraduate students for patients and medical students for clinicians. [37].

While making important advances, this prior work offers few insights into how to integrate intelligent systems into chaotic, human-centered clinical environments. More work is needed to capture how clinicians deliberate and reach a decision, to document the contextual barriers to computer interaction, and to understand clinicians' perceptions of and expectations for using intelligent tools to make care decisions.

A related strand of HCI research has looked at emergent, intensive, and routine care settings with a focus on new tools for care coordination [2, 9, 17], as well as communication tools for multidisciplinary meetings [28]. While this body of work provides valuable snapshots of clinical work, it has a strong focus on clinician coordination, documenting the times and places that many clinicians and healthcare activities densely aggregate.

Healthcare Context and Decision-Making

Research in healthcare organizational decision-making has focused on understanding clinical work and culture. We noted two different themes: evidence-based medicine and chaotic clinical environment.

An evidence-based principle dominates the clinical world. VAD implant physicians, for example, are expected to follow an eight-step approach to make a clinical decision [23]. They are also expected to use the VAD implant decision tree and risk models [12, 18, 29], multidisciplinary team model, patient communication guidelines [1, 30] and more. All of these tools promote a standard of care and are expected to capture and promote the best practices from across many healthcare centers.

Interestingly, clinicians do not always follow best practices. Empirical studies in clinical settings have repeatedly reported chaotic workflows [34, 36, 42], communication breakdowns, authority-based decision-making that diminishes or dismisses the input of some team members [11, 21], overconfidence, and preventable errors [16]. Very little empirical research has investigated the *when*, *why*, and *how* of clinical decision-making as it naturally occurs. Instead, most work simply notes how it does or does not deviate from the dominating best practice culture.

Our work attempts to bring these strands of related work together. Previous research in healthcare has identified many HCI-related adoption barriers and provided preliminary depictions of clinical environment. Beyond what have been done in the field of HCI, we apply HCI approach to investigate clinical decision making with an eye on where and how DSTs could help.

FIELD STUDY DESIGN

We wanted to understand how the decision making process to implant a VAD unfolds in the clinical environment. We wanted to know who participates and where decision-making happens, and to probe on when clinicians think an intelligent system might offer support for their work. We wanted to identify contextual barriers that might prevent people from engaging with a DST and to identify the times and places it might add the most value.

To address these needs, we chose to conduct a qualitative field study consisting of observations and semi-structured interviews. We chose an ethnographic approach so as to capture the richness of context, and also because this has become a standard HCI approach when designing new software systems meant to improve work. We analyzed our data using affinity diagrams [32] and by creating a service blueprint [8] that documents the decision pathway for individual patients. We chose affinity diagrams and service blueprints, methods from HCI and service design field over the more conventional use of grounded theory because our focus is more on discovering the opportunity for a technology to enhance future than on building a detailed theory of the present work situation.

The decision to implant a VAD involves participation from both clinicians and patients. Clinicians need to assess the medical necessity of this invasive therapy, and this was the focus of our research. Patients participate in this decision by deciding if they want to endure life with a VAD. While we recognize the importance of the patient in the decision, this phase of our work focuses exclusively on the clinician side of the decision.

We carried out this research at 3 different implant hospitals all in the United States, hospitals that regularly perform VAD implantation. In two of the hospitals we performed interviews and observations. In the third, we only performed interviews, as we could not secure permission to make observations for legal and privacy reasons. In general, concerns over access to protected patient health information along with the general sensitivity over this end of life decision has made getting access to clinicians extremely difficult for HCI researchers and practitioners.

The three facilities vary geographically and in scale. Their performance rankings range from top 5 to top 60 in the United States. Despite great inter-site differences we observed, we report findings that all three facilities share.

- Hospital 1: large-scale service performing over 60 heart transplants and over 100 VAD implants per year;
- Hospital 2: moderate-sized service performing over 20 heart transplants and over 30 VAD implants per year;
- Hospital 3: relatively small service performing about 20 heart transplants and 40–50 VAD implants per year;

We conducted observations in two Advanced Heart Failure services for 6 to 14 hours a day for 13 days. The observed VAD teams cared for approximately 75 patients who were formally or informally being considered for an implant. We followed attending cardiologists across all decision-related settings including morning rounds, clinician-patient consultations, clinician-to-clinician conversations, and weekly implant meetings. We observed out-patients from both General and Advanced Heart Failure clinics and in-patients from Advanced Heart Failure wards, Intensive Care Units, and Emergency Rooms.

