C6
8013

Disclaimer—This paper partially fulfills a writing requirement for first year (freshman) engineering students at the University of Pittsburgh Swanson School of Engineering. *This paper is a **student, not a professional***, paper. This paper is based on publicly available information and may not provide complete analyses of all relevant data. If this paper is used for any purpose other than these authors' partial fulfillment of a writing requirement for first year (freshman) engineering students at the University of Pittsburgh Swanson School of Engineering, the user does so at his or her own risk.

RFID RTLS WITHIN THE EMERGENCY DEPARTMENT

Grace Henderson, gih6@pitt.edu, 0012 Mena 1pm, Mari Kay Hannon, mkh56@pitt.edu, 0012 Mandala 2pm

Abstract*—Radio Frequency Identification (RFID) is an older technology that with new application has recently revolutionized hospital department operations. Through the implementation of RFID tags on tracking and monitoring patients, hospitals are able to increase efficiency in the discharging of patients from the emergency room. Compared to the rest of the hospital departments, emergency rooms are notorious for their unorganized and chaotic manner. However, through the use of RFID systems hospitals are able to reduce the disorganization of the emergency room (ER) through the tracking of patients, which ensures that each patient receives optimal time and care spent on them.

*Despite these potential improvements in healthcare, concerns have been raised surrounding the ethics of human tracking with RFID tags and the security of the patient's medical records stored on the RFID. Furthermore, due to RFIDs vulnerability to its work environment, the technology may not be the most sustainable Real Time Location System (RTLS) available for use in the emergency department or the hospital system in general.

Since RTLS is a newer innovation, it has been applied to few hospitals. Due to this limitation, it is difficult to ascertain just how sustainable RFID technology is environmentally, economically, and socially on a large scale. However, with more research and implementation, RFID application in RTLS have the potential to benefit hospital emergency departments around the world.

Key Words—Emergency Department, Healthcare, Patient-tracking, RFID, RTLS

CHALLENGES WITHIN THE EMERGENCY DEPARTMENT

Due to the urgency and high volume of patients the emergency department (ED) experiences, it is one of the most complex systems within the hospital departments. Consequently, the ED faces considerable challenges surrounding medical error and wait times. Because of its notorious inefficiency, the ED is perhaps the most in need of a system update compared to the rest of the hospital's patient flow operations.

One of the many issues the ED faces are medical errors. In fact, the emergency department has the highest proportion of preventable errors made (70-80%) compared to the rest of the hospital departments. These errors often have serious consequences, which in some cases lead to disability or death. In fact, every year in the United States medical error causes over 1 million injuries and 100, 000 deaths, most of which are within the ED, costing hospitals up to $50 billion [1]. According to Dr L.L. Leape, the director of Health Policy and Management at Harvard, most medical errors are caused by defects in the hospital system itself. The design of tasks, training, processes, and the work conditions within the hospital departments make healthcare errors much more likely. Some of these errors are the direct result of difficulty accessing and processing vital information. Therefore, in order to reduce these errors, management needs to address the system, not necessarily the people working for the system [2].

Another issue the ED faces is the overflow of patients that walk through their door. In fact, around 50% of hospital admissions in the United States, disregarding obstetrical admissions, occur in the ED [3]. The poor management of this large mass of patients leads to long wait times, which is detrimental to the patient's health and satisfaction with the hospital. This issue has only become more relevant in recent years due to an increase in the number of ED visits and a decrease in the number of hospital EDs. This ultimately has led to over 50% of emergency rooms being past maximum capacity which in turn, has caused increased wait times for patients and even refusal of healthcare [4].

One of the largest causes of long wait time is poor patient flow which is only exacerbated by overcrowding [4]. Therefore, if one can improve the "patient flow process," in a permanent sustainable manner, they can improve how EDs are run and increase both profit and patient safety. Above are only a few of the numerous issues the Emergency Department faces, and presents the need for a major operation change.

RFID TECHNOLOGY

RFID Technology Benefits Hospitals

Engineers have found numerous ways to implement different systems within the ED in the hopes of minimizing human error and increasing patient satisfaction. One of these

systems include the use of Radio Frequency Identification Devices (RFID) as information storage and location devices. This application works by issuing RFID tags to every incoming patient. The RFID tags are then scanned by RFID readers located within the hallways of the hospital. This allows the hospital to know the relative locations of all of their patients, improving patient safety and better ensuring that patients are not confused with one another [4]. The location of a patient is important because it allows medical personnel to ensure delivery of drugs, food, and other necessary equipment to the correct patient in a timely manner. The accurate location of patients also ensures that patients are not lost in transition from one healthcare personnel to another and their chart remains with their person [5].

