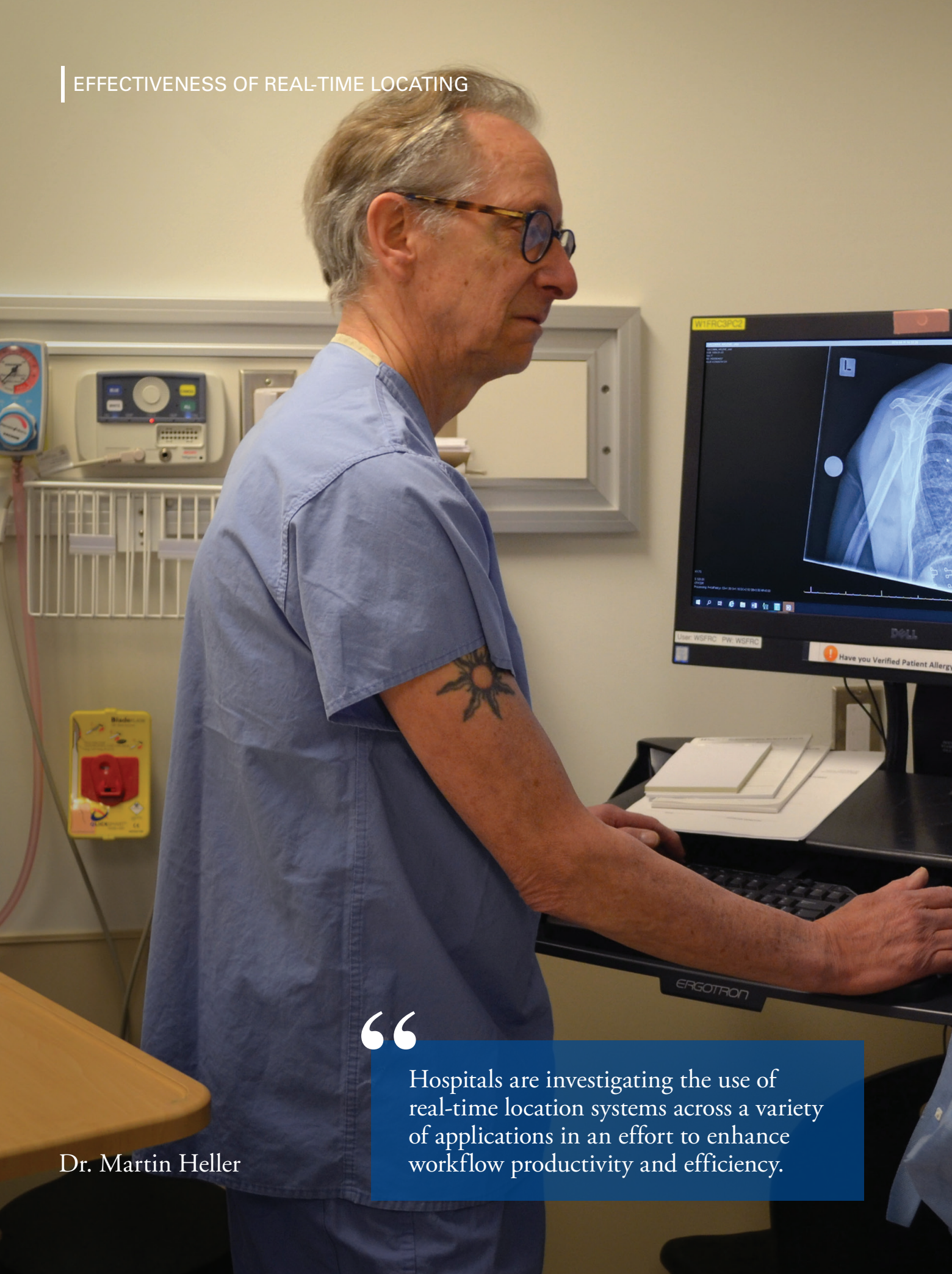

> Hospitals are investigating the use of real-time location systems across a variety of applications in an effort to enhance workflow productivity and efficiency.