We conducted IRB approved interviews with a total of 24 VAD clinical team members from 3 hospitals, covering many different roles and statuses that participate in decision-making. Interviewees were chosen according to their level of involvement in VAD decision-making. Our research collaborators at each hospital recommended an initial set of interviewees. We then expanded this set by recruiting others we observed to play important roles in the decision-making.

We confirmed our findings with a VAD cardiologist, a mid-level resident intern, and a VAD coordinator. Field notes were recorded using pen and paper. Interviews were audio-recorded and transcribed.

FINDINGS

Findings from this study are threefold. We first give an overview of the decision process around a VAD implant, including the participants and their work practices. Next, we highlight the decision-makers needs for decision support given the social and environmental contexts where the decisions get made. Finally, we identify three pathways of the decision-making process. We report findings based on shared observations among all studied sites along with quotes from the interviews, unless noted otherwise.

Overview of the Decision Landscape

The clinical decision to implant a VAD involves many clinician roles and unfolds across many clinical contexts. Table 1 provides a high-level abstraction of the decision-makers and contexts.

The clinical environment is extremely hierarchical; however, it is also collaborative across status levels. While many roles contribute to and execute on the implant decision, only a small and stable coalition has a final say. We refer to these ultimate decision-makers as *implant physicians*. These are mostly cardiologists, though at some sites surgeons and/or senior nurse practitioners also participate. The *midlevels* refer to other clinical members of the VAD team and also the non-clinical members who focus on insurance, social support, and VAD-related care coordination. The *consults* include other support services and physicians outside of the implant team.

Implant physicians function at the top of the hierarchy, leading major decision-related activities. They decide who transitions from clinic to hospitalization and who gets classified as a difficult case and gets being discussed at an implant meeting.

At *clinics*, implant physicians monitor out-patients and hospitalize them for a formal VAD evaluation. When an out-patient gets hospitalized and becomes an in-patient, a group of clinicians visit the patient every morning during *rounds*: they visit each patient after a brief deliberation in the hallway outside the patient's room, where they establish a care plan for the day. The attending cardiologist of the week picks and presents the "difficult" cases during a *weekly implant meeting*, where all available clinicians can voice their opinions. The attending cardiologist and surgeon take away a collective decision for each presented case. If approved for implant, they pick a surgery date. They may stop the procedure if a patient's condition changes prior to surgery.

We refer to the cardiologists who provide general heart failure services as well as the cardiologists that work at local hospitals as *general cardiologists*. We refer to non-VAD implant hospitals as *local hospitals*. Note that all patients visit a general cardiologist and most have been admitted to a local hospital before they get admitted to an Advance Heart Failure ward and get evaluated for a VAD.

Motivation to Use a DST

Implant physicians perceived no need for a DST. They view the decision to implant a VAD as easy. As long as patients have no definitive exclusion conditions, they will all get a VAD after failing on an identical, escalating sequence of less aggressive treatments. Under this strategy, clinicians thoughtfully order tests to detect red flags, and then deliberately and iteratively adjust daily medications to resolve the red flags. They spend much more time on daily care decisions than on the implant decision itself.

> "I am the VAD guy. They came to me for a VAD." (Cardiologist)

> "He was on a decent amount of diuretics. It's not really working. He doesn't tolerate [Medicine A] or [Medicine B]. We don't know what else to do. Then that's maybe a time that patient gets admitted for evaluation of LVAD." (Nurse practitioner.)

Implant physicians expressed no desire for a prognostic DST. Their tried-and-true precedence works for the majority of their cases. For the grey cases, implant physicians did not imagine that algorithmic predictions would help. While all physicians knew about the availability of VAD risk models, none used them in practice. Physicians' rationale for not using these models presented a number of barriers that a prognostic DST would likely face.

1. The implant physicians doubted data applicability. They did not think the patient history data used to derive the risk factors matched their grey case patients. Several pointed out pre-selection biases of the models. More noted that even if the estimated outcome fits for a cohort, it is not clear which side of the probability an individual patient would fall on.

   > "All these scores are not ideal." (Cardiologist)

   > "I would say right now, there's no data to guide that decision." (Cardiologist)

   > "I will still take the risk, and we're going to push like crazy to get him through. And the reason we do that is because a lot of those people get through." (Cardiologist)

2. The implant physicians perceived no need for risk prediction support, even for the grey cases. They were confident in their prediction; they did not believe a more precise prediction would be helpful because there is no clear-cut threshold between risky and too-risky, especially in cases where clinicians had to choose between "VAD them" or "let them die". Predicting is easy. Action taking is difficult.

   > "I can tell you who will struggle. That is easy. The question is who will recover from that struggle." (Surgeon)

3. They do not value computation in clinical practice. During the interviews, several clinicians describe computer science as "*all logic and data*" while clinical care is not. They repeatedly emphasized fuzziness in medical decisions and gave many examples to prove that experience matters more than computation.

