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Implementing Radio Frequency Identification within the Perioperative Process: A Case Study Perspective

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ABSTRACT

As a technology solution, radio frequency identification (RFID) has proven increased efficiency and accuracy within traditional production and inventory control environments. RFID also offers increased transparency, accountability, and quality across the healthcare industry. This paper provides an a priori perspective to implementing RFID applications in a hospital environment. The paper describes, examines, and discusses the opportunities and challenges that RFID poses across an individual hospital's perioperative and auxiliary services. Based on an 87-month longitudinal study of a large 909 registered-bed teaching hospital, this paper investigates the complexity of technological change dynamics, integrated information systems, as well as the benefits and learning curves associated with implementing RFID technology in a hospital's perioperative processes. This paper also provides theoretical and practical implications, as well as study limitations.

Keywords

Radio frequency identification, perioperative processes, patient safety, integrated hospital information systems.

INTRODUCTION

A hospital's perioperative process provides surgical care for inpatients and outpatients during preoperative, intra-operative, and immediate post-operative periods. Each perioperative sub-process (e.g. preoperative, intra-operative, and post-operative activities) is sequential where each activity sequence paces the efficiency and effectiveness of subsequent activities. As a result, the perioperative process is tightly coupled to patient flow, patient safety, patient quality of care, and stakeholders' satisfaction (i.e. patient, physician/surgeon, nurse, perioperative staff, and hospital administration).

From an operational perspective, a hospital's perioperative process requires multidisciplinary, cross-functional medical teams to maneuver within a complex, fast-paced, and critical environment—the hospital environment (McClusker et al., 2005). Providing quality perioperative care requires managing the complexity and customization of surgery, ensuring continuity of patient care in a timely manner, preventing unnecessary repetition, and ensuring safety through the entire perioperative workflow. Among these issues, safety, efficiency, and medical team integration are of paramount importance to perioperative management (Fairbanks, 2007).

Similarly from a hospital's financial perspective, the perioperative process is typically the primary source of hospital admissions, averaging between 55 to 65 percent of overall hospital margins (Peters and Blasco, 2004). Macario et al. (1995) identify 49 percent of total hospital costs as variable with the largest cost category being the perioperative process (e.g. 33 percent). Given the rising cost of healthcare, the public demand for healthcare transparency and accountability, and the current economic environment—managing, improving, and optimizing flexible, cost effective perioperative processes are critical success factors (CSFs) for any hospital. To this end, integrated hospital IS provide measurement and subsequent accountability for healthcare quality and cost, creating a dichotomy between quality versus cost that represents the foundation for healthcare improvement (Dougherty and Conway, 2008).

In this study, we discuss radio frequency identification (RFID) applications and data integrating technology within the perioperative sub-processes. Chang et al. (2008) discuss the application of RFID in the hospital environment to generate diverse benefits and found only benefits from the operator and the environment can achieve and enhance patient safety. These findings also retain the earlier, broader conclusion of Wears and Berg (2005) that information systems (IS) and/or information technology (IT) only yield high-quality healthcare when the use patterns are tailored to knowledge workers and their environment. To this end, the application of RFID in the hospital environment can yield an integration of technology benefits and improved patient safety (Ku et al., 2011; Nagy et al., 2006; RFID in Healthcare Consortium, 2008; Steelman, 2011).

This study highlights the implementation of RFID applications within a hospital's perioperative processes. The case results are facilitated by empowered individuals driven by integrated internal and external organizational data. The investigation method covers the longitudinal study of an integrated clinical scheduling IS (CSIS) within a large, teaching hospital. The implementation of an agile CSIS and subsequent contextual understanding of the perioperative processes and the sub-processes prescribed the opportunity to integrate RFID applications for quality of care, patient safety, and efficiency improvement. Specifically, the extension of RFID technology within internal best-practices provides the framework for redesigning preoperative tissue acquisition and intra-operative time-out checks. The system planning, construction, and implementation of the RFID applications provide change dynamics for evaluation and improvement to the overall perioperative process. This case study also identifies the complex dynamics associated with the hospital environment.

