Application of Radio-frequency Identification in Perioperative Care

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ABSTRACT

Every perioperative department could benefit from having an information system that facilitates managerial function and improves efficiency in the OR. The Patient Advancement Monitoring System–Surgical implemented in a hospital in Taipei, Taiwan, is one such a system that uses radio-frequency identification technology for tracking perioperative care of patients along workflow checkpoints. This web-based medical information system can facilitate care provided throughout perioperative services by providing instant patient information to staff members in cross-functional health care teams. Manpower is not wasted on duplicating data entry because the surgical progression is displayed in real time. Satisfaction with the system has been high for both nurses and administrators.

Key words: patient monitoring systems, perioperative care, radio-frequency identification.

The OR is a pivotal unit in a hospital. Highly professional teams use expensive and delicate equipment to serve surgical patients. The perioperative workflow connects with the ambulatory surgery service, the emergency department, medical and surgical nursing units, and the intensive care unit. The perioperative services department is considered a major cost and revenue center that involves more than half the business of the entire hospital.1 The perioperative patient flow includes

- being scheduled for surgery;
- being admitted into the hospital or surgery center;
- being prepared for surgery in a medical or surgical nursing unit or the emergency department;
- undergoing preoperative medical, anesthesia, and nursing evaluations;
- undergoing surgery;
- recovering from surgery in the postanesthesia care unit; and
- receiving postoperative care and being discharged from the facility.

Providing quality surgical care requires dealing with the complexity and customization of surgery,
ensuring continuity of care in a timely manner, preventing unnecessary repetition, and ensuring safety through the entire care workflow. Among these issues, safety, efficiency, and the integration of cross-functional medical teams are of paramount importance to OR managers.²

To improve management competency and enhance patient safety, we addressed the issue of data integration by tracking the entire surgical workflow throughout all perioperative areas and using radio-frequency identification (RFID) technology to develop the Patient Advancement Monitoring System–Surgical (PAM–S), a patient-centered, web-based medical information system. The PAM–S system is a complex system that incorporates the work of multiple surgical team members and provides consistent and sequential information. Goals of the PAM–S system are to enhance the quality, safety, and efficiency of OR management.

**RFID TECHNOLOGY**

Radio-frequency identification technology provides automatic, wireless identification and data capture for data management. Nagy et al³ reviewed applications of RFID in surgical settings in three domains:

- workflow tracking of assets and staff members (ie, productivity);
- medication and inventory supply chain (ie, cost control); and
- patient tracking (ie, safety).

Additional benefits of RFID technology are derived from the interaction among the three domains, such as patient identification when tracking assets (eg, productivity domain) or controlling supply inventory (eg, cost control domain).

Chang et al⁴ examined the status of RFID applications in relation to patient safety in Taiwan by administering questionnaires to perioperative practitioners and health care workers about the benefits of RFID applications on operational structure (eg, improving service efficiency), users (eg, reducing user workload), the organization, and the environment (eg, ability to reuse active RFID tags). They concluded that the benefit of data integration was the most significant factor and had the greatest potential to facilitate patient safety.

An RFID system consists of sensing chips and noncontact RFID tags, which may be active or passive, and RFID readers. The sensing chips and RFID tags send and receive information by wireless radio-frequency messages, so the RFID tag need not connect directly with the RFID reader to exchange information. The RFID tags have active and passive forms. A passive tag consists of a chip and an antenna to send messages to the RFID reader and is similar to a bar code on a wristband. An active tag (eg, a wristband similar to a watch) consists of a built-in battery to send messages over distance and a sensor to record temperature or position data.