   > "We ordered two tests. One test was telling you one thing, the other is telling you another…With the years of experience I have, I can still make a reasonably accurate decision." (Cardiologist)

   > "Often what happened was the test did not correspond to what the patient was saying. The test looked better than the patient. We need to do a decision how to deal with that." (Cardiologist)

These excerpts confirmed and explained physicians' lack of motivation for using DSTs. They felt no need for support in implant decisions and they did not trust that a DST could provide valuable support. In interviews, they expressed appreciation of prognostic DSTs as an educational tool for patients or as a presentation tool for clinician meetings, but never as a prognostic tool for medical decision-making.

Hospital Environment and Computers—Computers were both used and perceived primarily as a documentation tool related to legal and financial accountability. When asked how they use the EMR, many replied that they do "documentations" after work, often from home. Many check the EMR each morning from bed or when eating breakfast to see if anything changed during the night. When asked how long they spend using a computer each day, the typical response was, “Too long”.

Interaction with computers presents many challenges in a ward environment (Figure 1) where most in-patient clinical decisions happen. During the 4-to-6-hour rounds, clinicians visit more than 30 patient rooms. They are constantly moving and conversing, logging in and out of the EMR. Everything they have with them must fit into their pockets because before and after visiting each patient’s room they must wash their hands, and sometimes put on and take off disposal gowns and gloves as well [31].

These barriers naturally stratified across decision makers and computer users. For example, cardiologists give oral orders during meetings with patients, and a midlevel will take notes and enter them into EMR at a later time. A few midlevels would carry a computer with them when rounding. They often skipped the in-room patient conversations because of the hassle hand washing presented. As a result, almost no decision-making ever takes place in front of a computer.

Social Decision Support—When faced with difficult cases, we observed implant physicians turning to their colleagues. The consultative collaborations were frequent and clinicians generally found them efficient and effective.

Implant physicians relied on teamwork. Within a shift cycle, one attending cardiologist cares for all in-patients: often more than 40 patients per week. Each patient gets assigned a primary nurse and resident intern who prepare information and monitor unfolding situations. The nurse and intern handle all reporting and documentation, and they prevent patients from falling though the cracks. Cardiologists also consult surgeons for surgical risks, and pharmacists for nuanced medication changes. For patients with other organ complications, they turn to physicians with corresponding expertise.

Attending cardiologists fluently integrate inputs from colleagues through various routine and ad-hoc activities. During rounds, for example, they request midlevel follow-ups right after visiting a patient; they call other cardiologists whenever a problem emerges; they always consult pharmacists right after rounds and before ordering medications. Unlike EMR use, these collaborations happen when and where decisions get made. The implant physicians trust this social decision support process; they often immediately act on their colleagues’ input.

> “We are rounding or doing something else, so it’s much easier for me to call a surgeon and say there is a patient in this room…” (Cardiologist)
>
> “I asked the surgeon, would this condition be too risky to operate on. He said no. Then he will do it.” (Cardiologist)
>
> ***Interviewer:*** What do you do when feeling uncertain?
>
> ***Cardiologist:*** I look through medical record one more time, making sure I did not miss anything, and I ask my colleagues to see him.

Social decision supports happen at formal meetings, as well as through phone calls and during impromptu hallway chats. While midlevels were sometimes left out of the informal inner-circle conversations, neither physicians nor the midlevels expressed any concern that this lead to poor decision.

Three Paths to a VAD Decision

We created a service blueprint to map the VAD decision process narratives collected from observations and interviews. A consolidation of the customer journeys revealed three decision paths that could take a patient towards a VAD. Each anchors and shapes the decision-making situation distinctively. We use the scenarios below to illustrate the paths. Drawing on them, we note potential breakdowns and discuss design opportunities for DSTs respectively. A VAD cardiologist, a mid-level resident intern, and a VAD coordinator confirmed the abstraction of these three paths.

1. Standard Path (Black Line in Figure 2)—A heart failure patient stays at home on oral medication. The patients visit a local cardiologist regularly. As heart failure progresses, the doctor requests more frequent clinic visits for closer monitoring, and occasional hospitalization for intravenous medications. “You might need a mechanical heart in the future, but that’s way down the road.” The doctor tells the patient.