The following section reviews previous literature on retained surgical foreign bodies (RSFB) as medical errors, traceability requirements for tissue transplantation, and RFID technology applications. Following the literature review, we present our methodology, case study background, as well as an analysis of the observed benefits and lessons learned from the redesigned processes included in the IS/IT planning, construction, and implementation efforts. By identifying a holistic framework for analysis, evaluation, and synthesis between internal processes best-practices and external RFID applications, this paper prescribes an a priori environment to support RFID and data integration system planning, construction, implementation, as well as the ultimate perioperative process improvement with defined metrics and benchmarks. The conclusion also addresses study implications and limitations.

RSFB AS MEDICAL ERRORS

Healthcare professionals are human and the risks and consequences associated with human errors yield medical errors. However, healthcare quality measurements reflect clinical effectiveness and accountability, as indicated from the check of a patient's five rights—the right treatment for the right patient in the right dose in the right way at the right time. These healthcare quality metrics are routinely measured within process checklists, documented within hospital clinical IS, and reported to governing bodies like The Joint Commission on Accreditation of Healthcare Organizations. Gunn (2008) and Roeder (2009) indicate that the use of standardized perioperative records, database, and electronic documentation help provide standardized patient care.

Using a standardized checklist provides patient medical information for reference and allows routine evaluation of patient care and outcomes, while also encouraging education, training, and communication (Seifert, 2009). As a measure to minimize medical errors as perioperative patients are anesthetized during surgery, perioperative checklists advocate the security and comprehensiveness of patient care (Fowler et al., 2008). The World Health Organization (2009) recommends a commonly adapted surgical patient safety checklist (see Figure 1) for the following perioperative events: (1) before induction of anesthesia (i.e. preoperative sign in); (2) before the skin incision (i.e. intra-operative time out); and (3) before the patient leaves the operating room (i.e. intra-operative pause). However, checklists do not eliminate the opportunity for human medical errors.

Within the intra-operative process, RSFB is a significant medical error of inadvertently retained sponges or gauzes having occurrence rates between 1 in 2000 to 1 in 6000 surgical cases (Nicodemus, 2009; Stark and Goldstein, 2004). However, RSFB also include retained surgical instruments, needles, catheters, and other devices left in place unintentionally (Smith, 2001; Stark and Goldstein, 2004). All surgical procedures pose a risk for RSFB, which jeopardize patient safety and hold profound professional and medico-legal consequences to perioperative stakeholders. The medico-legal costs to a hospital associated with RSFB, even with little harm to the patient, can range from $50,000 to $150,000 per-occurrence (Stawicki et al., 2008).

RSFB is a "never" event, as professional consensus agrees that it should never occur in healthcare (Stark and Goldstein, 2004). The best general approach to RSFB is to prevent the occurrence and avoid all RSFB consequences. The most important preventive measure is to accurately count the pieces of surgical gauze/sponge and surgical instruments (Gibbs et al., 2005). If sponge or instrument counts pre and post procedure are discordant, then a re-count must be performed,

followed by x-rays and a possible exploratory surgery (Gawande et al., 2003). Moreover, approximately 70 to 80 percent of RSFB cases were associated with correct surgical counts (Mouhsine et al., 2005).

Figure 1 – World Health Organization (2009) Surgical Safety Checklist

TISSUE TRANSPLANTATION TRACEABILITY

Tissue transplantation is a much broader category than blood transfusions or organ transplants. The term "tissue" covers many human products transplanted for medical uses (i.e. heart valves, pericardium, tendons and ligaments, ground bone or bone chips, skin, corneas, etc.). Tissue transplantation is an applicable practice among all surgical specialties, although it occurs more common among certain specialties (i.e. orthopedic, burns, or cardiovascular). Traceability of tissue transplantation is generally defined as the ability to trace the path of a tissue product from the donor to the recipient, and vice versa.