An RFID tag can be programmed to send a variety of information such as the serial number, model number, price, stock number, date, and even a temperature record of deteriorated medications. Unlike a standard bar code reader that can analyze only one piece of data at a time, an RFID reader consists of a microprocessor that can rapidly and accurately track a large number of messages at one time. Radio-frequency identification technology is now widely applied in many medical services, such as hospital management,⁵ and for a variety of uses, such as managing inpatient medication administration,⁶ tracking dressing changes,⁷ determining whether an endotracheal tube is positioned correctly,⁸ and tracking safe transfer of patients between caregivers.⁹

Reviews by Gunn¹⁰ and Roeder¹¹ indicate that the use of a standardized perioperative record and data repository system and electronic documentation systems could help staff members provide standardized care to patients. Using a standardized framework for the patient flow process provides staff members with the most current patient updates and allows them to conveniently evaluate the care needs and outcomes of
individual patients. This should provide staff members with an accessible channel for education, training, and communication, in addition to providing accessible medical information about the patient for evaluation and reference by other staff members.\textsuperscript{12}

Westerling and Bergbom\textsuperscript{13} recommend that advocacy be integrated into the surgical patient care processes. One facet of advocacy is using checklists to ensure patient safety. Research conducted by Fowler et al\textsuperscript{14} showed that checklists can ensure the security and comprehensiveness of patient care. For instance, checklists are ideal for use before induction of anesthesia (ie, sign in), before the skin incision (ie, time out), and before the patient leaves the OR (ie, sign out). These checklists are integrated into the PAM–S system.

**THE PAM–S SYSTEM**

The PAM–S system was implemented at a medical center in Taipei, Taiwan, which has 742 beds and 1,600 staff members. Eleven surgical services use the 14-room OR suite (ie, cardiovascular, colorectal, general, neurosurgery, obstetrics and gynecology, ophthalmology, oral surgery, orthopedics, otolaryngology, plastic surgery, urology). Patients come to the OR from clinical services, inpatient services, and the emergency department. The annual surgical procedure volume is approximately 22,000 patients. Among these, 42% undergo ambulatory surgery, 52% undergo inpatient surgery, and 6% undergo emergency surgery. There are 60 nursing staff members in the OR.

Personnel who participated in the design of the systems included the quality control administrator, information engineer, OR head nurses, medical and surgical unit head nurses, emergency department head nurse, anesthesia department head nurse, patient transportation center head nurse, and engineer in charge of system development. The team held 88 meetings between June 2006 and February 2008. System implementation was completed in 20 months.

**System Framework and Design**

The PAM–S system uses RFID tags and bar codes. Ultra-mobile personal computers and desktop computers are used as data entry points. Radio-frequency identification is used for control of the patient flow process in the PAM–S system. The system is used to follow the perioperative processes of surgical patients, including scheduling, admission, emergency department treatment, anesthesia, surgery, and postanesthesia recovery (Figure 1). The PAM–S is also connected to the OR scheduling system in the hospital information system, which automatically updates its contents every three minutes.

When a patient is admitted to the OR, admissions personnel place an RFID tag on the patient’s wrist. The RFID wrist tag system is set at a frequency of approximately 2.40 to 2.48 GHz with a transmission range of up to 80 m; a receiver signal strength indicator of zero to 255; two color, light-emitting diode visual indicators; and one 3-volt lithium battery with a one-year battery life. The RFID tag is capable of saving and deleting data, and it is made of materials that can be sterilized and used repeatedly. The RFID tag and RFID reader are an integrated design capable of working together in a reading range of 50 m (Figure 2). The RFID readers are set up in medical and surgical nursing units, ORs, postanesthesia care unit (PACU) rooms, and waiting areas (Figure 3) and can automatically read the information transmitted from the ORs.

**System Objectives**

The RFID tags for the PAM–S system provide patient location information to calculate traveling or service times in and around the checkpoints. The RFID tag also serves as an adjunct for patient identification verification. Quality indicators (eg, completion of the preoperative check, patient identification verification, administration of prophylactic antibiotics) are calculated and integrated using the information entered into the system through various data entry points.

To reduce the workload of additional data entry loading, the PAM–S system is linked with the hospital information system to download basic
patient demographic information (e.g., name, date of birth, primary diagnosis, identification number, medical record number). The surgical scheduling system in the hospital information system also provides the date of surgery, date of hospitalization, type of anesthesia, surgery type, physician, time of surgery, and blood type information. Thus, this information can be verified again and again along the workflow without duplicated data entry.