As heart failure continues worsening, the local cardiologist refers the patient to an implant hospital. An implant cardiologist talks to the patient and family at the clinic, getting to know the medical history and social conditions. The implant physician orders more medications and tests, monitoring the patient’s trajectory. Midlevels educate the patient regarding consequences and cautions of a VAD implant or heart transplant: “*Quit smoking. Otherwise it will hurt your transplant candidacy.*” “*Try to lower your BMI to 32.*” “*Call your nurse practitioner if these symptoms appear.*”

As heart failure worsens, the patient get hospitalized at the implant hospital. The same implant team starts a formal evaluation. All members talk to and evaluate the patient during the first couple of days after hospitalization. At the weekly meeting, everyone voices their opinions and agrees on a decision.

The standard path depicts a systematic process of therapy escalation and a staged unfolding of decision considerations. Once all medication therapies prove ineffective, clinicians initiate a VAD workup.

When following this path, the implant team has time to get to know the patient, including their medical and social conditions. They have exhausted all less aggressive therapies. They are able to come to a decision easily and quickly.

> “I’ve had 9 months to get know him, to do tests on, to follow… It’s hard to say what else I will need. I had a lot of time to think through things.” (Cardiologist)

Occasionally, on this decision path, the choice can become more challenging for social or financial reasons. Patients with no insurance at the time of admission, or who have no one at home who can take on caregiver duties, raise non-medical problems with choosing a VAD.

While such issues can be overcome, they add uncertainties to implant outcomes and often require urgent problem solving by midlevels.

2. Late Referral Path (Blue Line in Figure 2)—Clinicians at local hospitals keep trying different therapies and delay making a referral to an implant facility. When the implant team first meets the patient, the patient has been too sick to survive an open-heart surgery.

The late referral path documents a major breakdown in the VAD decision process: missing the implant window. In a consolidated decision process, every physician involved carefully monitors patient progression, and escalates care or initiates referral in a timely manner. They cannot rush or skip any step because of reimbursement restrictions and ethical considerations. Facing this string of judgments, local cardiologists and primary care doctors who lack experience, knowledge, or even awareness of VAD candidacy evaluation might find referring within the implantable window challenging.

> "They (general cardiologists) go through a process: Do we think it's even reasonable to think about transplant or LVAD? And then if they think it's possible they'll call one of us. They're the gatekeepers." (Surgeon)

> "I think (they refer the patients) when they burn out all options, when they can't keep someone out of the hospital. Unfortunately most of the time they refer people who are extremely late in their clinical conditions so that the choice that we have to make is not an easy one." (Cardiologist)

Currently, most referrals and VAD education happen among established and stable clinician connections. New referral relationships seem to grow extremely slowly across social connections.

> "Some cardiologists have relatively stable referring relationships with us." (Cardiologist)

> A nurse practitioner spoke of giving her card to a newly implanted patient: "*After you get home, ask your local cardiologist to call me. I'll tell him how to take care of VAD patients*."

3. Emergency Room Path (Yellow Line in Figure 2)—Implant cardiologists met a patient for the first time in the emergency room. The patient was "crashing and burning". The physicians put him in an induced coma and predicted that if they do not implant soon, the patient will die. The blood tests suggested heavy alcohol and substance use history, which almost automatically excludes the patient from implantation. The team could not confirm this issue with the patient or the family. The decision has to happen fast.

> "These are uncomfortable decisions." (Cardiologist)

Although there is no definite time requirement for making a VAD decision, clinicians often find emergency room cases difficult because they often accompany incomplete clinical evidence and tight time constraints. Clinicians collectively described patients "*we have not met before*" as difficult cases. They find it difficult to make a quality medical judgment based solely on a snapshot of the patient's condition. For patients following the standard path, implant physicians always call the referring doctors in addition to checking the EMR. During hospitalization, detailed patient dynamics are carefully monitored. Clinicians rely on such information to differentiate minor side effects from notable signals of complications as well as to adjust and plan medication strategies.

> "I know his trajectory and tests from EMR. But I don't know what has been tried and how his body responded…" (Cardiologist)

When an in-patient experiences a sudden and steep decline, clinicians sometimes have to make a less-than-informed decision to avoid missing the implant window.

> "We've got a patient that came in here on breathing tubes. Families said go ahead, and patient woke up on a mechanical pump." (Cardiologist)

> "We decided to implant him. If he didn't have a caregiver, then come up with a caregiver." (Cardiologist)

Clinicians expressed the need to slowly prepare patients for the decision. They need time to build up a connection with a patient before they can truly understand the social situation and discuss this sensitive and fuzzy end-of-life decision. For urgent cases, the process becomes over-simplified; it gets turned into a social support checklist.

