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CE

Radiofrequency Identification

Exploiting an Old Technology for Measuring Nurse Time and Motion

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A national campaign is underway to increase the amount of time staff nurses spend at the bedside of hospitalized patients through redesign of the work environment. This kind of work redesign requires robust data depicting what nurses do and how they spend their time. Historically, these kinds of data have been difficult, costly, and time consuming to collect. Wireless capture of data on the movement of humans within the work environment (ie, time and motion) is now possible through radiofrequency identification technology. When small tracking devices the size of a quarter are affixed to their clothing, the movement of nurses throughout a patient care unit can be monitored. The duration and frequency of patient interaction are captured along with the duration of time spent in other locations of interest to include nurses' station, supply room, medication room, doctors' station, electronic documentation stations, family waiting rooms, and the hallway. Patterns of nurse movement and time allocation can be efficiently identified, and the effects of staffing practices, workflows, and unit layout evaluated. Integration of radiofrequency identification time and motion data with other databases enables nurse leaders to link nursing time to important cost and quality outcomes. Nurse leaders should explore the usefulness of radiofrequency identification technology in addressing data needs for nurse time and motion.

KEY WORDS

Nursing work environment • Nursing time allocation • Nursing administration • RFID

The nursing workforce is a significant driver of hospital costs, and the nursing work environment a threat to patient safety.[1,2] Nurse leaders are charged with finding the right balance between safety and efficiency in the design of work processes and deployment of nursing staff. Evidence-based management of these activities is encouraged.[2] Robust data depicting what nurses do and how they spend their time linked with patient-level cost and outcome data are ideal.[3,4] Data relevant to the work of nursing, the deployment of nurses, and the subsequent contribution to patient outcomes and cost of care are difficult, costly, and time consuming to capture.[5] New strategies are needed to efficiently generate the quantity and quality of data sufficient to support evidence-based management decisions. Radiofrequency identification (RFID) technology is an efficient data collection and communication system that may prove to be a useful strategy in this endeavor. The purposes of this article were twofold: (1) to describe how RFID technology functions in the collection and transmission of data and (2) to encourage creative and innovative application of this technology by nurse leaders to support evidence-based management of work process design and workforce deployment.

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DEFINITION AND EVOLUTION OF RADIOFREQUENCY IDENTIFICATION TECHNOLOGY

Radiofrequency identification has been described as the bridge between physical and information spaces and classified as a wireless automatic identification and data capture technology[6,7] Radiofrequency identification involves the automatic identification of objects and transfer of digitalized data associated with those objects via radio waves.[8–10]

Electromagnetic Theory

The theoretical roots of RFID technology extend from electromagnetic theory (EMT) initially conceived by physicists in the 19th century. Faraday first postulated that light and radio waves are a source of electromagnetic energy in 1846, and Maxwell provided the first published theory of the electromagnetic field in 1864.[11,12] Maxwell defined the conditions for propagation of electromagnetic waves and suggested that they would share the characteristics of light waves.[13–15] Empirical confirmation of Maxwell's theory was achieved in 1887 when Hertz documented the first transmission and reception of radio waves and validated that electromagnetic waves obey the laws of propagation and reflection.[11,12,16]

The first practical application of EMT to be exploited was radio communication. Marconi is credited with the idea of using radio waves for communication, and through a series of experiments in 1895, he developed a radio signaling apparatus.[13] Marconi came to be known as the father of wireless, and much of his early work focused on communication with and between ships at sea. A second major application of EMT, radar location, occurred in the early 20th century.[11] The idea of using radio waves to detect the location of objects from a distance was discussed as early as 1904 by Hulsineyer. Empirical validation of this idea came in 1922 when Taylor and Young documented the interruption of radio communication across the Potomac by a ship and presumed the cause to be interception of the propagation path between transmitters and receivers.[13] These investigators subsequently explored the use of radio transmission to detect the location of enemy vessels at the Naval Research Laboratory in 1931.[13]