All OR team members (e.g., surgeons, residents, nurses, anesthesia care providers, ancillary support members) are required to perform a sign in, time out, and sign out in the PAM–S as recommended by the World Health Organization Surgical Safety Checklist.\textsuperscript{15} Perioperative practitioners and health care workers entered the data into the PAM–S for audit.

**IMPLEMENTING THE SYSTEM**

Team members (e.g., clinical staff members, hospital quality control administrator, medical information engineer, RFID manufacturing representative) completed the system design in December 2006. A relational database (i.e., a database structured to

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**Figure 1.** The project framework shows the patient flow through the perioperative areas.

**Figure 2.** The radio-frequency identification reader automatically begins reading radio-frequency identification tags and thus monitors the patient’s advancement through the perioperative process.
recognize relations between stored items of infor-
mation) was used as a back-end platform database
to incorporate basic patient information from the
health information system along with details from
the OR scheduling system and information ob-
tained from the laboratory. The PAM–S online
database can be used to track patients concu-
rently, automatically collecting information or
analyzing statistical data. The implementation
process for the PAM–S included
- installing the RFID location display manage-
ment system;
- digitizing nursing forms and sheets;
- integrating the related patient medical history
  information application system and its test
  operation; and
- educating and training staff members.
When the system was in place, system operation
was tested and evaluated.

Installing the RFID Location Display
The team completed installation of the RFID
location display management system in December
2006. The RFID location displays were lo-
cated in the OR, patient transport center, anes-
thesia department, PACU, and equipment room.
The system can be used for ambulatory, inpa-
tient, and emergent surgical procedures. Pilot
testing of the system was conducted in one se-
lected general nursing unit. The complete work-
flow was equipped with 10 RFID readers and
21 checkpoints.

Digitizing Forms and Sheets
The team completed digitizing 28 forms and
sheets in June 2007. Examples of these forms
include a surgical log-in and home page identi-
fying the patient’s location (Figure 4), a preop-
erative preparation form that integrates the pre-
anesthesia evaluation and preoperative nursing
checklist (Figure 5), and a surgical patient op-
erative site verification, OR team members’
verification checklist, and postanesthetic health
status evaluation (Figure 6).

Integrating Patient Medical Information
Integration of the patient medical information ap-
plication system was completed in June 2007. With the
assistance of computer engineers, the PAM–S de-
velopment team started pilot testing the system. The
process was completed in three months.
Educating and Training Staff Members
Medical information personnel, quality control administrators, and the OR head nurse underwent education and training starting in January 2007. This training included

- initial education before incorporation of the system,
- second-stage training during which a simulation of the system was used before actual system use began, and
- third-stage training during implementation of the system and when online training materials were created.

There were a total of 22 training sessions. The process took 14 months to complete. Subsequent education was conducted for the rest of the perioperative team members (eg, nurses, surgeons, support staff members).

APPLICATION OF THE PAM–S SYSTEM
The PAM–S system can automatically generate information for all phases of surgical care. The information can be presented according to any variety of types of health care providers.

Figure 4. Surgical log-in and home page identifying the patient's location.
Perioperative Nursing Applications

During the preoperative period, OR nursing staff members conduct a preoperative consult, which includes assessing the surgical patient to

- learn about the patient’s expectations of the surgical procedure,
- briefly describe the surgical procedure,
- ease the patient’s anxiety before the surgical procedure, and
- prepare the tools and equipment needed for the procedure.

Before the preoperative nurse conducts the preoperative consult, he or she can check the computer files to establish a preliminary understanding of the patient, his or her condition, and the completeness of preparation for surgery. This greatly reduces work time because most of the preparation information has already been entered into the system by admissions personnel during the patient’s admission to the facility. In addition, the use of this system reduces the chances that information will be lost and increases the accuracy of the patient care handoffs (Figure 7). Patient transportation requests also can be transmitted online. This significantly reduces the chance of errors and incomplete information that can be experienced with traditional telephone notification.