> "Her husband was there. They were going through a divorce. She would never tell me that. Patients are always a bit intimidated by doctors. But they will tell the coordinators, who created a level of comfort, so they open up and tell them everything. That's an important piece of information, because if we put a VAD in the patient… who will take care of the patient?" (Cardiologist)

DISCUSSION

DSTs, despite compelling evidence of their effectiveness in lab studies, have mostly failed in clinical practice, failing to improve patient outcomes [24]. Healthcare researchers suggest that a lack of user-centered HCI considerations in the design of these systems plays a critical role in these repeated failures. Our field study helps to confirm this speculation. We identified many barriers that could negatively impact the use and perceived value of a prognostic DTS situated in VAD implant hospitals. We observed a perceived lack of need when making decisions and lack of trust in the ability of intelligent systems to help with difficult cases. We also observed many patterns in work practices and decision-making, as well as contextual barriers to computer interaction in the clinical environment that might prevent or deter clinicians from accessing a DST.

These observations forced us to reflect on the traditional forms most prognostic DSTs take. Most require clinicians to recognize when computational advice would be useful and then make an explicit effort to access a DST [33]. In addition, most imagine a single decision maker participating in making the decision at a single time and place [41].

Our findings suggest clinicians in VAD implant hospitals are not likely to use such DSTs. Below we highlight four barriers that emerged from our observation of VAD implant decision-making. We suspect most if not all of these barriers will generalize to other DSTs intended to support high-risk, clinical decisions. We then reframe the VAD decision process, identifying times and places DST support could be helpful, and new forms DSTs might take to better integrate into a clinical environment.

Barriers of DST Adoption

Attitudinal Barrier—First and most importantly, clinicians we interacted with have no desire to use a DST. Our findings confirms much of what previous work reported in other clinical contexts [15, 22, 25]. We advance this previous work with observations of a new context, VAD implant hospitals, and with a detailed discussion of need barriers, social barriers, informational barriers, and environmental barriers.

Need Barrier—Clinicians perceived no need for data support because they felt that they know how to effectively factor patient conditions into clinical decisions. Their experience with current tools like the VAD risk models has in no way provided any confidence that DST or other intelligent systems can provide valuable new data. It is unlikely that they would explicitly use any DST until they perceive a need and until they trust these systems can deliver value. A better DST would have the explicit goal of helping clinicians feel they are doing better work, and not necessarily automating the part of work that makes them feel like an expert.

Social Barrier—The lack of a real consideration for social context in the design of DSTs can be a significant deficit. The hierarchical but collaborative clinical culture poses a two-fold challenge for DST use. First, decision makers (physicians) and computer users (the midlevel) rarely overlap at the point of decision-making. Second, physicians have great trust in their social network of other physicians, who help them make more difficult decisions. It seems unlikely they will move towards computational support and away from social support when things are difficult. There may be an opportunity for systems that improve the process of getting and receiving social support as a core feature of the DST.

Previous field work in clinics reported that only junior clinicians use DSTs in ward rounds, and they concluded that many DSTs targeted the wrong users, the senior physicians who are unlikely to be in front of a computer [4]. Our observation echoes this. We suspect this comes from both a deeply rooted hierarchical workplace culture and with the younger personnel's generally higher level of facility with computing and new technology. DST design needs to integrate and even leverage this layer of social context in order to place the information in front of real decision makers. DSTs could be designed such that younger clinicians become a rich information channel through which the DST recommendations are passed to more senior decision makers. Furthermore, DSTs have to demonstrate their value to the decision makers because all decision supports, social or computational, happen on their demands.

Informational Barrier—We observed a mismatch between clinicians' information needs and DST's information flow. The commonly assumed function of a prognostic DST is to predict the likely trajectory a patient will take based on a list of quantitative measures. Our patient trajectory paths demonstrate that none of the major decision breakdowns happens in this prediction.

At the input end, DSTs take in quantitative and explicit inputs, while challenging decisions are often characterized by unavailable or ambiguous medical and/or social evidence. Clinicians are unlikely to use a tool that only does the easiest part of their job; telling them a textbook case is, “textbook”. Even if they approach the system when facing a difficult case, they might find it difficult to fill in some of the blanks, such as diagnosis for an emergency-room-path patient. They might find the information that most concerns them is not captured in the prediction, such as the patients home life and social support, which are critical and difficult factors most often not captured in the medical history.

In terms of DST output, physicians need support for action taking. Consultation between cardiologist and surgeon best captures this: *Is this case too risky to operate on? No? Ok, then do it.* A probabilistic prediction can be obscure in telling whether to execute a therapy or not, to do it now or to “wait and see”. DSTs only predict outcomes of “conducting a therapy now”, with little sense of waiting and seeing.