Independent and parallel observations of interruption in the radio propagation field by aircraft were noted by British engineers conducting research on short-wave radio and television.[13] A British meteorologist, Watson-Watts, initially sought to make use of this discovery for the purpose of locating thunderstorms and warning pilots of their impending arrival.[17] The need for early detection and warning of incoming German aircraft during World War II served as the impetus to shift his research focus to military defense. Watson-Watts was the first to successfully demonstrate that an aircraft flying through radio waves would deflect some of the signal and that the reflected signal could be detected by a receiver and used to identify the flight course.[14,17] This finding would change the course of the war effort as well as the course of radio technology research and earn Watson-Watts recognition as the inventor of radar.[17] Significant financial resources were mobilized by the US and British governments to rapidly capitalize on this new discovery. Radar technology advanced from this point forward primarily as a result of the interdependent collaborative efforts of British and US scientists and primarily for the purposes of military defense.[13–15]

Two-Way Wireless Communication

The convergence of these two technologies, that is, radio communication and radar, became the foundation of what we now know as RFID technology. Stockman[18] is credited with the genesis of RFID because he was the first to demonstrate two-way wireless communication based on the principle of modulated reflected power.[11,18] In conventional radar applications, an electromagnetic signal is radiated toward a target. Reradiation occurs as the waves are reflected off the target and back toward the transmitter. This type of reflection is said to occur in an omnidirectional and uncontrolled manner, creating a large amount of scatter and loss of power. The returning waves function as carriers of information because their return pattern can be used to identify the existence and location of the target.

Stockman[18] demonstrated that manipulation of the reflected power beacon could establish two-way communication between the transmitter and target. He theorized that manipulation of the reflected waves could be achieved through processes of target reflector modulation. Modulation involves varying some aspect of the signal wave,[8] which Stockman achieved with placement of reflectors on the target. The reflectors afforded some control over the direction of the reflected waves, thereby reducing scatter and loss of power. Signal strength was effectively increased, and the nonscattering target was established as a potential source of information transmission. Stockman recognized that practical application of the principle of reflected power communication would require considerable research on modulation methods and technological advancement to facilitate further control over reflected waves. It would take some 30 years, but by the 1970s, the practical applicability of RFID technology was ripe for development in the commercial sector. This was facilitated by Harrington's theory of loaded scatters in 1964 and the subsequent development of appropriately sized antennas, receivers, transistors, integrated circuits, and microprocessors.[11]

Commercial Applications of Radiofrequency Identification Technology

One of the earliest commercial uses of RFID was for electronic article surveillance by retailers.[11] Articles of merchandise became the targets of interest and were equipped with small modulating devices called "tags." Transmitters were typically placed at each exit. The signal reflected from a tag passing through the exit carried information that triggered an alarm. Other early applications of RFID technology included animal and vehicle tracking. In the 1980s, RFID technology expanded to include electronic toll collection via "toll tags" placed on vehicles and gated access entry via handheld access cards. By the late 1990s, the application for supply chain and inventory management was realized.[11,19] Wal-Mart became an early adopter of RFID technology for inventory management and is credited as a key driver in its continued development.[9,19] In 2003, Wal-Mart required that suppliers deploy RFID tags to track product pallets, cases, and individual items. By 2006, nearly 300 Wal-Mart suppliers were providing tagged goods into their inventory system.[19] Radiofrequency identification has been heralded as one of the 10 greatest contributory technologies of the 21st century with global sales projected to increase from $4.96 billion in 2007 to over $26 billion by 2017.[9,10]

Radiofrequency Identification Technology in Nursing Administration

Healthcare has been identified as one of the three fastest-growing RFID application areas along with retail and commercial services.[20] Radiofrequency identification has evolved into an automated wireless data collection methodology designed to capture data about the location and/or movement of uniquely identified objects. The primary focus of RFID has traditionally been on accurate identification of the location of objects (ie, supplies) within a specific spatial range and, secondarily, the movement history of objects among specified locations (ie, warehouse and nursing units). Because objects are said to exist and move in the context of the space-time dimension, the element of time is inherently captured when generating the movement history. The serendipitous capture of time along with motion increases the potential usefulness of RFID technology for the purposes of nursing administration. The intrinsic and instrumental value of time spent with patients has been described in the literature, and the sustained momentum behind the Transforming Care at the Bedside (TCAB) initiative provides further testimony to the significance of nursing time allocation to nurse leaders.[21,22]