RFID systems can also be utilized through the discharging of patients in the ER. Through the use of RFID as a real time location system (RTLS), hospitals are able to significantly optimize the ER bed turnover rate. RFID RTLS does this by tracking patients once they are ready to leave the ER bed, allowing hospital personnel the ability to know exactly how many rooms and beds are open to future patients in the waiting room. The implementation of RFID systems have the potential for success in hospital emergency rooms by ensuring correct patient identification, minimizing human error, and optimizing the hospitals use of time, making the ER process as efficient as possible.

How Does it Work?

The very beginnings of RFID technology began in 1901, when radio waves became the means of communication across the Atlantic Ocean; signaling ships in what we know today as morse code [6]. Since this discovery, RFID technology was further researched and by 1935 during World War II, Alexander Watson-Watt discovered the usage of radio waves to locate physical objects in the sky, which was used to locate the Allied bomber planes [7]. After its use in World War II, RFID continued to evolve and develop further such that by 1973 the first patents for active RFID tags with rewritable memory and passive transponder RFIDs were received [7]. Due to the rigorous research and improvement of RFID technology and its proven versatility, RFID tags have become incorporated in a variety of fields including asset security, warehouse management, and healthcare [7].

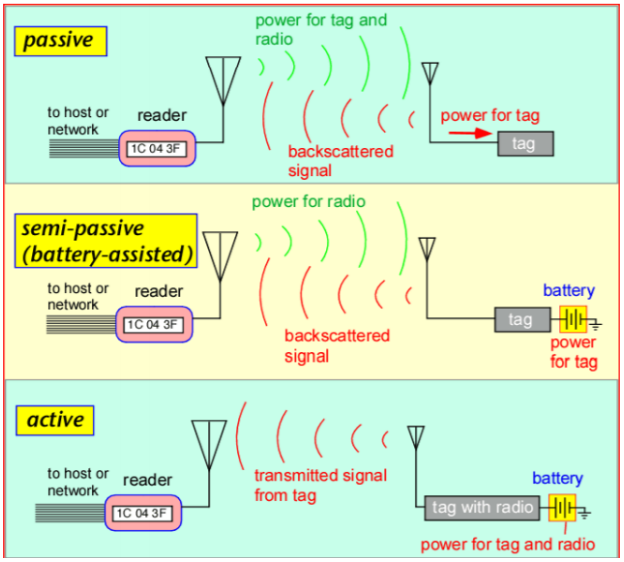

FIGURE 1 [18]
The inner workings of RFID

A typical RFID system contains three parts: a tag, reader, and antenna. Within every RFID tag, there contains an integrated circuit that stores the tag's information. Whenever an RFID tag comes within range of an RFID reader, the integrated circuit transmits its information to the RFID reader through induced electromagnetic waves. With this simple process in mind, there are three distinct versions of RFID tags that transmit information: passive, semi-passive, and active tags [7].

Passive tags are RFID tags that do not contain their own power source and are solely powered from the signal carried through the reader. This signal induces an electromagnetic field within the integrated circuit of the RFID allowing the tag to transfer information to the reader. Semi-passive tags, on the other hand, contain their own power source, and mainly operate the same way passive tags do. However, the difference between the semi-passive tags versus passive tags is their own energy source gives them the ability to have a larger reading range and they are able to power electronics attached to them. For example, there are some semi-passive RFID tags that are incorporated within thermal sensors. With the semi passive RFID tag's battery, it is able to power the thermometer as well as act as a passive RFID and send information back to the readers. Conversely, active tags include their own battery and incorporate their own energy source into the tag's operations. These tags can emit signals at a greater distance and higher rates than both passive and semi-passive RFID tags [7].