Dr. Martin Heller

The Impact of a Real-Time Locating System within the Perioperative Environment on Physicians and Patients' Families

Martin Heller, Joseph Koval, Ethan Miller and Shirley Solomon

Abstract

Background: **Humber River Hospital has implemented a real-time location system (RTLS) within the operating room in order to provide real-time information about patients' status and manage the many components involved during the perioperative journey.**

Objective: **The aim of this study was to explore both physicians' and family members' perceptions of the functionality and efficiency of the RTLS within the perioperative environment.**

Methods: **Semi-structured interviews were conducted with physicians and patients' family members to elicit various perspectives regarding the use of RTLSs throughout the perioperative process. Interviews were recorded and transcribed to extract key themes.**

Results: **Three themes gleaned from physician interviews were system weaknesses, perceptions of potential benefit, and benefits to family members. Three themes uncovered from family member interviews included convenience, ameliorating anxiety, and reducing interruptions.**

Conclusion: **Overall, physicians reported that the RTLS had potential to enhance workflow but that significant improvement regarding its implementation and use was needed to reach its full benefit. Family members were unanimous that it provides them with all the tracking information they desire.**

Introduction

Multifaceted interactions with patients, visitors and staff are constantly occurring in hospitals. Alongside these ongoing human exchanges, various medical supplies and equipment are used in the process of care delivery. Keeping track of patients, visitors, staff and medical equipment and materials poses a significant challenge for hospitals. In the operating room (OR), managing communications and workflow is essential. The ability to track patients, specimens, devices, equipment and staff in a reliable manner facilitates efficient workflows (Fisher and Monahan 2012). Hospitals are investigating the use of real-time location systems (RTLSs) across a variety of applications in an effort to enhance workflow productivity and efficiency (Kamel Boulos and Berry 2012).

Humber River Hospital (HRH) is the first digital hospital in North America and the first hospital in Canada to implement an RTLS in its surgical department (HRH 2018). To enhance the efficiency and productivity of the surgical perioperative process, physicians, nurses, technicians and other staff members who are part of the surgery team require up-to-date and real-time information about the patient's status and operational workflow (Meyer et al. 2007). The advanced software program implemented at HRH provides tracking information to family and friends regarding each phase of the operative journey that the patient undergoes (HRH 2018; Humber River Hospital Foundation n.d.). Family and friends can receive updates sent directly to their smartphones, which include surgical updates and the patient's location, progression through the operative process and visitation readiness (HRH 2018). The RTLS functionality for physicians and other staff is to provide real-time patient status information that supports effective workflow through the stages of the operative process, from preoperative preparation to post-anesthesia care. The purpose of this study was to uncover both physicians' and family members' perceptions of the impact the RTLS has had on workflows, communication, decision-making and efficiency.

HUMBER RIVER HOSPITAL is one of Canada's largest community acute care hospitals, serving a population of more than 850,000 people in the north-west Greater Toronto Area. The multi-site hospital currently operates out of its Wilson Avenue acute care site and Finch and Church Street reactivation care centres with a total of 722 beds, just over 3,800 employees, approximately 700 physicians and over 1,000 volunteers.

Affiliated with the University of Toronto and Queen's University, Humber River Hospital is North America's first fully digital hospital. Part of Humber River Hospital's digital infrastructure includes completely automated laboratory services, robots sorting and mixing medications, electronic health records, tracking systems, for patients undergoing surgery, that update families through their cellphones and patient bedside computer terminals – all varieties of technologies that automate information, eliminate paper and provide a connected experience for patients, staff and families.

Humber River Hospital was awarded Accreditation with Exemplary Standing in 2018 and, since its opening in 2015, has received numerous awards and accolades for technological advancements and innovation (www.hrh.ca).