Transforming Care at the Bedside began as a small demonstration project to identify improvements in the work environment that would enable nurses to spend more time at the bedside and has expanded into a formal program with multiple internationally recognized sponsors. Participating organizations are tasked with the development, testing, and implementation of strategies that eliminate time waste, add value for nurses and patients, and increase the amount of nursing time for direct patient care. The need to capture data on how and where nurses spend their time has intensified, and the application of RFID technology in healthcare has now expanded beyond supply chain management to include evaluation of the work environment through tracking time and motion of patients and staff.[6,20–22]

Hendrich and colleagues[22] were among the first to capitalize on the capacity of RFID technology for tracking human resources in their national time and motion study of medical surgical nurses. Using RFID technology, they were able to document nursing time allocation across various locations on and off the nursing unit and generated evidence suggesting that nurses spend more time at the nurses' station than with patients. This finding has subsequently been used to fuel the drive for change and serves as a baseline against which new strategies for work process design can be evaluated. In tandem with the TCAB initiative this has resulted in heightened efforts to explore relationships between various aspects of the work environment and nurse time at the bedside.[23] A growing number of nurse leaders may therefore be interested in the application of RFID technology as a data collection system for monitoring nurse time and motion. The following description of how RFID technology works will assist nurse leaders in evaluating its usefulness for this purpose.

TIME AND MOTION WITH RADIOFREQUENCY IDENTIFICATION

When applied to a nursing unit, RFID technology has the capacity to generate data about the movement history of multiple nurses simultaneously (Figure 1). The process of data collection and entry into a database is automated, thereby reducing the cost, burden, and bias associated with human data collectors. Because the movement history of the whole population of nurses on a unit can be accurately and efficiently captured, the precision of any aggregated time estimates (eg, nursing hours per patient day and direct care time) should theoretically be superior to those acquired by traditional methods (eg, derivation from administrative databases or work and time sampling).[5,24] Inherent in the movement history generated with RFID are data relative to the following time dimensions: duration of time in specific locations, frequency of location changes, frequency of travel to specific locations, time intervals between travels to specific locations, duration of transit time, and distance traveled over time (Figure 2).

Components of an Radiofrequency Identification Tracking System

Tracking time and motion with RFID technology involve object recognition, wireless transmission of information

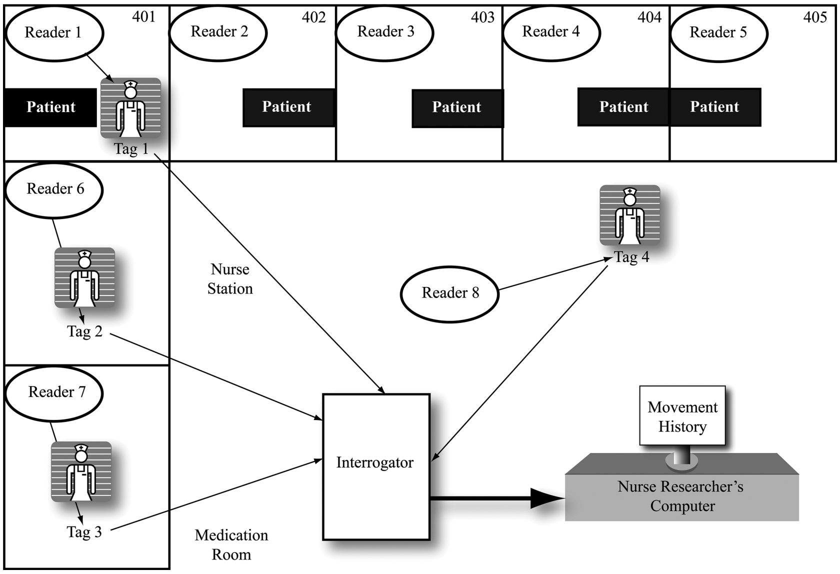
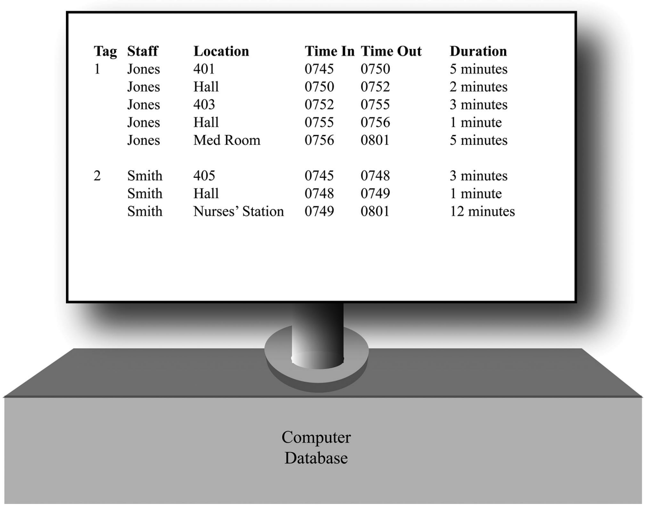