Tissue transplantation is a rapidly growing industry that is closely regulated by the Food and Drug Administration (FDA). However, the FDA makes it tissue and medical device regulatory decisions based on reviews of studies and tests performed outside the FDA domain. To ensure product integrity, the FDA relies on reports of adverse product experiences in the marketplace. In the event of a recall, Federal law requires tissue banks to maintain donor information on all tissue and The Joint Commission issued a standard in 2005 that requires implanting hospitals to maintain chain-of-custody (i.e. traceability) documentation on tissue donor information to reside within the receiving patient's medical history (Brubaker and Wilson, 2010). Conversely, Strong and von Versen (2010) identify some international standard and definition gaps in the quality mapping of tissue banks' 'coding and traceability'. To this end, international initiatives are underway to develop a consensus solution. In the interim, regulatory and governing entities recommend and/or require traceability through chain-of-custody documentation. Currently, the most common approach is for each organization that receives donor tissue to be responsible for the integrity of its traceability trail from the point of receipt to the point of distribution. In the current healthcare environment, ensuring traceability integrity requires active involvement from all parties: Federal and state governments, manufacturers, wholesalers, distributors, providers, surgeons, and patients.

RFID Technology

Basic RFID technology consists of a tag (i.e. a transmitter composed of an antenna wrapped around a micro-chip) to transmit a signal and a transceiver with antennae to receive the signal and re-transmit it to a server. The tag contains radio frequency circuitry and memory containing the various data to be transmitted. RFID uses the radio frequency portion of the electromagnetic spectrum to transmit signals. The presence of an internal power source determines the category of RFID in use—passive or active. Passive tags are relatively small, inexpensive (e.g. cost $0.50 to $1), and have limited range (i.e. inches) compared to active tags (e.g. cost $50 to $80 and above) having internal power to permit continuous broadcast over greater distances and a sensor to record data (Nagy et al., 2006). RFID has discernible advantages when compared to barcode technology because: (1) RFID can provide identification that is unique to a particular object; (2) the RFID reader can read multiple tags simultaneously; and (3) the RFID reader does not require a line of sight. However, RFID is orientation sensitive, particularly passive tags that require magnetic induction between the reader and the tag to supply power and receive signals. Hence the passive tag transmission range limit.

Ku et al. (2011) identifies RFID technology applications across the hospital environment as well as patient care along perioperative workflow checkpoints. Nagy et al. (2006) categorizes perioperative RFID applications across three domains: (1) workflow tracking (i.e. efficiency); (2) supply chain (i.e. cost effectiveness); and (3) patient tracking (i.e. quality of care or patient safety). Interaction among these domains yield additional RFID technology benefits by providing real-time, wireless identification, and data capture into integrated IS that minimize or eliminate the opportunity for human error. Chang et al. (2008) examines the status of RFID applications in relation to patient safety and concludes that the benefit of data integration is the most important factor with the greatest potential to facilitate patient safety and quality of care.

RESEARCH METHOD

The objective of this study is to investigate RFID applications and data integrating technology implemented via an integrated hospital IS. Case research is considered to be particularly appropriate (Eisenhardt, 1998; Yin, 2003). An advantage of the positivist approach (Weber, 2004) to case research allows concentrating on a specific hospital service in a natural setting to analyze the associated qualitative problems and environmental complexity. Hence, our study took an in-depth case research approach.

This study spans activities from October 2004 through January 2012, with particular historical data available from 2002 and 2003. During the 87-month study, we conducted field research and gathered data from multiple sources including interviews, field surveys, site observations, field notes, archival records, and documents reviews. Concentrating on one research site facilitated the research question investigation and allowed the continued collection of longitudinal data. Our research site is a large teaching hospital (University Hospital), licensed for 909 beds and located in the southeastern region of the United States. University Hospital is a magnet hospital and U.S. News and World Report recognized University Hospital as a Best Hospital in 18 of the last 20 years.

The perspective of this research focused on University Hospital's perioperative process for its 32 general operating room (OR) suites from November 2004 through January 2012. Perioperative Services is the University Hospital department that coordinates the hospital's perioperative process. During this time span, University Hospital's Perioperative Services broadened its scope to include three other surgical services within the University Hospital System, adding cardio-vascular suites and two off-site surgical clinics for an additional 38 OR suites.