Because of their differences in both power source and reading distance, each tag has its own benefits based upon their application. Passive RFID tags are by far the most cost effective at $0.15 each, and are excellent in application when applied for information storage and tracking such as anti-theft technology. A main benefit to using passive RFIDs is their sustainability. Because they do not have a battery, these tags

typically have a twenty plus year life span and do not need to be replaced. For example, passive RFID tags are implemented in numerous libraries where they attach passive RFIDs onto the book. When a person removes the book and leaves the library before checking the book out, the alarm will sound. Active RFIDs on the other hand, are more expensive than passive RFIDs and have a shorter lifespan. However, active RFIDs have the longest reading range, and are in primarily used in application for tracking large cargo that requires a large range for reading. For instance, active RFID tags are used for the automatic toll payment, E-Z pass. This pass consists of an active transponder that attaches to the car windshield and when it comes in relatively proximity of a toll, the transponder will send the toll the carrier's account to collect the person's toll payment.

Not only are there three different kinds of RFID tags, the RFID chip itself contains the option of three varying levels of capability. The tag can be either read only, write once, or a combination of read and write. Read only RFID tags indicate the information stored within the tag must be incorporated during the manufacturing process and cannot be modified or erased. Generally, these tags contain unique serial numbers used for identification of specific objects. For instance, RFID implants within humans and animals are typically read only tags such that the personal ID may never be overwritten or changed. Whereas write once RFID tags are relatively similar to read only tags however, can be encoded once with information after manufacturing, and after cannot be erased or modified. These tags are useful in the assembly line application, where workers can update and tag products as they progress throughout the supply chain at certain checkpoints. The most important RFID tag for RTLS systems is the read-write RFID tag. These tags are much more forgiving and allow data to be written and erased on demand as many times as the user wants. In fact, data can be added numerous times throughout operations which ultimately give the user greater advantages to these types of tags [7]. In general, hospital EDs choose to incorporate read-write RFID tags in their patient-flow systems due to the ability to reuse their RFID tags with new patients.

RFID tags are extremely beneficial in the hospital ED because they have the capability of being read by radio waves without requiring line of sight to scan or human intervention. Not to mention, the fact that multiple RFIDs can be read at one time [8]. Compared to barcodes, and other scan-based data collection technologies, RFID operates faster and stores over ten times the amount of data [9]. RFID tags are also long lasting and are a sustainable technology that needs incredibly minimal maintenance or replacements. Not to mention, RFID tags significantly decrease the amount of time spent checking in items in systems, allowing them to be the technology of future operations. While RFID technology is clearly prevalent in the average person's daily life, it has yet to be applied, in a large scale, to hospital RTLS within the United States.

APPLICATION IN HEALTCARE

Although RFID technology dates back to the 1900s, RFID systems have only recently started to be incorporated into hospital departments. One of the first cases of RFID implementation as a RTLS within hospitals was used by Taiwanese hospitals in 2003, due to the SARS outbreak in Taiwan. This SARS outbreak led to 37 patient deaths [4]. Due to this catastrophe, the Department of Industrial Technology, Ministry, and Economic affairs in Taiwan required all of their hospitals to implement different healthcare improvement plans, in hopes to prevent further medical catastrophes from reoccurring [4]. Ten of those hospitals within Taiwan chose to incorporate RFID technology within hospital departments. These hospitals incorporated RFID RTLS systems that tracked patients and monitored and identified those who came in close contact with infected patients. At the end of the two year implementation period of these RFID technologies, researcher interviewed staff and project managers who all agreed the implementation of RFID RTLS systems bettered their hospital's efficiency [4]. Through these studies it has been concluded that the implementation of RFID can improve numerous ED inefficiencies including hospital discharge.

Since then, RFID has been applied to the healthcare system in hospitals around the world. The ways in which RFID is used within hospitals ED are diverse and have evolved since 2004. In the chart below lists just a few ways this device has been used in the healthcare systems.

Table-II: List of the most relevant areas for RFID applications in healthcare.14

Years	*Up to 2004*	*2005-2010*	*2011 Onwards*
Main uses	Error prevention of products [drug dose, correct blood and treatment, mother/ baby mismatch etc] Patient tagging for error prevention, Locating staff/ staff alarms, Locating assets	Error prevention of products now including auto luer connections and parts, Patient tagging for error prevention, Locating staff/ staff alarms/tags that record incidents, Locating assets/speedy, accurate stocktaking , Theft prevention, Cost control, Recording procedures[eg for defense of lawsuits] Drug trials compliance monitoring/ prompting, Behavioral studies to optimise operations, Pharmaceutical anti-counterfeiting	Error prevention of products Patient tagging for error prevention, Locating staff/staff alarms, Locating visitors/ visitor alarms/ virtual queuing , Locating assets/ speedy, accurate stocktaking, Theft prevention , Cost control, Recording procedures[eg for defense of lawsuits] Drug trails compliance monitoring/ prompting[taking drugs] Drug trials compliance monitoring/ prompting Patient compliance monitoring/prompting [taking drugs] Behavioral studied to optimise operations, Pharmaceutical ant-counterfeiting Track and trace of most medicines, consumables and assets