FIGURE 1. Example of application of RFID on a nursing unit.

about the object through the air interface, and direct entry of transmitted data into a computer system.[3,8] Object recognition begins with the attachment of special tags to each staff member as it is the tag that gets recognized rather than the staff per se. These tags, also called transponders or transceivers, generally contain a microchip and coiled antenna (Figure 3). This enables the tags to function as a receiver, modulator, and transmitter of radio waves.

A second device, called a reader, is used to create an electromagnetic field in a number of different frequencies in the unlicensed spectrum at specific time intervals (Figure 3). Common frequencies include 125 KHz (low), 13.56 mHz (high), and 860 to 960 mHz (ultrahigh).[9] The initial electromagnetic field may be created by infrared, ultrasound, or radio wave readers.[25] Aided by its antenna, the tag receives the electromagnetic waves and harnesses the energy to power the microchip circuits housed within. Once powered, the microchip drives the process of modulation (Figure 3). In this process, the rhythmic sinusoidal waves are altered in such a way as to superimpose preprogrammed information about the tag upon the reflected waves.[8,10] The information superimposed on the carrier wave is digital and is transmitted with the aid of the coiled antenna. The transmitted information generally includes the time of tag recognition, tag location, and the unique tag identification number. Some tags have the capability to carry additional data elements about the staff member wearing the tag (eg, education level, years experience, patient assignment, and so on) programmed on the microchip and subsequently superimposed on the reflected wave.[8,26]

The process of object recognition is complete when the reflected carrier wave containing the preprogrammed information is received and interpreted. This is accomplished by a device called the interrogator (Figure 3), which may or may not be integrated with the reader responsible for the original signal. In instances where the original electromagnetic field was created by ultrasound or infrared readers, a second device for reception and interrogation of the reflected signal may be required. The interrogator receives, filters, and decodes the information that was superimposed on the carrier wave signal.[6,17] Once interrogated, the data may be stored internally or transmitted to another information system for storage and further manipulation by specialized application software (Figure 3).



Tag	Staff	Location	Time In	Time Out	Duration
1	Jones	401	0745	0750	5 minutes
	Jones	Hall	0750	0752	2 minutes
	Jones	403	0752	0755	3 minutes
	Jones	Hall	0755	0756	1 minute
	Jones	Med Room	0756	0801	5 minutes
2	Smith	405	0745	0748	3 minutes
	Smith	Hall	0748	0749	1 minute
	Smith	Nurses' Station	0749	0801	12 minutes

FIGURE 2. Example of RFID movement history.