CASE BACKGROUND

Figure 2 depicts University Hospital's clinical scheduling IS (CSIS) architecture as of October 2004. University Hospital has six main IS: (1) a large-scale hospital materials management IS, which included pharmacy, material and medical device management (Vendor L); (2) a large scale enterprise resource planning IS (Vendor 0); (3) a patient record Admit/Discharge/Transfer IS (Vendor Q); (4) a cost accounting IS (Vendor T); (5) a financial budgeting IS (Vendor H); and (6) a CSIS (Vendor C) that included three modules for clinical scheduling, routing sheets, and cost data. All IS were integrated with uni-directional constraints placed on sensitive information. The institutional intranet served as portal access to extend each of the six IS. The arrows identify data streams that flow between the integrated IS via a common interface engine. User authentication via the intranet was single entry with particular user-IS rights and privileges negotiated upon authentication.

University Hospital opened a new diagnostic and surgical facility in November 2004. Perioperative Services relocated into three floors, with ORs located over two floors and CSS located separately on a third. The move expanded Perioperative Services to cover an additional floor and nine additional ORs. The new facility housed 40 state-of-the-art OR suites. Within

six weeks, scheduling metrics reflected chaos. On-time surgical case starts (OTS) plunged to 18% during December 2004. In a highly competitive hospital industry, having only 18% OTS is unacceptable as 82% of scheduled surgeries risk patient care and safety. In January 2005, the C-level executive committee changed Perioperative Services management structure to form a cross-functional, multidisciplinary perioperative executive team empowered to evoke change. The perioperative executive team consisted of surgeons, nurses, anesthesiologists, and perioperative management. Between January 2005 and March 2007, the perioperative executive team initiated a continuous process improvement effort to address the perioperative crisis. By early 2007, the process improvement effort had obtained proof of concept and scheduling metrics were on target towards the acceptable benchmark.

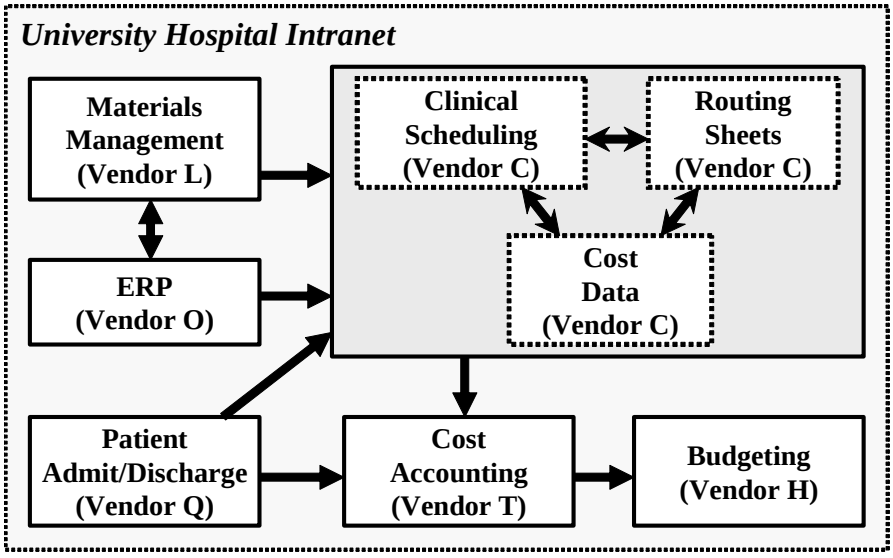

Figure 2 – IS architecture (October 2004)

The continuous improvement achieved by Perioperative Services over FY2005 and FY2006 allowed the perioperative executive team to move forward in early 2007 to extend the CSIS across University Hospital and address hospital-wide patient flow. All areas of University Hospital were integrated with Vendor-C's CSIS. The project, labeled IMPACT, targeted patient flow and patient satisfaction through the multidisciplinary use of patient electronic medical records and tracking technology.