FIGURE 2 [7]
Shows the ways in which RFID has been used

As seen from the chart, RFID can be used in hospitals many different ways to permanently solve different operational problems. With RFID technology, hospitals have created a sustainable system that prevents human errors in distributing products such as drugs and blood bags. RFID has also been used to make sure staff and assets can be located. While the ways in which RFID systems can be implemented to improve hospital operations, this paper focuses only on one. The paper's purpose is to show how RFID RTLS can be incorporated in Hospital's ED in order to minimize waiting

times within the ED and improve the overall process to discharge patients from the ER in a sustainable manner.

FUTURE USES OF RFID

Emergency rooms within hospitals are notorious for their excessively long waiting times as well as the misdiagnosis or mistreatment of patients. According to the case study in Taiwan, Dr. Liaw studied the factors leading to the patients premature departure from the emergency room. He discovered that almost half of the ED patients left without any diagnosis because they were unwilling wait for more than one hour [11]. This statistic only further proves that the general population is unhappy with how hospital EDs are currently run, and shows how vital the need for an updated system is. Through the implementation of RFID RTLS systems, hospitals are able to significantly cut back the amount of time each patient spends in the hospital ED.

RFID systems have been implemented and theorized to better numerous different hospital inefficiencies. Some of these examples include having the RFID systems track patients throughout their entire stay at the Emergency Room. Yen-Chieh Huang and Chih-Ping Chu have created a computer simulation that incorporates both RFID data storage and RTLS system in order to optimize the patient's entire stay within the ER. Their simulation focuses on addressing five major factors that cause hospital inefficiencies: long period of waiting time before seeing a doctor, long period of waiting time in the examination rooms, patient's departure without any excuse, a patient's departure without payment, and long period of waiting time to receive a hospital room [11]. This simulation focuses on the application of the semi-active RFID tag that system solves these five inefficiencies. It should be noted that this case study has not actually been implemented in any hospital, and all the data analysis is concluded from case study simulations.

Yen-Chieh Huang and Chih-Ping Chu's implementation of RFID begins as soon as the patient enters the hospital's triage entrance, where they will be categorized based off of the severity of their injury. After the patients are triaged, they will be fitted with an RFID wristband that stores their basic medical diagnosis and information. The patient then waits in the waiting room until they are ready to be seen by the physician. If the patient waits in the emergency room for an allotted amount of time, the RFID tag will not have been read for a certain amount of time and will signal hospital management that the patient has not been receiving any medical attention as well as mention type of care the patient needs. This personalized message allows hospital management to contact the right specialized physician for the patient [11]. This aspect of the RFID RTLS solves the first main inefficiency within the hospital ED and ensures that each patient will be seen in a timely manner; cutting the wait time significantly. The second problem within the hospital is also solved with this system attribute through the system's ability to automatically send the patient's medical records and files to management ensuring that the correct medical physician can treat the patient efficiently and accurately.

This RFID system also incorporates RFID readers at the exits of the hospital, so that as soon as a patient with an RFID tag leaves, medical personnel will be alerted that they have left the building [11]. This aspect of the system solves the third and fourth major problems within EDs: patients leaving the hospital without any excuse or payment. It also alerts personnel as soon as patients leave in order to optimize the medical professionals time to assist patients who are still present in the ER. The last aspect of this system, ensures that patients in need of a sickbed within the hospital receive it within a timely manner. In order to incorporate this aspect within their system, the RFID will signal when the patient will be moving rooms. From there if the RFID does not receive any information after the patient was marked to move rooms, the RFID will signal the management center after a pre allotted time alerting the medical personnel a patient is in need of a room transfer [11]. Overall, the RFID system can incorporate so many different aspects of hospital inefficiencies all at once and better both the patients stay as well as save hospital staff time.