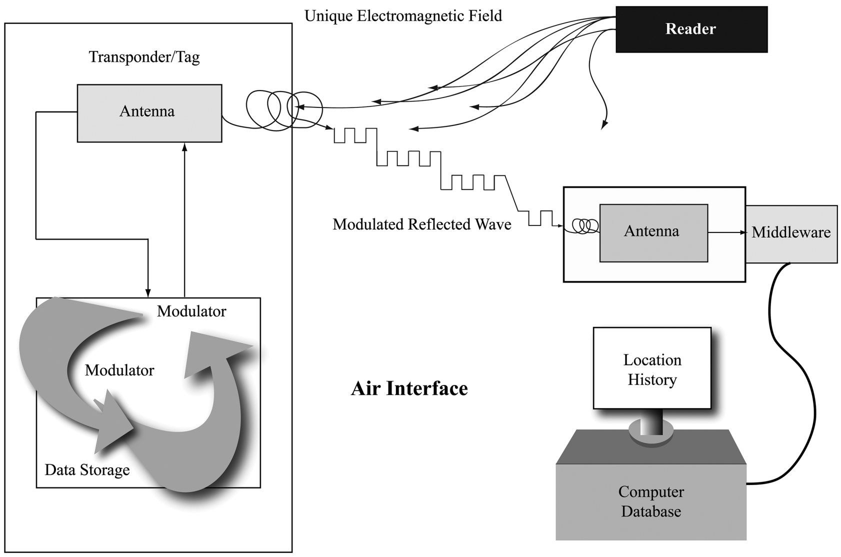


FIGURE 3. Schematic representation of underlying RFID mechanism.

Characteristics of Radiofrequency Identification Data

Once the data programmed on a tag's microchip have been transmitted, the cycle of transmission repeats until the source signal from the reader stops or until the tag is moved outside its range. If a reader initiates a source signal at 3-second intervals, the tag will transmit a reflected signal in response every 3 seconds. The tag from a nurse remaining in the same location for 60 seconds would therefore respond with a total of 20 signals. The information transmitted in these 20 signals would be identical except for the transmission timestamp. Interrogators receive streams of repeating digital data points, often from multiple tags simultaneously. Raw unprocessed RFID data are therefore inherently voluminous and noisy.[10,27,28] In order for these data to be interpretable, they must be broken down into separate bytes of meaningful information.[26]

Radiofrequency identification data are meaningful when they reflect specific events of interest. By definition, an event is something that takes place at a particular time and place.[21,25] Events of interest are described as those that need to be monitored.[27] Radiofrequency identification events are classified as primitive or composite. A primitive event is said to occur at a singular place and time, while a composite event reflects multiple primitive events linked by predefined operators (eg, AND, OR, NOT, etc). Each response of a tag to the source signal from a reader is a primitive event as it represents a tag being recognized in a specific location at a singular point in time (eg, nurse Smith in room 319 at 6:29 pm). The collection of digital data points comprising a basic primitive event is called a tuple.[28] The tuple contains the data points that minimally reflect the tag number, location, and time of transmission. Each cycle of data transmission by a tag's microprocessor generates a tuple of information, the size of which depends on the amount of data programmed on the tag.

The volume of data points received by an interrogator is influenced by the number of tags in use, the size of each tuple, and the number of tuples generated per tag across a given period of data collection. It has been estimated that retailers using this technology for inventory management can generate as many as 300,000 million tuples per day[27] and that Wal-Mart alone generates around seven terabytes of data every day from their item-level tags.[10] The volume of data generated when tracking time and motion of nursing staff is also significant. For example, each nurse wearing a tag within range of readers set to repeat the source signal at 3-second intervals will generate 20 tuples of data every minute. Ten nurses could generate up to 96 000 tuples of data during each 8-hour shift. Not all of the primitive events represented by these data are equally significant, however. For example, the tuples generated every 3 seconds when a nurse is in the same location add no informational value.

Important events to monitor when tracking time and motion of nursing staff include duration of time nurses spend in specified locations, the sequence and pattern of location changes, and the duration of time between trips to a single location such as a particular patient room. These are examples of composite events. The duration of time a tag remains in a specific location or between trips to a location is derived by summing the elapsed time between specific primitive events (ie, the first and last transmission from a single location or last transmission from one trip and first transmission from another trip to the same location). Location changes are derived based on defined relationships between primitive events (ie, consecutive tag transmissions that are identical except for location and time). Therefore, when tracking time and motion of human resources, the only tuples worth recording and monitoring are those associated with the entrance to and exit from specific locations. When events are not considered noteworthy for a specific purpose or application, they effectively become a source of noise. In this context, they may unnecessarily hinder the data storage, retrieval, and analysis process.