Since completion of the IMPACT project, Perioperative Services has completed several continuous improvement projects including adapting heuristic OR scheduling rules to provide a modified block OR scheduling in 2009 and re-engineered the preoperative patient flow to a preoperative assessment and treatment clinic within Perioperative Services in 2011.

RFID APPLICATION EVALUATION AND PHASED PLAN

Given the success of previous continuous improvement projects, the perioperative executive team began considering RFID applications adaptable to the current perioperative processes in late 2009. The opportunity to achieve real-time, wireless data integration into the integrated CSIS was a desired RFID benefit as well as the interaction efficiency, cost effectiveness, and patient safety benefits. Cross-functional teams were identified to evaluate potential RFID data integration applications and requests for proposals were initiated in February 2010. University Hospital segments large IS/IT projects into phases and requires a graduated proof of concept (POC) from each IS/IT project phase prior to proceeding on to the next phase.

Two RFID applications were chosen to begin the initial project phases, due to the minimum infrastructure installation and implementation requirements. Both of these RFID applications were implemented in other hospitals and the third-party vendors had proven track records of implementation success. Three other more rigorous RFID applications were targeted for later phases to provide time for architecture and infrastructure modifications as well as the opportunity to gain RFID implementation experience and flatten the anticipated learning curves associated with the more difficult implementations. Specifically, the phased plan in Table 1 represents University Hospital's RFID project to integrate RFID technologies with the current CSIS.

Project Phase	Perioperative Process/CSIS/RFID Integration	Required Proof of Concept (POC)
1	Track, manage, and report potential sponge RFSB during each surgical procedure	Based on existing research, requires continued checklist count during the pause surgical procedure timeout. POC will track surgical count discrepancies.
2	Track, manage, and report tissue inventories as well as transfer traceability documentation to the patient's medical record.	Requires a transfer of tissue history data to the receiving patient's medical history. This POC requires CSIS metrics / benchmarks and a high data quality with no source data entry. The particular inventory and its history will be transferred first to the circulating nurse and then to the receiving patient's history, without source data entry.
3	Track, manage, and report medical device inventories as well as transfer traceability documentation to the patient's medical record. Medical devices include artificial joints (i.e. ankle, knee, hip, etc.), pins, screws, bolts, bone graphs, stints, etc.	Requires a medical device history data transfer to the receiving patient's medical history. This POC requires high data quality without source data entry as well as productivity increases as a requirement. POC also requires high validity as to the contextual location of the individual medical devices within a defined proximity. The particular inventory and its history will be transferred first to the circulating nurse and then to the receiving patient's history, without source data entry.
4	Track, manage, and report medical equipment within the sterile field of each operating room.	Requires installing RFID infrastructure within the sterile field of each OR. Implementation time for medical equipment will vary, depending on the ability to schedule infrastructure installation. POC also requires high validity as to the contextual location of the individual medical equipment within a defined proximity.
5	Track, manage, and report perioperative staff within the sterile field of each operating room.	Requires the same sterile RFID infrastructure as the medical equipment, so implementation time will be significantly less. POC requires high validity as to the contextual location of the individual perioperative staff within a defined proximity. POC will include surgical personnel time in and time out without source data entry.

Table 1 – Phased Perioperative Process / CSIS / RFID Data Integration Project

PHASE ONE: SPONGE RFSB TRACKING IMPLEMENTATION

Phase one was fully implemented in July 2011. A turn-key, third-party solution provider was chosen via request for proposal (RFP) and the subsequent request for quote (RFQ). The integration solution uses passive RFID tags stitched into the seam of each sponge used in the ORs. During July 2011, each operating room was equipped with a portable wand reader, a detection mat that must be placed under the patient, and a RSFB sponge detection console. The additional RFID tagged sponges cost approximately $15 more per averaged surgical case. Figures 3 and 4 illustrate the RFID equipment used in each of the operating rooms to detect sponges as RFSB.