Benefits

RFID has numerous benefits incorporated throughout this system. The waiting time alert within the RFID system solves the problem of long patient wait times endured within the emergency room. With this time automated RFID RTLS, every patient is promised proper treatment and cared for as quickly as possible. Furthermore, the data storage within the RFID allows hospitals to notify medical specialists who can best help the patients and address their individual needs. For instance, if a patient comes into the ER with a medical issue pertaining their eyes, the RFID can signal the ophthalmology department and send an ophthalmologist to take care of this patient. More importantly, this RFID RTLS shows a permanent sustainable solution to the inefficient operations of the hospital ED. With reduced waiting times as well as improvement on quality of care, it can be concluded that RFID systems within hospitals can be extremely beneficial to hospital emergency departments around the world.

CASE STUDY – MOUNT SINAI

The Problem

As it has been mentioned earlier, there is no question that there are numerous inefficiencies within the ER, and with the help of RFID systems in hospital ED's, there are hopes to better the overall discharging process. One hospital in particular, Mount Sinai Medical Center, successfully incorporated RFID RTLS system that improved their bed turnover rate and departure time of patients from the ER.

Mount Sinai Medical Center, located in Miami Florida, has 1,171 hospital beds and around 51,000 hospital discharges per year [10]. Mount Sinai Medical Center, like many other hospitals, struggled with bed turn around times within their ED, and struggled to know exactly when ER beds became available. It is important for hospital's to know how many beds are available because it allows hospital staff to assign patients to their room as quickly as possible. Mount Sinai significantly struggled to know the availability of their hospital rooms within their ER. In fact, according to a study that Mount Sinai's hospital executive board conducted, concluded it took the hospital up to 2.5 hours after a patient had been discharged to identify that a room was empty [10]. The challenge to locate these empty beds was due to the unpredictable discharges of patients and the time each individual took to leave the hospital once given discharge papers.

The original system set in place by Mount Sinai was such that once the patient was given discharge permission, the nurse would input the discharge information into their computerized discharge system, Computerized Physician Order Entry system (CPOE), which filled out patients discharge forms. The patient was then able to leave at their own time, and when they exited the hospital the ward clerk noted when the patient left. The clerk, then notified housekeeping and entered the time into the Admission Discharge Transfer System. However, this system was flawed because the ward clerks often became extremely busy with other work and missed patients leaving the floor. Because of this pressing issue, Dr. Joseph Kannry, an internal medicine associate from Mount Sinai Medical Center, decided to run a case study to see how successful RFID RTLS systems can improve Mount Sinai's discharge process.

System Description

The new system Dr. Kannry put in place simply incorporated RFID RTLS that removed the need for the ward clerk to sign patients out of the hospital. In this new system, the nurses still complete the old processes of entering patients discharge information in CPOE however, the nurse also assigns an RFID tag to the patient in question and delivers the RFID to the patient along with their discharge papers. This RFID tag cannot be read within the patient's individual rooms. Yet, as soon as the patient enters the hallway with their RFID the RFID readers on each floor detect the patient's location while they are exiting the hospital. The readers can detect tags up to 30 feet away and are connected to ethernet cables. Upon exiting the floor, the RFID reader records the unique tag and patient departure time. Then, when the patient leaves to check out they return the RFID and discharge papers at the desk, alerting the hospital system that the patient has departed and their room is now available for housekeeping.

Results

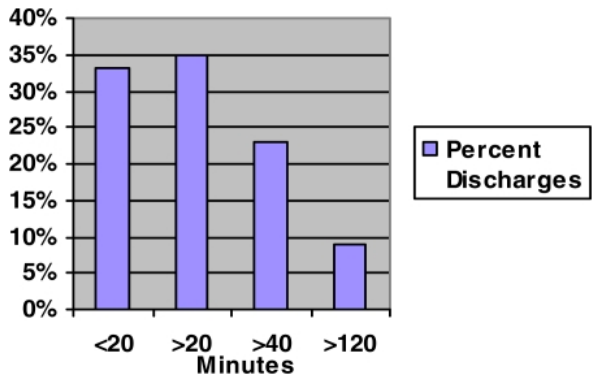

FIGURE 3 [10]
Chart shows percent discharged in each time frame during the study at Mount Sinai.