When the patient arrives in the OR waiting area, the nurse checks the contents of the preparation checklist and the surgical patient safety checklist and signs the sheets stating that nothing is missed. Nursing personnel record the time and all preparation procedures before surgery, including the patient’s information and that the RFID tag was secured on the patient’s wrist during the admission process. Forms that the preoperative nurse completes include the preoperative consult sheet, preoperative preparation checklist, and surgical patient safety checklist.

The main role of OR nursing personnel during the intraoperative period is care of the patient. The goal is to improve safety and ensure quality patient outcomes and to facilitate success of the surgical procedure. After the patient enters the OR, the circulating nurse completes the intraoperative nursing record, surgical preparation checklist (eg, sign in, time out), equipment checklists, nursing care certificates, and surgical equipment records.

During the surgical procedure, OR nursing staff members input surgery-related information step by step during the progress of surgery. This allows OR supply room, PACU, and postoperative nursing unit staff members to monitor the progress of surgery, prepare in advance to care for the
particular patient, and prepare for subsequent patients.

Additionally, PACU nursing staff members should check information such as the progress of surgery and medical updates before the patient is transferred to the PACU to ensure proper preparation for the patient care hand off. The primary role of OR nursing staff members during postoperative periods is to transfer the patient to the PACU and update PACU nursing staff members.
on the condition of the patient to ensure proper postoperative care. The PACU nurse checks the information entered into the computer in the form of operating care records and OR and PACU checklists to ensure accuracy of the patient information. For the postoperative consult (ie, patient care hand off), nursing staff members should check the most current laboratory reports to facilitate the interview process as well as record the consult results in the computer.

OR Administrator Applications
Throughout surgery, OR administrators are able to use the PAM–S system to access and manage basic information, including surgery type, surgical procedures, surgical time, anesthesia type and time, blood transfusion type and volume, use of surgical instruments, time in the OR, and other procedural information. Thus, the OR administrator can conveniently access comprehensive information regarding the surgical patient for decision making and statistical analysis of process and outcome audits. The PAM–S system can automatically generate quality indicators, including

- completion of services (ie, completeness of data entry into the forms for designated checkpoints),
- occupancy of surgical nursing units,
- completeness of the preoperative preparations,
- surgical cancellations,
- OR turnaround time,
- the need for reoperation, and
- timing and completeness of prophylactic antibiotic administration.

USER SATISFACTION EVALUATIONS
The OR nursing staff members started using the PAM–S system in March 2008. In March 2009, after one year of use, we conducted a PAM–S system user satisfaction survey. Fifty-two (87%) of the 60 OR nursing staff members responded to the survey; of those who responded,

- 78.3% considered the system easy to operate;
- 82.6% agreed that use of the system could improve communication between surgical teams;
- 91.3% agreed that the system is conducive to improving patient identification and promoting surgical safety;
72.2% believed that the system is helpful in improving efficiency of departmental administration; and
95.7% believed that department chiefs and hospital administrators are very much in favor of using this system.

The nurses described their overall satisfaction rate of this system at 80%.

Administrative staff members who used the PAM–S system included surgical supervisors, quality management center supervisors, OR supervisors, and anesthesiology department supervisors. Forty-eight (67%) of the 72 administrative staff members responded to the survey; of those who responded, 98% viewed the administrative functions of the PAM–S system positively. Their overall satisfaction rate was 95%.

THE BENEFITS OF USING THE PAM–S SYSTEM

Through use of the PAM–S system, data are captured that allowed objective evaluation of patient care processes. The information stored in the PAM–S system provides process and outcome audit capability for OR administrators. For instance, the patient identity check correction rates increased from 75% at baseline (March 2008) to 100% after implementation (March 2009). The American Society of Anesthesiologists physical status classification verification rates increased from 53.2% to 86.9%. Instrument loss rates decreased from 0.146% to 0.089% after implementation. Appropriate antibiotics prophylaxis administration rates were maintained between approximately 81.4% and 100% for six major surgical entities (ie, cardiac bypass surgery, transabdominal hysterectomy, vaginal hysterectomy, total knee/hip replacement, appendectomy). The first surgical start time delay rates have decreased from 4% to 1%, and the average surgical time delay has decreased from 25 to 10 minutes. The physician time out execution rates have increased from 43% to 70%.