Methods

Study design and participants

This study was a qualitative analysis examining the efficacy and functionality of the RTLS throughout the perioperative period. The perspectives of physicians and patients' families were elicited. Physicians who met eligibility criteria included those who had a minimum of 1-year experience using RTLS at HRH. Eligibility criteria of patients' family members included participants who had a family member who underwent a surgical procedure at HRH, familiarity and personal use of the RTLS and willingness to participate. All individuals who participated were native English speakers and 18 years of age or older and possessed the capacity to consent to participate in the study. Veritas IRB, an independent Research Ethics Board, approved this study.

Data collection

Data were obtained through semi-structured, in-depth interviews with physicians and patients' family members over the course of 1 month. Twenty participants were interviewed in the study, including 10 physicians and 10 family members. Informed consent and demographic data were collected in person prior to interviews. Members of the research team conducted the interviews in one-on-one or focus group settings according to participant preference. All physicians participated in one-on-one interviews, whereas family members participated in focus group interviews. Physician interviews ranged from 15 to 20 minutes, whereas interviews with family members were typically approximately 10 minutes.

TABLE 1.
Content analysis of transcribed data: examples of meaning units, condensed meaning unit and theme

Meaning unit	Condensed meaning unit	Theme
"[The system] was supposed to time the patient in the room and out of the room so we could track turnovers and operating efficiency. ... A patient comes in with a tag and [the sensor] is supposed to pick up that tag. And to my understanding, it never worked. So if you do want operating room efficiency time, then it's up to the nurses to put in that data manually of when they 'think' the patient came in, when they 'think' the patient got into the operating room, when they 'think' the patient left the operating room."	RTLS system doesn't pick up tag; nurse must input data	System weakness
"[The monitor board] is very, very poor in telling me where the patient is. I would say fifty percent of the time or more I would look at the board and I'll go to that place and the patient won't be there. So the board almost becomes completely useless. Then I have to find one of the nurses and just ask them. So I find that it's not foolproof and not updating within real time most of the time."	The monitor does not provide accurate information; physician has to ask nurse	

Data analysis

Interviews were analyzed by manifest content analysis. This method is suitable for identifying predominant themes from the participant's words (Downe-Wamboldt 1992). First, two analysts read the transcribed text separately. Next, the analysts extracted and summarized the units of meaning and further categorized them based on similarities (see Table 1 for an example of the process). Each analyst created preliminary categories, and any discrepancies were resolved through discussion. To illustrate emerging themes, select quotations were chosen from the data. Descriptive analysis of the survey data was conducted using SPSS version 25.

Results

Three main themes emerged based on analysis of the transcripts from the interviews with physicians: system weaknesses, perceptions of potential benefit and benefits to family members. Additionally, three main themes emerged based on analysis of the transcripts from the interviews with family members: convenience, ameliorating anxiety and reducing interruptions. Each theme is described with quotations from the participants. Descriptive statistics of the demographic characteristics of family members and physicians are presented in Tables 2 and 3.

Themes from interviews with physicians

System weaknesses

The prevailing theme among all physician participants was that the RTLS was prone to error. There was consensus that the inefficiency was primarily due to the system's weak tracking capabilities. Due to this issue, nurses were required to enter patient status information manually when it was not tracked by the system, which meant that physicians were not provided with real-time patient status information. The physician participants explained:

> [The system] was supposed to time the patient in the room and out of the room so we could track turnovers and operating efficiency. ... A patient comes in with a tag and [the sensor] is supposed to pick up that tag. And to my understanding, it never worked. So if you do want operating room efficiency time, then it's up to the nurses to put in that data manually of when they "think" the patient came in, when they "think" the patient got into the operating room, when they "think" the patient left the operating room.

> [The monitor board] is very, very poor in telling me where the patient is. I would say fifty percent of the time or more I would look at the board and I'll go to that place and the patient won't be there. So the board almost becomes completely useless. Then I have to find one of the nurses and just ask them. So I find that it's not foolproof and not updating within real time most of the time.