Overall, this experiment was a successful application of RFID RTLS which improved the discharge process within the ED. In total, the study cost $12,000 and was conducted on a total of 86 patients. Over 67% of the 86 patients discharge time decreased by 20 minutes or more, 35% of which were 20-40 minutes faster [10]. The only problem Dr. Kannry encountered throughout this study were the 5 out of the 86 RFID tags that went missing during the trial. These missing tags brings up the question of the relative sustainability and economically friendly this system is in on a larger scale. For instance, if 1% of the $12 RFID tags are lost per month, the cost of maintaining the system may become too expensive. However the one benefit of the trials use of passive RFID tags, is their sustainable life span of twenty years or more. Thus, the only maintenance required to maintain this system would be replacing lost tags. Not only is this study shown to be financially sustainable, the nurses and staff felt this system is a permanent solution to their ER bed turnover rate. The staff found the new system helpful and noted that their jobs were made easier due to the RFID technology. According to Joseph Kannery, "The experiment was so successful that the study was stopped prematurely and leadership decided to begin planning for deployment." [10]. Thus, it can be concluded that this study clearly improved hospital efficiency in the process of discharging of patients, and by the end of the study this system was permanently implemented within the Mount Sinai Medical Center.

CONCERNS WITH RFID TAGS

While RFID systems can greatly improve how the emergency department system operates, the technology does have its drawbacks. For example, one of its shortfalls includes its inability to be read from far distances, since RFID reading ranges are extremely limited [12]. This lack of consistency can cause major problems within hospital RTLS simply because when the readers cannot read the RFID tags, patients are no

longer accurately tracked. Additionally, there is currently no set standard for the frequency range, coupling modes, communication, and power sources with which each reader and tag. This has caused data incompatibility issues which has slowed the adoption of RFID into healthcare and made implementing RFID on a large scale challenging [12]. Thus, the actual storage of information within the RFID tags may not always be read, which will confuse the RFID RTLS system, and give false readings, which will not always optimize every situation.

The RFID tags can also have difficulties when it comes to the scanning of the tag. The signals emitted by the tags are affected by temperature, noise, distance, and tag orientation. Those factors may lead to the tag being improperly read or not scanned at all. Despite advances in RFID technology, it is likely that an uncertainty in its ability, no matter how small will always remain [13]. An additional issue, one signature to RFID within a healthcare environment, is the risk or fear that the RFID RTLS system would cause electromagnetic interference with essential medical equipment [14]. For this reason alone, hospitals have been very reluctant to use RFID systems.

Another challenge with using RFID systems becomes which type of RFID tag does one need, passive or active RFIDs. While passive RFIDs are very cost effective, around $.15 per tag, it is hard to read passive tags held close to the human body. To ensure that the tag scans, one would have to hold the tag from their body, putting the tag close to the receiver. This would disrupt workflow and could not be realistically followed by every person wearing a tag. Conversely, active tags are more expensive. Active RFIDs can cost anywhere between $10-$25 per tag [10]. Even though, the cost of the RFID tag seems relatively insignificant, it has to be taken into account that these RFID tags have a possibility of being stolen by patients or lost in the transfer from patients to medical personnel.

Security Issues

Despite the overall benefits of RFID tags, storage of personal information within these tags brings up the issue of how safe it is to store personal information on unencrypted RFID tags. One major issue with RFID tags storing personal information is that they can be easily scanned by unauthorized personnel, collecting personal data. Since RFID tags can be read by any scanner, it is possible for an outside person to read a patient's RFID tag and collect personal information. Furthermore, since the RFID tags implemented in hospitals are unencrypted, it may violate the Health Insurance Portability and Accountability Act under Protected Health Information (HIPAA PHI) [14]. HIPAA PHI clearly states the federal protection of personal medical information and gives patients rights to distribute their medical information accordingly. [15] Therefore, with such serious accusations and concerns with RFID systems, it will be difficult for RFID technology to gain major traction and sustainability within hospitals due to the liability risks of information hacking.