Error or noise can be introduced into the reading process due to interference with or malfunction of any of the component devices. Examples of error in the reading process include duplicate reads, missed reads, and "ghost reads."[10,26] Interference with reception of the source signal by the tag or transmission of the reflected waves may result in missed reads. For example, a misread may occur if a nurse places a laboratory coat or jacket over the tag. Interrogators bombarded with multiple simultaneous tag transmissions also may result in missed reads. Rapid tag transmission cycles may result in duplicate reads, while ghost reads result when the interrogator detects an identifier not stored on any of the tags expected to be in the reader's field.[12] A special software, called middleware (Figure 3), is usually integrated into the interrogators to filter commonly encountered errors and irrelevant primitive events.[10,26] The filtered and processed data received by the end user are therefore reduced to meaningful composite events that are ready for analysis.

INTEROPERABILITY, MEANINGFUL USE, AND QUALITY IMPROVEMENT

The usefulness of RFID data is enhanced when combined with data from other sources.[26] In the context of supply chain management, for example, RFID data concerning location of supplies within a facility are commonly linked to RFID data about supplies in a warehouse as well as vendor delivery schedules and pricing data. When monitoring time and motion of nursing staff, functionality would be enhanced if RFID data could be linked with other data to include human resource, clinical, financial, and safety. For example, linking nursing time and motion data with a clinical database (ie, the electronic medical record) would enable an analysis of how much time was spent with uniquely identified patients and what clinical outcomes were achieved. A link to the financial database would facilitate the analysis of nursing cost per patient type such as diagnostic related group. A link to human resource databases (ie, payroll) would facilitate an analysis of time allocation patterns based on specific nurse characteristics (eg, education, experience, age, and shift length). When linked with a safety database (eg, errors management), relationships between patterns of unit activity and patterns of error and missed care could be explored. A thorough exploration and evaluation of these relationships are necessary to explicate the role of nursing services in providing value-driven healthcare and justify allocation of scarce resources.[3] Integration of such databases, although theoretically feasible, currently requires specialized application software that is often proprietary and potentially costly.[10]

The type and efficiency of analyses potentially achievable through the integration of RFID data with these other data sources are especially appealing in the context of the new meaningful use rule mandated by the American Recovery and Reinvestment Act.[29] The newly released criteria for meaningful use place much emphasis on the use of data for improvement in the quality and cost of care.[30] Integration of RFID time and motion data with these other databases is congruent with the intent of meaningful use as well as the goals of TCAB. Examples of specific issues of concern regarding the quality and cost of nursing care that can be explored with data generated through RFID technology are provided in Table 1. In addition to the retrospective analyses described above, the real-time knowledge of nursing movement history possible with RFID technology allows identification of delays in patient contact in time for corrective action. For example, alarms could be set to alert staff when no one has entered the room of a patient on fall precautions or frequent turning protocol within the designated timeframe. Charge nurses would be able to more accurately ascertain how much time patients are receiving throughout a shift and make adjustments in assignments as indicated. Process design teams could rapidly identify the effects of workflow and technology changes (eg, bar code technology for medication administration) on nurse-patient interaction time. Real-time visualization of nursing movement could also help identify issues related to the physical design of patient care units. For example, the effects of decentralized workstations and location of medication storage rooms on nursing time at the bedside could be quickly evaluated.

CHALLENGES AND LIMITATIONS

Despite the myriad potential applications of RFID, there are some inherent challenges and limitations to the exploitation of this technology for the purposes of nursing administration. Key challenges include electromagnetic compatibility issues, employee reaction to performance monitoring (PM), and concerns about an incomplete data collection model.