Another weakness that was pointed out by some of the physician participants was that the tags often went missing.

TABLE 2.
Demographic characteristics of physician study participants

Age range of physicians	*n*	(%)
25–34 years	0	0
35–44 years	3	30%
45–54 years	3	30%
55–64 years	2	20%
65–74 years	2	20%
75 years and over	0	0%
Gender		
Male	9	90%
Female	1	10%
Gender diverse	0	0%
Years of experience as a physician		
1 to < 3 years	0	0%
3 to < 5 years	0	0%
5 to < 10 years	2	20%
10+ years	8	80%
Length of time at Humber River Hospital		
1 to < 3 years	1	10%
3 to < 5 years	2	20%
5 to < 10 years	2	20%
10+ years	5	50%

One physician participant noted:

> A lot of the times the patient's [tag] is broken or missing. The [tags] get attached to the patient, and the [tag] then goes home with them or it goes in the laundry and … just disappears. And that's one of the issues with them because I'm sure they're not cheap. So very few patients have [tags] now.

One physician participant also explained that when they attempt to press the button on the patient's tag to indicate that the patient is ready for surgery, it often does not function:

> Sometimes the beeper thing – you have to walk outside the room. [There are] some areas that don't connect. It doesn't always click right by the patient's bed. You have to walk around the room sometimes to get it to work.

Many physician participants reported that they had ceased using and relying on the RTLS because of the technical and user issues in tracking patients. As one physician participant explained:

> More often than not, I just find myself going into the preop area, and I just ask the nurse, "Where is my patient?" because it's so often wrong that there's no point in me going to the board [to find] where my patient is. [T]hey're not there. [I] come back. I just ask the nurse, which I know defeats the entire purpose of [the system], but the inaccuracies are responsible for me just going to ask [the nurse].

Of note is that issues with the system were not less prevalent among interviewees who considered themselves to be "computer savvy," as noted by the following comment from a physician participant:

> Well, I don't use it, I work with computers a lot, I'm more computer savvy, but I gave up on the system because I found it useless. I couldn't get it running on my phone a couple of times, so I just gave up.

Perceptions of potential benefit

A second theme involved physician participants' perceptions of the RTLS's potential benefit. Although all physician participants agreed that improvements to efficiencies in the OR could be beneficial, participants were divided on whether the RTLS would be capable of providing that benefit. Several physician participants questioned the system's capability of improving processes in the OR. One physician participant commented:

> It cannot affect processes; it just monitors them. It's like recording OR wait times. It has no effect on wait times. It's more a monitoring tool than an impact tool. ... I don't think it's achieved what it's set out to do.

Other physician participants believed that even if the system had functioned as intended, it would not have played a part in supporting their work:

> I'm not hurt by not getting the text message. It doesn't change anything. It's like extra peas for dinner; if it's

TABLE 3.
Demographic characteristics of family member study participants

Age range of family members	*n*	(%)
18–24 years	1	10%
25–34 years	1	10%
35–44 years	3	30%
45–54 years	4	40%
55–64 years	1	10%
65–74 years	0	0%
75 years and over	0	0%
Gender		
Male	1	10%
Female	9	90%
Gender diverse	0	0%
Highest degree/level of education completed		
Less than high school graduation	1	10%
Secondary high school diploma or equivalent	2	20%
Some postsecondary education	3	30%
Postsecondary certificate, diploma or degree	4	40%

there, it's there; if not, it's fine. It's not a significant enhancement.

I have never used it. For me, as long as the patient shows up in the operating room and ends up in the recovery room, that's all I need.

Conversely, other physician participants emphasized the potential benefits of the RTLS, such as potential improvements to time management, patient care and OR efficiency:

If we had data to say what are the delays and why are the turnovers so long because those are the two biggest things that kind of decrease our efficiency; you know, if we have 3 to 4 cases in a day and we are operating for … 4 hours and our turnover time and delays are taking up the rest of the 3 hours in the day, then, certainly, there's an opportunity to increase efficiency.