Cost Analysis

A final consideration is the cost of using a RTLS system. Initially, the cost of an RTLS is high. Although the cost varies on the size and complexity of the RTLS, each system will require man hours for installation and design of needed software, as well as multiple tags and readers. One reader alone can cost up to $1200 and multiple are needed for each area of the hospital [15]. Depending on the size of the area one is trying to track patients, this can be very costly. Therefore, to be sustainable and a worthwhile investment, the system implemented must save enough money to pay for the installation costs. Because each RTLS is different in terms of the hours needed to apply the system, the goals of the system, and the size of the area covered, a definitive return on investment (ROI) cannot be given. Furthermore, because almost all of the studies currently available are simulation only, it is very challenging to be able to deliver an estimate. However, if the system is designed well, it can be expected to significantly lower wait times and reduce medical error. This will lead to cost reduction; however until further research is done, the ROI cannot be concretely calculated.Thus, the overall sustainability of the system comes into question: with potential scanning issues, high initial cost and the potential for lost or stolen RFIDs is the RTLS worth the investment? Are RFIDs in RTLS applied to the ED considered sustainable?

SUSTAINABILITY

Sustainability can be thought of as a concept containing three different pillars; environmental sustainability, economic sustainability, and social sustainability [16]. RFID tags can be considered environmentally sustainable because their tags are reusable. In fact, passive RFID tags can last up to 20 years before they need to be replaced. However, the one environmental con of RFID tags is their disposal process. Due to the fact all RFID tags are composed of silicon and metallic components, the tags are non-biodegradable. Furthermore, RFID tags contain numerous different metals that makes these tags difficult to dispose of [17]. Currently, most RFID tags are not environmentally disposable, however, in 2009 Stanford University officially announced the first ever biodegradable RFID tag [17]. Therefore, with more research and engineering, RFID tags have the potential to become more environmentally friendly.

The case studies mentioned earlier exemplify how RFID RTLS systems are extremely economically friendly due to their overall improvement on the hospital's patient flow. For example, Dr. Kannry's case study in Mount Sinai was an economic success. Kannry spent only $12,000 but was able to increase efficiency in the hospital by 67%. In this case, a small initial investment lead a significant improvement in

operations, proving that RFID systems can be incredibly economically viable. Even though the ROI for Dr. Kannry's case study is not known, it is easy to prove the overall effectiveness of their study. The cases' statistics showed great improvements that imply RFID RTLS systems are worth the upfront cost of installation. These systems allow more patients per hour which will improve their overall profit and can reduce misidentification of patients. Therefore, the Mount Sinai application was economically sustainable. This implies that similar applications of RFID RTLS can also be worth the investment.

Lastly, RFID RTLS are socially sustainable because they make the hospital EDs a more comfortable experience for both patients and hospital staff. Across the board, it has been noted that hospital EDs are one of the most inefficient and unpleasant hospital departments. Many of this unhappiness stems from the long waiting times and lack of proper and careful healthcare. However, with the Dr. Kanry's incorporation of passive RFID tags he was able to decrease waiting times for rooms up to two hours per patient. This significant cut in waiting times clearly shows that the quality of the patient's stay at the ED was improved which encourages social sustainability. Furthermore, RFID RTLS improve social sustainability among not only patients, but also the hospital staff. In fact, Dr. Kannry's study noted that all the hospital staff and nurses strongly supported the new implementation of the RFID system, for it made their jobs more efficient and allowed them to take the time saved by the system to better help patients. Thus with all of these factors in mind it can be concluded that RFID RTLS systems are overall extremely sustainable.

RECOMMENDATIONS

While RFID technology is far from perfect, there is still great potential for its use within the ED. According to a paper released in 2013, healthcare's consumption of RFID tags and services is only expected to rise [4]. Yen-Cheih's study displayed the versatility of RFID systems and how one system can optimize five different inefficiencies within the ER. Furthermore, there is no doubt that the use of RFID in Mount Sinai Medical Center was a complete success. This minimally invasive use of RFID technology greatly optimized the hospital's discharge time and was a sustainable solution to make the ED much more pleasant for both patients as well as the hospital staff.

Despite the great possibilities RFID technology offers to the ED, there are many privacy and social issues related to human applications of RFID technology in the ED that requires more research and study before RFID RTLS on a large scale can be successfully applied. Some of the improvements required for such systems include, but are not limited to the encryption of personal data within the RFID and better scanning ability for RFID tags that are less susceptible to its environment [4]. With the addition of these factors, RFID RTLS will open new doors for RFID applications in the hospital ED, making for a better tomorrow.