Electromagnetic Compatibility

Electromagnetic compatibility is defined as the capacity of an electrical device to operate in its electromagnetic

Table 1

Examples of Questions Relevant to the Nursing Work Environment That Can Be Explored Through RFID Technology

How much time does a nurse spend with patients during a shift?
How much time does each patient receive from the nursing staff each shift?
Do nurses spend more time with patients at higher-acuity levels?
Is there a difference in the amount of time spent with patients based on medical and/or nursing diagnoses?
Are patient assignments being made in a way that enables equitable distribution of nursing time among patients?
Are patient assignments being made in a way that enables equitable distribution of transit time among nurses?
How does the addition of technology change the amount of time nurses spend with patients?
How does a change in patient ratios affect the amount of time nurses spend with patients?
How do changes in skill mix affect the amount of time nurses spend with patients?
How many trips to the supply room do nurses make during a shift?
Is there a difference in the amount of time spent with patients based on the physical design of the nursing unit?
How much time does a nurse spend at the nursing station during a shift?
How does the electronic medical record affect the amount of time nurses spend with patients?
How much time does the nursing staff spend in transit during a shift?
What is the average length of time per encounter between nurses and patients?
How does the number of patient admissions and discharges affect the amount of time nurses spend with patients during a shift?
How does nursing experience affect the amount of time a nurse spends with patients?
How does nursing education affect the amount of time a nurse spends with patients?
Do patients who receive more direct interaction time with nurses have better outcomes?
How often do nurses make rounds on patients each shift?
How often are patients at risk for falls left unattended for more than an hour?
How often are patients at risk for decubitus ulcers left unattended for more than 2 h?
How often do nurses make rounds on patients following major procedures?
Do patients who receive more direct interaction time with nurses report better pain control?
Do patients who receive more direct interaction time with nurses report higher satisfaction with nursing care?

environment (EME) without disturbing or being disturbed by it.[31] It is important for safety reasons that medical devices and equipment reliably function as intended. Electromagnetic emissions external to a device or piece of equipment can alter functionality. When this happens, electromagnetic interference (EMI) is said to occur. The potential consequences of EMI cover a wide spectrum ranging from momentary, minor inconveniences to catastrophic malfunctions.[32] The risk of EMI to active medical devices (eg, pacemakers) and equipment (eg, ventilators and infusion pumps) from generalized environmental EM emitters has long been recognized.[33–35] Consensus standards for the development and testing of medical equipment and implantable devices exist and address functionality when exposed to generalized environmental EM emitters.[36] During the design and testing process, the threshold of tolerable environmental EM emissions for devices and equipment is determined. This threshold is commonly referred to as the immunity level of a device.[37] When operating in an environment with EM emissions below this threshold, devices are considered immune from EMI. In contrast, emissions above this threshold increase susceptibility of a device to EMI. The effectiveness of current standards and processes, however, is challenged by the increasing adoption of wireless mobile technology.[38]

The EME created by wireless mobile technology is increasingly more dynamic and rich with multiple EM fields. Every time a wireless mobile device moves toward or away from a medical device or piece of equipment, the EME changes. Further, there is an additive effect of such technology on the EME. While the emissions from a single mobile device (eg, cell phone or RFID tag) may not exceed the immunity level of a particular piece of medical equipment, when added to the ambient emissions from other sources, an EME that exceeds this threshold may be temporarily created. In this context, wireless mobile devices (including RFID systems) contribute some risk for EMI-related safety issues and, with increased use, will serve to further increase ambient EM emission levels within healthcare facilities.[39]

The extent of this risk is not easily quantifiable, making assessment of risk-benefit for wireless mobile technology in healthcare challenging. Reported strategies for managing the risk of EMI include on-site (in vivo) ad hoc testing of devices using standardized methodologies, standardization and regulation of frequency bands and power levels, periodic EME assessment and risk analysis, and adoption of EMI management policies.[39–41] Nurse leaders interested in adoption of RFID technologies must therefore work closely with biomedical engineering colleagues to facilitate a safe integration process.