[I]f I could get an alert on my phone that says that the patient has just left the block room, then I could start making my way to the operating room. You don't want to go to the operating room and the staff are telling you they were waiting for you.The hospital has a big footprint. These are the things that are supposed to help you navigate that.

If we know where our patient is, we can go right there instead of asking a nurse,"Where's my patient?" It would improve the amount of time we are able to spend with patients because we only have a limited amount of time between cases, and if half that time is taken looking for a patient … we have less time to spend with our patient. So I think it would have been able to improve patient care indirectly that way if it were to work.

You could have true benchmarks for operating room turnover, you could know when one patient left and the next came in, housecleaners could know, porters could know, nurses could know, the surgeons could know – everybody would have real data. But instead what we have is what the nurses put in to the [EMR] and compiling it later on and trust that the right time was put in.

Benefits to family members

Counterbalancing the physicians' frustrations with the RTLS was the awareness that it was beneficial to patients' family members. All physician interviewees uniformly agreed that the system provided the greatest benefit to family members, citing most frequently that it greatly reduced their anxiety as they waited for their loved ones to come out of surgery:

[Family members] do have some comfort in knowing where [the patients] are. It does provide them with a little bit of reassurance, and I know I have gotten some positive feedback from family members.

It's certainly nice for patients and families to be able to know where they are in the operation. If an operation is expected to go for two hours and it goes for five hours, then the family is still aware that they are in the operating room or something is still taking place, so they're not wondering what's going on.

Notably, physician participants exclusively referred to the system as a patient tracking system "for family members."

Themes from interviews with family members

Convenient and user-friendly

All participants were enthusiastic about the RTLS. The system was simple to understand, follow, and implement. This allowed for users with varying levels of technological expertise to navigate it with relative ease. One family member participant reported, "I'm bad with technology, … but it was so easy even I could do it." Many other family member participants further supported its use and claimed that it was "really easy" to use and "clear." Furthermore, many family member participants reported that receiving updates directly to their phones made it very convenient to use. Although status updates were displayed on a waiting room monitor, personal phone updates allowed for notifications virtually anywhere. As a result, family member participants were able to leave the waiting area to purchase food or use the restroom, without the fear of missing important status updates. One family member participant stated, "[I]f you're gone, something is going to happen; you're going to miss it. This way it is on your phone and you can take it with you …" In addition, receiving updates directly to one's phone eliminates the need to search for a specific patient's identifying "numbers" among the many other patients on the monitor.

Ameliorates anxiety and reduces interruptions

During the perioperative period, patients' loved ones are often waiting many hours until they finally communicate with the surgeon or reunite with the patient. The RTLS provides status updates directly to the patients' loved ones throughout the perioperative journey. Family member participants reported that the updates and notifications provide "peace of mind" and "relieve a lot of stress on people." A family member participant stated, "[It] makes you feel like you're in the loop throughout the process." The notifications allowed the family member participants to feel involved and not "forgotten." Furthermore, it was perceived that when family member participants received notifications and status updates, it reduced interruptions for healthcare staff. A family member participant explained that a direct notification from the RTLS eliminates "people bothering [the nurses] every two minutes." Moreover, family member participants are aware of what they need to do or where they need to go regarding the patient without having to request information from healthcare staff.