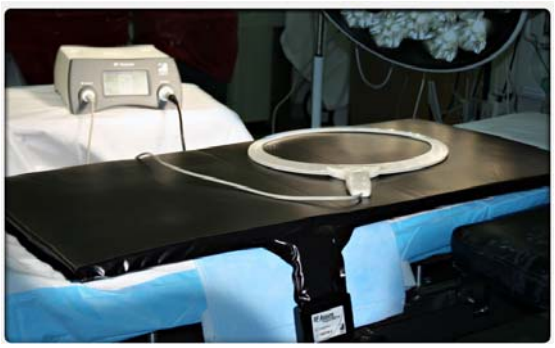

Figure 3 – RFID Sponge RSFB Detection System

Figure 4 – RFID Tagged Sponge

Based on 1,600 clinical trials (Steelman, 2011; Tsikitas, 2010), the chosen RFID application found 21 missed sponges after correct counts (10 of which were in the surgical wound) and 7 sponges following incorrect counts (including 2 left inside patients). X-rays were used in 13 cases, but in no instance did the X-ray detect a sponge that had not been detected by the RFID system and the system produced no false negatives and no false positives. The end-of-surgery checklist counts continue to be performed and operating procedures now include the use of the RFID detection system. Phase one of the RFID project is implemented with acceptable POC performing to system expectations.

PHASE TWO: TRACK AND TRANSFER TISSUE TRACEABILITY CONSTRUCTION AND IMPLEMENTATION

University Hospital views this RFID application as a solution to maintain and report stringent Joint Commission standards in the transfer of tissue donor history to a receiving patient's medical history as well as manage 147 tissue products that approximately amount to $500K (i.e. Tissue Bank cost) in monthly inventory. The existing CSIS has a tissue donor information module and a certified third party integration vendor was chosen via RFP/RFQ. This initial system construction phase began in January 2011 to update the current CSIS version to accept the third party data integration.

Physical infrastructure construction begin in July 2011, upon the completion of phase one. As the third party solution provider is an application service provider (ASP), Perioperative Services management negotiated with University Hospital's IT department to obtain a static, external IP address for the RFID application to be serviced by the ASP. The RFID application also required University Hospital's legal counsel to review and amend the service level agreement (SLA) to meet system needs.

The RFID application uses secured cabinets, refrigerators, and freezers to store the tissue inventory. Refrigeration and sub-zero refrigeration are required for specific types of tissue transplants. A real-time integration between the CSIS and RFID system allows circulating nurses to authenticate via badge or typed identification number for inventory access. The circulating nurse removes the tissue transplant required and selects the receiving patient off the OR real-time schedule. The tissue charge and the donor transplant history are transferred to the patient account and medical records, respectively without source data entry. Figures 5, 6, and 7 depict the tissue freezer, refrigerator and work station, and RFID cabinets, respectfully, located on each floor of the OR suites. The passive RFID tags are read by the workstations located beside the freezer and refrigerator. The cabinet has readers on each cabinet drawer and tissue inventory is refreshed each time the cabinet door is closed. The RFID application provides a real-time tissue inventory and identifies tissue product that is beyond its shelf-life.

Figure 5 – Tissue Freezer

Figure 6 – Tissue Refrigerator

Figure 7 – Tissue Cabinet

Testing of the RFID system and CSIS integration in September 2011 identified several opportunities for improvement. The RFID cabinet identified a design flaw in that there were insufficient numbers of readers per drawer. Cabinet drawers had to be refitted with additional rows of readers to provide consistent, accurate inventory. In testing the integration between the CSIS OR schedule and the patient pick screen on the RFID system, the biomedical device data stream in University Hospital's interface engine would not segment the OR schedules by location. As a result, all patients from all 70 operating

rooms populated the pick screen. Since November, dual data entry is being performed on tissue inventory and donor history transfer until the biomedical device data stream and interface engine can be corrected via version upgrades.