Environmental Barrier—Finally, hospital environments pose unique restrictions to computer use. Clinicians are constantly on move. They frequently log in and out on different public computers in hallways. They need to put on and take off protective gloves and clothing, and many must wash their hands well more than 60 times per day. Collectively, these raise many concerns that suggest the current WIMP (windows, icons, menus, pointer) style interactions might always struggle in this environment.

Re-framing the VAD Decision

Our findings demonstrate that a VAD decision is anchored by many small, unfolding healthcare decisions, including:

- *Patient condition clarification*: disease progression monitoring, tests, diagnosis, social evaluation etc.;
- *Daily care decisions*: stabilizing a patient to buy time for decision-making, optimizing patient condition to reduce treatment risks;
- *Care escalation decisions*: adjusting clinic visit frequency, hospitalizing, escalating treatment, etc.

The decision paths illustrate how failing any of these decisions can harm the VAD decision. None of the major breakdowns in the three decision paths failed in factoring patient condition into a prognosis, the decision that most prognostic DSTs aim to support. This revealed a real need to reframe the scope of a VAD implant decision. A new way to see this decision is as a consolidated VAD decision process unfolding in stages, over time, and across healthcare facilities including clinics, local hospitals, and implant hospitals. We believe this alternative view of clinical decisions will inspire new possibilities for more effective DST designs. While much related work has assumed decision support must be delivered to the time and place of decision-making [24], we see great potential in DSTs supporting healthcare trajectories as patients move down pathways towards major decisions.

Implications for the Design of Effective Clinical DSTs

We draw three implications from our findings to inform and inspire DST designers in addressing adoption barriers as well as in exploring new design possibilities: embrace context, make the decision process a design material, and blend human and machine intelligence.

Embracing the Richness of Clinical Context—A core goal of our study was to explore how a DST might better fit in clinical workflow and social context. Our study revealed rich details illustrating the context, which open up new opportunities for DST designs to integrate and leverage.

DSTs should be integrated into EMRs or they should at least automatically take in EMR data as inputs. They need to minimize input of data due to clinicians' frequent hand washing and lack of time spent in front of a computer.

The fact that seasoned physicians do not perceive a need for decision support suggests that DSTs have to make an effort before they can reach and convince these decision-makers. Designers should leverage the midlevels who more frequently use EMRs as a channel for delivery of decision support. Designers should approach this with some caution, as this may disrupt the hierarchical decision structure that is in place, but it could also positively elevate the role midlevels play in decision-making, thus encouraging them to participate. Central to this point is that establishing credibility and value across all members of the implant decision team should be a primary design goal.

In addition to midlevels, we also view the weekly implant meetings as an opportunity. A DST that wants to demonstrate value might automate the process of preparing patient information for this meeting. By automating the tedious information retrieval tasks, a DST could ease its recommendations into the discussion materials that the whole implant team reviews.

Decision Process As Design Material—Our finding illustrates that a healthcare trajectory, as well as its decision process, is pushed forward by a string of treatment escalations. We believe this new perspective on decision-making inspires a new theme in the DST design space: Decision support along the trajectory.

A VAD implant decision is anchored by a set of many smaller decisions that clarify and optimize patient conditions. Our illustrations of patients' journeys indicate that a breakdown at any of these steps can negatively limit therapeutic choice. We see a real opportunity for DSTs to provide much more integrated support. Currently, DSTs take only one form. They support making right *or* good decisions; they either help making a diagnosis, or a treatment choice, or a prognosis. Our findings prompt DST designers to consider combining a range of DST components with various forms and functions in order to support many small decisions that often lead up to a major clinic decision.

We observed that initiating timely care escalation has a crucial and direct impact on VAD decision quality. The late referral path offers a perfect example. DSTs might be able to improve patient outcomes by supporting physicians across healthcare facilities with smart adjustment of patient clinic visit intervals, timely consideration of hospitalization, referral, and a formal workup for VAD. All along this process an intelligent system could be monitoring to make sure a patient does not arrive at an implant facility after it is already too late for an implant. We see these functions as particularly valuable for local or primary care doctors who do not specialize in VAD, but care for the majority of heart failure patients. In a broader sense, DSTs could help surface newer care options to primary care and local doctors who are not current on advances in sub-specialties.

A better clinical DST could prompt both patients and care providers to resolve fixable implant exclusions. DSTs could flag behavioral factors such as smoking, drinking, and a patient's BMI. In addition, it could also prompt upstream social workers, as well as patients and their families to address a lack of effective social support needed for post VAD life and a lack of insurance that would cover this expensive procedure. Solving these issues earlier in the decision process reduces the likelihood a patient might miss an implant window due to an exclusion criteria that could have been resolved.