Discussion

The purpose of this study was to evaluate the impact of the RTLS on surgeon and patient family experience at HRH. Focus groups and one-on-one interviews with 10 surgeons and 10 family members were analyzed to examine themes. Of note was the significant divergence between the two groups' experiences. Surgeons felt that the system failed to meet their expectations, with particular reference to real-time patient location. Conversely, family members uniformly found the RTLS to be a valuable asset, significantly improving their perioperative experience. This satisfaction carried a secondary benefit for OR staff and surgeons, who could trust in the efficacy of the family notification process and its resultant reduction in overall family anxiety. Reflecting on the divergence of perspectives highlights how the RTLS represents a focal point of information, demonstrating that these two stakeholder groups (physicians and families) have such differing informational needs. For anxious family members awaiting news of their relative's surgery, the automated RTLS functioned extremely well in alleviating their anxiety and meeting the family's expectations regarding open communication. In contrast, surgeon expectations of the system were not met, primarily due to unfulfilled process information needs. Surgeons viewed the RTLS as having the potential to improve workflow processes, but the failure of the system to provide precise time-tracking functionality for each stage of the perioperative workflow process eliminated the potential for surgeons to monitor or enhance these processes. A properly functioning RTLS has the potential for genuine improvement in OR team satisfaction and ultimately in improved patient care as tracking data are analyzed and incorporated into policy change (Kamel Boulos and Berry 2012). Without this potential, the OR team is limited in its ability to improve the workflow. Prolonged discontentment with workflow may hinder the team's ability to achieve high-reliability processes and outcomes.

Ideally, the RTLS should have provided a precise real-time indication of the patient at all times through automation alone. Simply put, knowing, for example, when the patient is entering the OR allows the surgeon to be present in a timely fashion as there are often multiple diversions requiring attention between cases. Some institutions have employed radiofrequency identification (RFID) tags, which attach to the patient's armband (thus decreasing the likelihood of tags becoming lost with linens, although this does not completely address tags that inadvertently go home with patients); these RFID tags do not require buttons to be pressed but are simply "tracked" for their locations (Kamel Boulos and Berry 2012). However, use of such devices would mean the loss of capturing time for surgeon and anesthesia activity and the assumption that intraoperative activities proceed as soon as the patient has entered the OR. The core issue is that the current RTLS at HRH is configured to provide precise *locating* versus precise *timing*. According to Kamel Boulos and Berry (2012), "In the end, all RTLS technologies share the common objective of determining the location of assets and individuals as precisely as is needed by the target population" (p. 3). The findings from this study have elucidated the need to match the technology application to the needs of the key stakeholders for it to succeed.

Second, using information obtained from the RTLS should allow verifiable parameters to be monitored, such as patient registration, patient preparation, OR turnover time and recovery room delays. Previous studies examining RTLS technology in healthcare have reported enhanced workflow efficiencies in complex practice settings, such as the emergency department (Laskowski-Jones 2012). At best, data that are generated through the RTLS should provide physicians with some ability to make day-to-day decisions through monitoring all of the patient flows (such as anticipating the next surgical case), which is highly variable based on the individual surgeon's practice. Kamel Boulos and Berry (2012) suggested that the RTLS has the capacity to track patient flows for managing throughput and alleviating bottlenecks. Some physician participants reported that colleagues have the RTLS data uploaded to their smartphone, which allows them to make some decisions in their daily scheduling, whereas others forgo seeking any information from the RTLS altogether. This variation of user acceptance can influence the perception of value for surgeons and hospital administrators. Kamel Boulos and Berry (2012) suggested that one of the most common reasons information technology projects fail is because they do not achieve the necessary functionality. Optimizing the existing RTLS at HRH using feedback from physicians and the OR team could salvage the system and standardize its use.

RTLS data should serve as a tool to impact service planning along with the communication and information needs of patients' families. With the feedback received from families, surgeons confirmed that families were in such favour of having the RTLS information that, despite its current state, for the purpose of patient-centred care and in aligning with the hospital's value of compassion, the system is worth the effort to use it. Although the system is not currently reliable and requires fallback to manual data entry by nursing staff in the ORs tracking the patient's progress, surgeons understand the importance of the system to patient experience. Change management strategies based on inefficiencies identified with the patient flow functionality are necessary to improve physician and OR team confidence in the system.

