2006

Radio Frequency Identification Applications in Health Care

Angela M. Wicks
Bryant University

John K. Visich
Bryant University

Suhong Li
Bryant University

Recommended Citation
International Journal of Healthcare Technology and Management, Vol. 7, No. 6, 2006, pp. 522-540.

1

Radio frequency identification applications in health care

Angela M. Wicks, John K. Visich, and Suhong Li
Management Department, Bryant University, Smithfield, RI 02917 USA

Abstract: When lives are at stake, zero defects should be the established standard. This philosophy applies whether the federal government is attempting to protect the nation's drug supply from terrorist attack or in other healthcare environments where patient safety is critically important and where medical errors can result in death or serious injury. Therefore, any technology that can reduce the threat of terrorist attack, reduce medical errors, and increase patient safety should be thoroughly tested and evaluated. Radio frequency identification (RFID) is one technology that holds great promise. In this paper we discuss the potential benefits, the areas of applications, implementation challenges and corresponding strategies of RFID in the healthcare industry.

Keywords: Health Care, RFID, Supply Chain Management, Adoption and Implementation, E-Business.

Reference to this paper should be made as follows: Wicks, A., Visich, J., and Li, S., (xxxx) 'Radio frequency identification applications in health care', *International Journal of Healthcare Technology and Management*, Vol. x, No. x, pp. xxx-xxx.

Biographical notes:

1 INTRODUCTION

When lives are at stake, zero defects should be the established standard. This philosophy applies whether the federal government is attempting to protect the nation's drug supply from terrorist attack or in other healthcare environments where patient safety is critically important and where medical errors can result in death or serious injury. Therefore, any technology that can reduce the threat of terrorist attack, reduce medical errors, and increase patient safety should be thoroughly tested and evaluated. Radio frequency identification (RFID) technology is one technology that holds great promise. "RFID…[has] the potential to revolutionize business processes across a wide range of industries including…health care…[and] pharmaceuticals" [14, p. 1]. RFID technology can be used to track pharmaceutical drugs, the blood supply, and battlefield casualties and accident victims, to track and manage hospital patients' medications, medical supply usage, medical processes, and to track and evaluate outpatients' compliance with medication treatment plans after hospital discharge or following clinical visits.

Government forces and major international retailers are major drivers of RFID technology. The Department of Defense has issued warnings that drugs could become the target of terrorist attacks; the warnings are based on Interpol warnings about terrorist involvement in counterfeiting [29]. Therefore, the Secretary of the Department of Health and Human Services, Tommy Thompson, recommended in February of 2004 that the pharmaceutical industry implement RFID tagging on all drugs at the unit level by the year 2007 in order to track drugs throughout the economy to prevent drug counterfeiting [3] and distribution by terrorists groups and other criminal elements. The U.S. Food and Drug Administration (FDA) have called for the widespread use of RFID technology by 2007 to track drug distribution [7]. The FDA has identified several benefits of RFID technology including the ability to: deter and detect counterfeit drugs, conduct efficient targeted recalls; manage inventory; identify theft; identify diverted drugs; and the improvement of patient safety by assuring correct dispensing of drugs [16]. In addition, the U.S. Department of Defense issued a policy memo on October 2, 2003, that required its 43,000 suppliers to put RFID tags on pallets, cases and on any single item with a cost of more than $5,000 beginning January 1, 2005, and RFID tags will be required for doing business with the Department of Defense by the end of 2006 [9,3,39].

Retailers and manufacturers such as Wal-Mart, Proctor & Gamble, Gillette, Marks & Spencer, Tesco, CVS, and many others are the driving forces behind the sudden surge in RFID applications in the consumer goods field. And, healthcare products are a major market segment of consumer goods. Due to the possible benefits of RFID systems, Wal-Mart has requested its top 100 suppliers to tag pallets and cases they ship to Wal-Mart distribution centers by January 2005 [2,19] and for its next top 200 suppliers by January 2006 [37]. Their objective is to replace bar coding and scanners with RFID tags and readers in order to increase speed and efficiency in the supply chain [45], and to reduce inventory, out of stock merchandise and labor cost in stores and warehouses [40]. Procter & Gamble and Gillette are using the technology to track products from the production line to the store shelves. Gillette estimates that its sales would be 15% higher if shelves were always stocked. Marks & Spencer announced in May, 2004 that they were replacing barcodes with RFID tags throughout its refrigerated food supply chain. Tesco is testing RFID technology to track trays and cases moving from its distributors to two of its UK (United Kingdom) stores [25]. CVS is testing RFID technology to improve customer satisfaction; CVS is concerned with accuracy in filling prescriptions and in providing the types of inventory expected by the customer [4]. Some other early adopters of RFID technology include The Gap, Woolworth's, Allied Domecq, Argos, Benetton, Prada [47], and Target (Industrial Engineer, 2004). Also, enterprise software companies, such as SAP, Oracle, Microsoft Corp., Manugistics, and WebMethods Inc., have planned to add support for RFID to their products.

The mandates from the major retailers and the US government are driving the growth of the RFID market. The overall global market for RFID in 2002 was US $965 million; the market is expected to grow at an annual rate of 45% to US $4.6 billion by the year 2007 [20,44]. Sales of RFID technology for supply chain applications was nearly US $89 million in 2002 with an expected growth rate of 38% through 2007, and projected sales of US $448.4 million by 2007 [20]. Health care is included in the top three fastest growing market segments [20], and nearly one-fifth of those healthcare companies responding to the *Information Week* 500 survey say they have tested and deployed RFID technology [33].