Developing DSTs to support the management of a panoramic healthcare decision process marks a clear space for future research in both data science and HCI. We imagine prior research on care planning could be leveraged in support of this. We strongly encourage data scientists to explore healthcare process data and predicting longer-term treatment outcomes. We also suggest HCI researchers investigate the decision-making activities in local or primary care settings and further examine this concept.

Blending Human and Machine Intelligence—Our findings highlight the attitudinal/informational barriers DSTs face. Currently clinicians have little motivation to use DSTs and many barriers stopping them. In our study, implant physicians expressed no need or desire to use any DST or risk model because they find no difficulty in making a VAD candidacy judgment. They also found DST data support for VAD decision inferior to fellow colleagues' input. This provokes us to critically re-consider the role of DST in decision-making tasks.

In our study, VAD physicians reported that they know how to make a VAD decision. As trivial as it sounds, it is a missing perspective in DST literature that has instead focused on the clinicians as a source of errors, biases, overconfidence, and communication breakdowns. This assumption behind DST development and design, though not immediately evident in interfaces, perhaps seeds this attitudinal barrier. Many of our participants implied that makers of current prognostic systems want to replace their expertise with inhuman technology. Taking a lesson from early HCI work in participatory design, we need to make technical advances that skill workers instead of de-skilling them [14].

Clearly there are opportunities for designing new interactions between DSTs and clinicians that work to integrate the abilities of both agents. One straightforward solution is to focus on more pliable forms of interactions, such as alerts and reminders. To date, one of the only successfully adopted DSTs has been alert systems. These systems require minimal user effort to manage and pose little disturbance on those who can make a correct decision.

At a deeper level, the attitude and informational barriers have resulted from a simple fact that clinicians will not use DSTs for tasks they feel they can do better than a machine. There is a real need for new DST design that better allocates human and machine intelligence into different components of healthcare decisions. Clinicians might make better judgments than algorithms in synchronization of clinical evidence and social evaluations. Some patient situations reported by our participants suggest these difficult situations are where data-centered systems are less likely to offer helpful advice.

In other decision tasks, such as clarifying and monitoring patient condition as well as managing care escalation, machine intelligence can and should help. We see emerging opportunities in these spaces for DSTs to add value. For example, when facing an emergency-room-path patient with sparse data available, clinicians seem the most likely to benefit from the collective intelligence that is collated across many implant centers. Such cases might be the best opportunities for DSTs to gain trust from clinicians by addressing an actual situation where a need for support might be present. Clinicians might also value computational support in referral management. We observe inter-site clinician collaborations are not remotely as frequent and ripe as the ones between colleagues. Information technologies could potentially perform matching inter-site consultations much more precisely and catalyzing new referral relations much faster than the currently manual methods.

We encourage DST designers to deliberately blend different clinicians and decision support components in decision space. Central to this implication is to make clinicians feel they are becoming better at their job, and to enhance clinical decision quality by leveraging advantages of both human and machine intelligence.

CONCLUSION

In this paper, we have presented a field study to understand how clinicians collaboratively decide whether and when to implant a patient. We expanded previous work on DSTs by providing a rare description of the who, where and how of clinical decision making in practice and identifying opportunities where DSTs can add value. These findings challenge the commonly assumed form of DSTs and suggest an alternative perspective on DSTs' role in decision-making.

Given the great potential of machine intelligence in improving healthcare, we strongly encourage HCI researchers join filling in the gap between DST technologies and clinical contexts. DST development teams should work closely with HCI researchers and practitioners in search of near-term, pragmatic solutions to breach acceptance barriers. There is also a real need for HCI researchers to investigate clinical decision-making in various healthcare settings to enable the design of real-world-ready DSTs.

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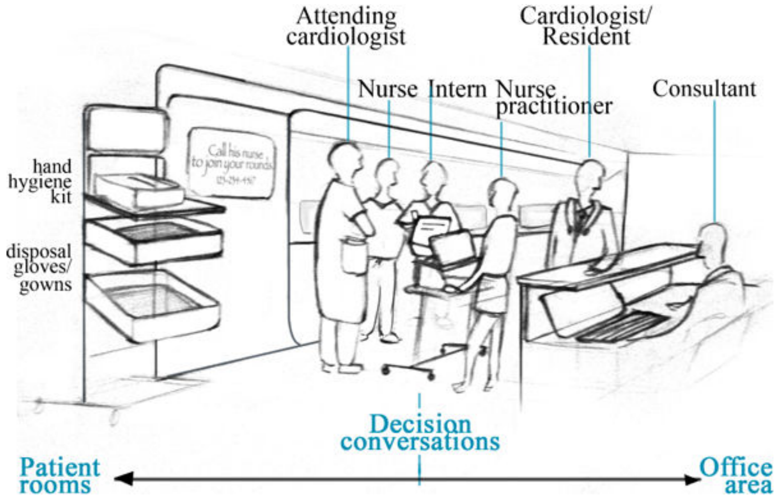

Figure 1.