Kamel Boulos and Berry (2012) suggested that RTLSs are high-involvement products that require input and consultation from a large variety of stakeholders. Understanding the clear divergence of experience between patients' family members and surgeons perhaps allows for better future planning when it involves a technologically advanced system such as the RTLS. When multiple stakeholders are impacted, heuristics must be considered. Nielsen-Shneiderman Heuristics identified 14 different principles for human factors analysis that can be applied to RTLSs (Zhang et al. 2003) (see Table 4).

For example, we anticipate that families will use the RTLS solely as a monitoring tool; thus, the principles of "visibility of the system state" and "minimalist" would be most important for this group (e.g., the data tells families where the patient is in the system, and no additional extraneous information is communicated). Surgeons, however, would require a heuristics view of "match between the system and the world" as they would be expected to make decisions regarding the timing of their next surgical case in the context of the current state of the OR environment. Surgeons and hospital administrators would additionally benefit from "informative feedback," such as that derived from this study, and "documentation" that enables continuous quality improvement.

TABLE 4.
Nielsen-Shneiderman heuristic principles

Principles	Analysis
Consistency and standards	Good error messages
Visibility of system state	Prevent errors
Match between system and world	Clear closure
Minimalist	Reversible actions
Minimize memory load	Use users' language
Informative feedback	Users are in control
Flexibility and efficiency	Help and documentation

Source: Zhang et al. 2003.

Functionality for each user group would also entail careful application of implementation science where consistency and process adherence are tested through a small area of the perioperative program (e.g., an orthopedic service only) to identify challenges and incremental changes through Plan–Do–Study–Act cycles. Once user groups accept system functionality and refinements based on the specific inputs provided by key stakeholders, then the appropriate change management requirements can be implemented on a broad scale. Ultimately, initiating a complex system such as the RTLS within the OR should involve rigorous clinical testing in the receiving environment, including soliciting end-user feedback. Once a comprehensive trial has taken place and all concerns have been addressed, the full potential of this technology can be realized.

Study limitations

There are limitations that must be taken into account when interpreting the findings presented in this study. First, memory bias may have influenced the narrative of the participants. As well, the data from this study were obtained via face-to-face interviews, which may have resulted in respondents exhibiting social desirability bias. However, all interviews were conducted

by a research coordinator to limit influence on participants' responses, and both positive and negative perceptions were exhibited by the participants. Lastly, the data were derived from a single hospital site and therefore reduce the degree to which the study's findings are generalizable to other hospital settings.

Conclusions

A significant challenge for hospitals is keeping track of patients, visitors, staff and medical equipment and materials. In the OR, the challenge of managing communications and workflow is essential to enhancing efficiency and productivity across the perioperative process. The ability to track patients is a major factor in facilitating effective communication with family members and raising the level of satisfaction with their experience. At HRH, the advanced software program aimed at tracking patients and ensuring timely and consistent information to family and friends regarding each phase of the operative journey that the patient undergoes has been overwhelmingly successful. The RTLS functionality for physicians and other staff to provide real-time patient status information that supports effective workflow through the stages of the operative process, from preoperative preparation to post-anesthesia care, requires substantive improvement. With continued feedback from surgeons and the OR team, RTLSs can be refined to enable real-time management of perioperative workflow and support continuous quality improvement.

What We Learned:

1. Surgeons were dissatisfied with the RTLS as a tool for managing workflow. Patients' family members were uniformly satisfied with the RTLS as a communication tool.This satisfaction carried a secondary benefit for operating room staff and surgeons, who could trust in the efficacy of the family notification process and its resultant reduction in overall family anxiety.

2. RTLSs must provide precise time-tracking functionality for each stage of the perioperative workflow process to enable monitoring and enhancement of these processes. Regardless of the imprecision of the RTLS time-tracking functionality, family members found that the system reduced their anxiety and was convenient and user-friendly.

3. Future enhancements to RTLSs should consider heuristic design principles.

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