After incorporation of the PAM–S system, medical errors were reduced to a minimum and correct patient, OR, and surgical procedure identification rates have been maintained at 100%. The preoperative prophylaxis antibiotics were all administered 31 to 60 minutes before the surgical procedure, and the surgical supplies (eg, instruments, sponges, suture needles, blades) were accounted for 100% of the time. This improves the quality of care that patients receive.

DISCUSSION

Advances in computers and information technology have helped improve quality of life and the quality of work performance. The PAM–S system used in this project was designed based on the concepts of the preoperative, intraoperative, and postoperative care needs for patients, covering the entire care process to facilitate detailed and comprehensive information sharing between staff members. A web-based PAM–S system provides an excellent information-sharing platform. Key information needs to be entered into the system only one time, and cross-functional team members can then share and double-check this information online with great convenience and accuracy.

Sixty OR nursing staff members work at the hospital where this system was implemented. Their work experience ranged from one to 30 years; 50% had worked in the perioperative field for longer than 20 years, and their average age was 39.8 years. Before 2005, these nursing staff members had no experience in using computers for documentation of medical care. Therefore, it was a challenging task to implement an innovative information technology system. When the system was first proposed, the project was met with skepticism and the nurses’ fear of having to input additional data. These concerns have been resolved through persistent communication and intensive computer education and training provided for perioperative practitioners and other health care workers during the first year between pilot testing and implementation.
The use of the PAM–S system helps administrative personnel track the progress of surgical procedures to better manage OR turnaround time. Before this system was implemented, the average OR turnaround time was 25.8 minutes; the turnaround time was reduced to 20.2 minutes after implementation of the PAM–S system—an improvement rate of 25%. The PAM–S system proved to be effective in improving OR efficiency.

Use of the PAM–S system in the OR also benefits family members in the waiting room by providing real-time information. Messages of patient arrival time, surgery starting time, and surgery ending time can be displayed on a computer screen. This function greatly improves our service quality to ease the anxiety of the waiting families.

There are several areas to consider for potential upgrades to the PAM–S system. According to Fowler et al, the system should include interfaces for

- volume,
- procedure mix,
- procedural duration data,
- percentage of add-on and emergency procedures,
- block time utilization,
- budget variances,
- percent compliance with the quality indicators,
- start time accuracy for first procedures of the day,
- room turnover times, and
- patient and staff member satisfaction.

**CONCLUSION**

The web-based, RFID-initiated PAM–S system proved to be useful in enhancing quality care, patient safety, and efficiency of OR management. The data entered into the system along the surgical patients’ entire care workflow are verified, shared, and analyzed through the PAM–S information management platform. The information can be used for decision making to improve the quality of care, patient safety, utilization efficiency, inventory management, and service satisfaction.

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Application of Radio-frequency Identification in Perioperative Care

PURPOSE/GOAL

To educate perioperative nurses about the advantages of implementing a radio-frequency identification (RFID) patient monitoring system in a health care facility.

OBJECTIVES

1. Describe RFID technology.
2. Discuss the components of an RFID-based surgical patient monitoring system.
3. Explain nursing responsibilities related to use of an RFID-based surgical patient monitoring system.

The Examination and Learner Evaluation are printed here for your convenience. To receive continuing education credit, you must complete the Examination and Learner Evaluation online at http://www.aorn.org/CE.

QUESTIONS

1. Radio-frequency identification technology can be applied in different domains within the surgical settings, including the domains of
   1. competency.
   2. cost control.
   3. productivity.
   4. safety.
       a. 1 and 3       b. 2 and 4
       c. 2, 3, and 4    d. 1, 2, 3, and 4

2. The RFID tag must connect directly with the RFID reader to exchange information.
   a. true      b. false

3. An RFID tag that consists of a chip and an antenna to send messages to the RFID reader is considered.
   a. active.    b. passive.