Several opportunities for improvement were also identified with the RFID tags during the interim testing phase. The sub-zero temperature required by several tissue products degraded the adhesive on the RFID tags to where they would not stay on the tissue package. As a work-around, the RFID tags were placed with the tissue in plastic bags. Unfortunately, the sub-zero temperature degraded the plastic bags to where they crumbled on contact. Through several iterations with the tag manufacturer, a plastic bag was obtained that would withstand the sub-zero temperatures. Given the opportunities outstanding, phase two implementation is still underway until the POC is met.

REMAINING PHASES

As of February 2012, the implementation of phase two tissue POC has not been successfully met. Hence the remaining project phases are on hold. The following paragraphs elaborate on each of the outstanding phases.

University Hospital considers medical devices as high-value inventory items (in excess of $5M) that occupy very little space. Even though they are located in secured areas, their physical size affords many opportunities for inventory error. Visiting vendor representatives can easily create large inventory discrepancies by misplacing a handful of screws, pins or bolts—thus the need for contextual location of each inventory unit in phase three.

Medical equipment, within each operating room, is mobile. Hence an entire OR can be cleared in a matter of minutes and human nature allows for errors when resetting each OR. Phase four's cross-validation in the RFID/CSIS integration will check for: errors of omission that impact the patient's safety; errors of duplication that limit the use of scarce medical equipment; and errors of surplus in having equipment that is not needed. Currently, equipment checklists are manually entered before and after each surgery. By installing RFID infrastructure in each OR and installing RFID active tags on all medical equipment, contextual inventory by room will be dynamically managed while achieving productivity increases. Additional POC will require substantiation of the productivity increases as well as: automatic identification of duplications and/or omissions; automatic identification of surplus; and automatic identification of non-conforming operating room set-ups.

With respect to phase five, tracking the location of perioperative staff in the sterile field of the OR allows for Joint Commission documentation. While the patient is physically in the operating room, perioperative procedures and regulations require the documentation of each person (i.e. name, title, time of entry or exit, and length of attendance) attending, entering, or exiting a surgical procedure. Manual data entry of these events into the CSIS is currently the University Hospital standard operating procedure. However, phase five implementation will provide all perioperative staff badges with active RFID tags. Furthermore, surgical patients currently have barcode wrist bands. The contextual location of all surgical patients, perioperative staff, and visitors within the sterile field, through RFID/CSIS integration, will provide automatic logging of all individuals in attendance during each surgery. Additional POC will require substantiation of attendance logs without source data entry

CONCLUSION

Empowered individuals, integrated IS, and a holistic framework for RFID application and data integration improved patient safety against sponges as RSFB and will provide tissue donor history transfer without source data entry. Moreover, both RFID application implementations have anticipated advantages and benefits for all stakeholders. The potential elimination of RSFB due to sponges increases the quality of patient care, patient safety, and clinical outcomes. Anesthesiologists, surgeons, nurses, and perioperative staff have a technology application to double-check surgical checklist sponge counts, which reassures perioperative team members. Perioperative Services gained greater accountability to capture data with fewer data quality problems. Lastly, hospital administration will minimize RSFB risk and gain reporting capabilities to meet Joint Commission standards via the existing CSIS with increased documentation and decreased source data entry.

Adopting a holistic framework for planning, constructing, and implementing RFID application and data integration initiatives educates hospital stakeholders on the benefits of integrated IS, performance monitoring, and process improvement. The cycle of analysis, evaluation, and synthesis reinforces communication and stimulates individual as well as collective organizational learning. Perioperative staff gained increased communication and increased professional awareness.

Our case study contributes to the healthcare IT literature by examining how RFID application and data integration are applicable to the hospital environment and our case study prescribes an a priori framework to foster their occurrence. This paper also fills a gap in the literature by describing how the interaction between RFID domains of efficiency, cost effectiveness, and patient safety are applicable to the perioperative processes. This study was limited to a single case, where future research should broaden the focus to address this issue along with others that the authors may have inadvertently overlooked. The case examples presented in this study can serve as momentum for further methodology comprehension and extension, while the results should be viewed as exploratory and in need of further confirmation. Researchers may choose to further or expand the investigation; while practitioners may apply the findings toward other RFID applications in the hospital environment.

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