SOURCES

[1] P. Croskerry. "Emergency medicine: A practice prone to error?" Croskerry and Sinclair. 10.2001. Accessed 2.15.2018. https://www.ncbi.nlm.nih.gov/pubmed/17610769

[2] L. Leape. "A Systems Analysis Approach to Medical Error" Journal of Evaluation in Clinical Practice. 1.29.1997. Accessed 2.22.18 http://onlinelibrary.wiley.com/doi/10.1046/j.1365-2753.1997.00006.x/pdf

[3] S. Saghafian. "Operations research/management contributions to emergency department patient flow optimization: Review and research prospects" Taylor and Francis Online. 06.09.2015. Accessed 2.23.2018. https://www.tandfonline.com/doi/full/10.1080/19488300.2015.1017676?scroll=top&needAccess=true

[4] S. Ajami. "The Advantages and Disadvantages of Radio Frequency Identification (RFID) in Health-care Centers; Approach in Emergency Room (ER)" Pak J Med Sci. 2013. Accessed 2.24.18 https://www.pjms.com.pk/index.php/pjms/article/viewFile/3552/1232

[5] R. Sangwan. "Using RFID Tags for Tracking Patients, Charts and Medical Equipment within an Integrated Health Delivery Network" IEEE. Accessed 2.24.18. http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=1461346&tag=1

[6] J. Land. "The History of RFID"IEEE. Accessed 2.24.18 http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=1549751

[7] A. Tokie. "RFID: Past, Present, Future." State University of Novi Pazar. 2012. Accessed 1.11.18. www.np.ac.rs/yu/preuzimanjasve/publications/vol4br1/774-vol4no1rad4/download

[8] D. Wyld. "Preventing the Worst Case Scenario: An Analysis of RFID Technology and Infant Protection in Hospitals" 2009. Accessed 1.15.18. https://print.ispub.com/api/0/ispub-article/5214

[9] S. Ting. "Critical Elements and Lessons Learnt from the Implementation of an RFID-enabled Healthcare Management System in a Medical Organization" 2011. Accessed 2.24.18. https://link.springer.com/article/10.1007/s10916-009-9403-5

[10] J. Kannry. "Small-scale Testing of RFID in a Hospital Setting: RFID as Bed Trigger" AMIA Anny Sym Proc. 2007. Accessed 2.24.18. http://europepmc.org/articles/PMC2813671

[11] Y. Huang. "RFID Applications in Hospitals - A Case Study for Emergency Department" 2011. Accessed 2.24.17 https://pdfs.semanticscholar.org/89d5/84fc685a1177efcb8b64405c8b55c375248c.pdf

[12] C. Chen. "Key drivers for the continued use of RFID technology in the emergency room" 2008. Accessed 2.24.18.

http://www.emeraldinsight.com/doi/pdfplus/10.1108/01409170810851348
[13] M. Laskowski. "Uncertainties Inherent in RFID Tracking Systems in an Emergency Department" Accessed 2.24.18 http://www.emeraldinsight.com/doi/pdfplus/10.1108/01409170810851348
[14] B. Rosenbaum "Radio Frequency Identification (RFID) in Healthcare: Privacy and Security Concerns Limiting Adoption" 2013. Accessed 2.24.18 https://link.springer.com/content/pdf/10.1007%2Fs10916-014-0019-z.pdf
[15] "Guidance Regarding Methods for De-identification of Protected Health Information Accordance with the Health Insurance Portability and Accountability Act (HIPPA) Privacy Rule" Accessed 2.24.18 https://www.hhs.gov/hipaa/for-professionals/privacy/special-topics/de-identification/index.html
[16] "The Three Pillars of Sustainability" 2014. Accessed 3.27.18 http://www.thwink.org/sustain/glossary/ThreePillarsOfSustainability.htm
[17] "How Green is RFID" 2008. Accessed 3.27.18 http://www.corerfid.com/Files/White%20Papers/071%20Green%20Issues%20Fact%20Sheet.pdf
[18] T. Peabody "RFID Technology Selection and Economic Justification for Healthcare Asset Tracking" Accessed 3.27.18 http://digitalcommons.calpoly.edu/cgi/viewcontent.cgi?article=2052&context=theses

AWKNOLEDGEMENTS

We would like to thank all of our teachers along the way who have nurtured us and encouraged us to love to learn and explore our world. We would also like to thank all of our friends and family who have been there to support us into achieving what we have today.