4. An RFID tag can be sterilized and used repeatedly.
   a. true      b. false

5. Some objectives for an RFID-based patient monitoring system could be to
   1. allow calculation of quality indicators.
   2. facilitate calculation of travel or service times.
   3. provide patient location information.
   4. verify patient identification.
      a. 1 and 2      b. 3 and 4
      c. 1, 2, and 4  d. 1, 2, 3, and 4

6. Using an RFID-based patient monitoring system, patient demographic and surgical information can be verified along the workflow without duplicated data entry.
   a. true      b. false
7. During the surgical procedure, OR nursing staff members input surgery-related information step by step, which allows OR supply room, postanesthesia care unit, and postoperative nursing unit staff members to  
   1. process surgery-related charges.  
   2. monitor the progress of surgery.  
   3. prepare in advance to care for the particular patient.  
   4. prepare for subsequent patients.  
      a. 1 and 3  
      b. 2 and 4  
      c. 2, 3, and 4  
      d. 1, 2, 3, and 4  

8. Quality indicators that can be tracked in an RFID-based patient monitoring system include  
   1. completion of services.  
   2. occupancy of surgical nursing units.  
   3. OR turnaround time.  
   4. surgical cancellations.  
   5. timing and completeness of prophylactic antibiotic administration.  
      a. 4 and 5  
      b. 1, 2, and 3  
      c. 1, 2, 3, and 4  
      d. 1, 2, 3, 4, and 5  

9. The information stored in an RFID-based patient monitoring system provides process and outcome audit capability for OR administrators, including  
   1. antibiotic prophylaxis administration rates.  
   2. instrument loss rates.  
   3. first surgical start time delay rates.  
   4. patient satisfaction levels.  
   5. physician time out execution rates.  
      a. 4 and 5  
      b. 1, 2, and 3  
      c. 1, 2, 3, and 5  
      d. 1, 2, 3, 4, and 5  

10. Use of an RFID-based patient monitoring system in the OR also can benefit family members by displaying real-time information about patient arrival time, surgery start time, and surgery end time.  
    a. true  
    b. false  

The behavioral objectives and examination for this program were prepared by Rebecca Holm, MSN, RN, CNOR, clinical editor, with consultation from Susan Bakewell, MS, RN-BC, director, Center for Perioperative Education. Ms Holm and Ms Bakewell have no declared affiliations that could be perceived as posing potential conflicts of interest in the publication of this article.
CONTINUING EDUCATION PROGRAM

Application of Radio-frequency Identification in Perioperative Care

This evaluation is used to determine the extent to which this continuing education program met your learning needs. Rate the items as described below.

OBJECTIVES
To what extent were the following objectives of this continuing education program achieved?

1. Describe radio-frequency identification (RFID) technology. Low 1. 2. 3. 4. 5. High
2. Discuss the components of an RFID-based surgical patient monitoring system. Low 1. 2. 3. 4. 5. High
3. Explain nursing responsibilities related to use of an RFID-based surgical patient monitoring system. Low 1. 2. 3. 4. 5. High

CONTENT
4. To what extent did this article increase your knowledge of the subject matter? Low 1. 2. 3. 4. 5. High
5. To what extent were your individual objectives met? Low 1. 2. 3. 4. 5. High
6. Will you be able to use the information from this article in your work setting? 1. Yes 2. No
7. Will you change your practice as a result of reading this article? (If yes, answer question #7A. If no, answer question #7B.)

7A. How will you change your practice? (Select all that apply)
1. I will provide education to my team regarding why change is needed.
2. I will work with management to change/implement a policy and procedure.
3. I will plan an informational meeting with physicians to seek their input and acceptance of the need for change.
4. I will implement change and evaluate the effect of the change at regular intervals until the change is incorporated as best practice.
5. Other: ____________________________________

7B. If you will not change your practice as a result of reading this article, why? (Select all that apply)
1. The content of the article is not relevant to my practice.
2. I do not have enough time to teach others about the purpose of the needed change.
3. I do not have management support to make a change.
4. Other: ____________________________________

8. Our accrediting body requires that we verify the time you needed to complete the 2.8 continuing education contact hour (168-minute) program: ___