Staff Reaction to Performance Monitoring

The majority of the proposed applications of RFID in nursing can be categorized as PM. Research suggests that PM can result in attitudinal and behavioral reactions among staff and that both positive and negative reactions can be experienced.[42,43] Nurse leaders may have legitimate concerns about staff reaction to the type of PM possible with RFID technology. In contrast to traditional PM that is achieved through direct and often intermittent observation, electronic PM (EPM) such as that described in this article has the potential to generate continuous and voluminous data about multiple dimensions of work performance. Negative reactions may therefore be heightened with EPM. A heightened perceived invasion of privacy is one possible reaction to EPM.

The combined effects of technological advances and the aftermath of 9/11 have rendered privacy a significant social and political issue in the United States. The courts have supported employer use of monitoring practices, however, and it has been argued that a legal right to privacy for employees is nonexistent.[44] Germane to the legal stance on employee monitoring is interpretation of the workplace as a public domain and the employment-at-will doctrine. Privacy has been traditionally conceived as the right to control access to one's personal or private domain.[44,45] The workplace, however, is owned by and under the control of the employer. It is a public rather than private domain and therefore not subject to the same legal protection against intrusion. Under the employment-at-will doctrine, employment has been considered terminable by either the employer or employee for any reason.[46] When applied to the issue of EPM, this has been interpreted to support the practice of EPM, provided that employees receive prior notification. The employer has the right to establish EPM as part of the conditions of employment, and the employee has the right to accept or decline employment under those conditions. Continued employment is considered consent to EPM.[45,47,48]

While employers may have the legal right to engage in EPM, careful consideration and planning are warranted prior to implementation. Comprehensive reviews of research related to potential staff reactions to EPM are available in the literature.[43–49] Electronic PM may affect staff perceptions about work and the workplace (eg, job satisfaction, trust, and fairness) as well as staff behavior (eg, citizenship behaviors and unproductive behaviors). Strategies to facilitate positive staff reactions to EPM include clear communication about what will be monitored and how the information will be used, allow input into selection of activities to be monitored and establishment of performance standards, and provide feedback regarding the results of EPM and any subsequent changes implemented.

Radiofrequency Identification Data Collection Model

When used in isolation, RFID technology does not capture the full spectrum of nursing activity and therefore is an incomplete data collection model. While time and motion can be efficiently captured with RFID systems, specific nursing interventions implemented and the cognitive aspect of nursing (ie, critical thinking and clinical reasoning) are not recorded. In this sense, it offers no advantage over traditional productivity assessment methods. A more complete model can, however, be acquired through the creative integration of RFID technology with other methods and devices. For example, the PDA has been used in combination with RFID to link specific activities with the time and location of implementation.[20] Qualitative and quantitative methods have been successfully combined to link clinical decision making and the nursing process with time and motion.[50] It is possible that the addition of RFID technology to this mix of methods could enhance the efficiency of the quantitative data collection component.

Conclusions and Implications

Radiofrequency identification technology is potentially useful in exploring how factors in the work environment affect nursing time at the bedside and how nurse time at the bedside affects patient outcomes. The usefulness of RFID stems from its ability to precisely track the time and motion of multiple nurses simultaneously with minimal human resources. Radiofrequency identification technology is already available in many healthcare organizations where it is used for supply chain management. The time is ripe for exploitation of this technology to address many of the concerns relative to the cost and quality of nursing care. Effective use of this new application of RFID technology will require collaboration among key stakeholders including nurse informaticists, nurse researchers, nurse administrators, statisticians, and electrical and computer engineers.

Further refinements in the tag technology may be required to enhance the precision and reliability of time measurement, given the speed and frequency of movement by nursing staff compared with hospital supplies or retail inventory. For example, better methods to affix tags to nurses are needed to minimize missed reads related to tag movement and obstruction by clothing. Likewise, further refinements in middleware may be required to accurately identify and record events of interest to nurse leaders while filtering primitive events with no added value. Events of interest may be defined differently among research questions, and likewise the need for linkage with other databases may differ. Such linkages may require development of middleware and application software uniquely designed to meet the needs of nurse researchers or, at the very least, modification of existing programs. Given the nature and volume of the data generated through this technology, new data management and analytic methods also may be required. The nursing community is encouraged to explore creative and innovative ways to integrate this technology for the purposes of advancing nursing science.

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