The field illustration of an in-patient rounding scene. Hospital environments pose unique restrictions to computer use: Clinicians are constantly on the move, frequently putting on and off protective clothing, logging in and out of different public computers in hallways. These barriers naturally stratified across decision makers and computer users.

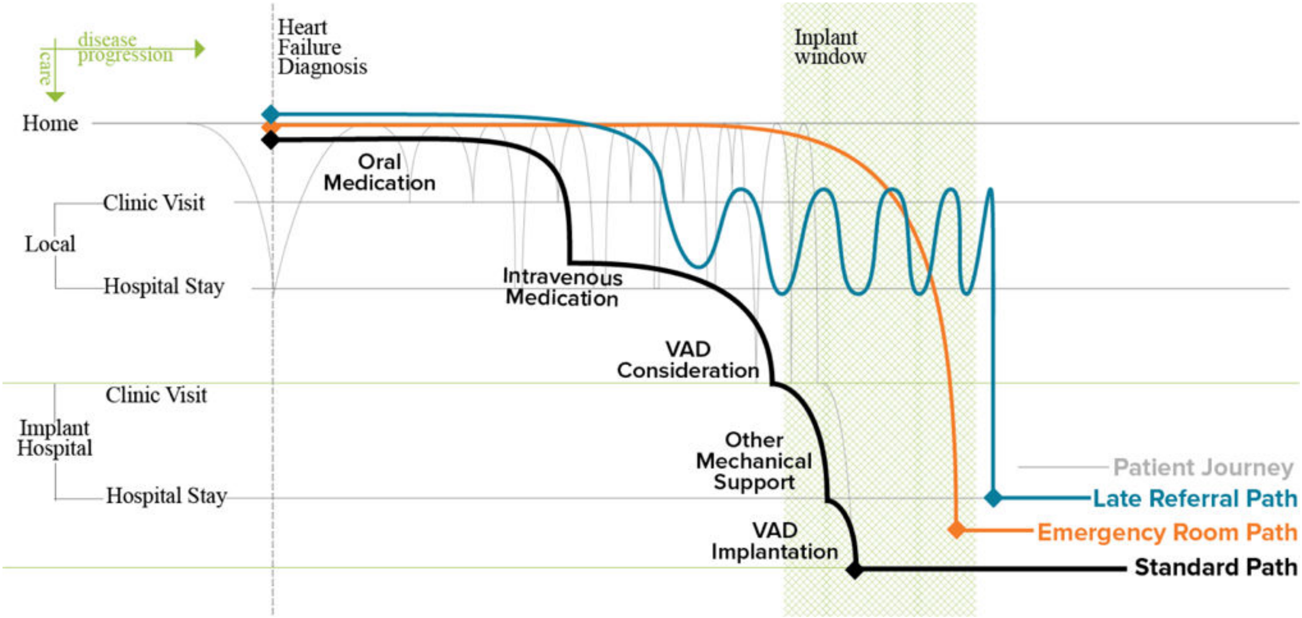

Figure 2.

An abstraction of VAD decision path and patient journey. Despite variations in timespan and different escalations and patterns, patients basically followed one of three paths to get to the VAD decision. The standard path (black) illustrates a systematic escalation of care and prepares relatively robust VAD decisions. Patients who followed the late referral path (blue) have missed the implant window before arrival at an implant center. The emergency room path (yellow) usually accompanies incomplete clinical and social evidences, making VAD clinicians' decisions difficult.

Table 1

Clinicians and activities of a VAD implant team. They unequally participate in routine decision-making activities. ■ marks the clinicians who lead or always attend the activity; □ marks those who attends occasionally or in a subset of hospital sites.

		Procedure		
VAD Team		***Clinic***	***Ward Round***	***Weekly Meeting***
Implant Physicians	Cardiologists	■	■	■
	Surgeons	□	□	■
Medical Midlevels	Nurse Practitioners	□	□	■
	Fellow & Interns	□	■	□
	Physician Assistant	□		
	Registered Nurses		□	
	VAD Coordinators			■
Social Midlevels	Finance Coordinator			
	Social Workers			■
	Palliative Care			■
Consults	Pharmacists			
	Nutritionists		*On Demand*	
	Other physicians			