In spite of increased pressure for its implementation, RFID technology is not well understood by both companies and consumers. An online survey of more than 350 information technology (IT) executives in April 2004, conducted jointly by BearingPoint Inc., the Software and Information Industry Association in Washington and International Data Group's *CIO* magazine, found that only 22 percent said they have a high understanding of the technology, less than half said that they have a moderate level of understanding [15]. On the other hand, a survey of 100 North American consumers conducted by Cap Gemini Ernst and Young in 2004 reported that only 23% of consumers have heard of RFID technology [43].

The increased popularity and the lack of understanding of RFID technology create a dilemma that calls for immediate research to explore RFID technology and guide its implementation in practice in the health care industry. However, there is a very limited and fragmented research in this area. It is understood that RFID technology is being widely adopted in a number of industries; if healthcare organizations do not develop the RFID infrastructure now, they could be facing an environment where "other industries will impose their standards on the healthcare industry" [3]. This study aims to focus on the application of RFID technology in the healthcare industry by reviewing relevant literature, discussing how RFID systems work, its applications and benefits, the implementation challenges and the corresponding strategies. This research will offer useful guidance for healthcare organizations that wish to implement RFID and offer a springboard for future research in this area.

2 LITERATURE REVIEW

RFID is not new technology; it was developed during World War II to identify aircraft to prevent friendly-fire incidents [44]. Commercial use began in the 1980s, primarily in the transportation industries of railroad and trucking [30]. Other early RFID commercial applications included the EZPass electronic highway toll collection system, ExxonMobil's purchase authorization system SpeedPass, keyless car entry systems, and livestock tracking systems [44]. Target Stores is testing RFID to control its supply chain operations, and Boeing is testing RFID to track airline parts [44]. However, the technology was not applied on a wide scale until the RFID-ready mandate issued by Wal-Mart. Therefore, academic research on the topic has been limited and fragmented, focused mainly focusing on retailers/manufacturers or certain functional areas such as packaging and forecasting.

For example, Jones et al. [25] discuss the opportunities and implementation challenges of RFID technology for retailers in the UK. Småros and Holmström [41] considered RFID as a data capture method in consumers' refrigerators to develop a new type of e-grocery related service, vendor managed inventory (VMI) in the household. Kärkkäinen [26] discussed the potential of RFID implementation for increasing supply chain efficiency of short shelf life products through a RFID trial conducted at UK retailer Sainsbury's. Brewer and Sloan [6] regarded RFID as an intelligent tracking technology in manufacturing which provides real-time

time information throughout the supply chain to support logistics planning and execution. Kärkkäinen and Holmström [27] considered RFID as a wireless product identification technology to enable material handling efficiency, customization and information sharing in a supply chain and discuss some benefits of RFID in supply chain. Moreover, Jansen and Krabs [23] consider RFID technology as an efficient way for companies to replace their one-way packaging systems with returnable systems (containers) in order to save energy and resources and to reduce waste in packaging. Lapide [31] suggested the benefits of RFID for forecasting, such as improved forecast accuracy, correct demand data for out-of-stock items, more accurate point of sale (POS) data from retailers, and better tracking of products sold with or without promotion.

Little research in Healthcare-specific applications of RFID exists. Hosaka [21] simulated hospital bedside and nursing station conditions to determine the range of the tag and antenna. The study also presented several ideas to solve implementation issues for hospital use. Glabman [18] presented a theoretical paper that examines the various applications for RFID in healthcare. This paper will extend Glabman's study to include implementation issues of RFID in healthcare industry.

3 THE RFID SYSTEM

All RFID systems are comprised of three main components: (1) the RFID tag, or transponder, which is located on the object to be identified and is the data carrier in the RFID system; (2) the RFID reader, or transceiver, which may be able to both read data from and write data to a transponder; and (3) the back-end database which associates records with data collected by readers [25].

RFID tags can be placed in two primary categories: active and passive tags. Active tags contain a battery that provides power so the tag can transmit a signal, up to 100 feet, to a reader. Passive tags do not contain a battery and hence are much cheaper than active tags. Passive tags are read when they pass through the electromagnetic field of a reader [13]. Tags can be chip-based or chipless. Chip-based tags consist of a microchip that stores data and a coupling element, such as a coiled antenna, used to communicate via radio frequency communication, while a chipless tag does not contain an integrated electronic chip. Chipless tags can be used in anti-counterfeiting and anti-theft applications. Tags can be read-only, write once/read many times or read-write. Data on a read only-tag cannot be changed unless the chip is electronically reprogrammed and they are often used to track assets that will have a unique ID over their lifetime. A read-write tag will allow changes to the stored data and they are used to track items through the supply chain [47]. This paper will focus on the passive, chip-based, read-write tags for the following reasons. Passive tags are significantly cheaper than active tags and therefore can be used to cost effectively track at the pallet, case and item levels. Read-write tags provide a living history of the item being tracked and, therefore, increase transparency in the applications for which they are used.

RFID tags can be manufactured from a variety of chip and code formats. One code format that enjoys substantial support in the retail industry is the Electronic Product Code (EPC). The EPC uses a 96-bit scheme advocated by EPCglobal (previously known as the Auto-ID Center [45].

3.1 How RFID systems work

Figure 1 shows how a RFID system works. First, a unique identifier, such as an EPC, is embedded into the microchip in a tag. The microchip can also incorporate functionality beyond simple identification and include integrated sensors, read/write storage, encryption and access control. The tag is then attached to an item, case or pallet. In healthcare applications the tag would be applied to patients or equipment such as machines, gurneys, and wheelchairs. As the item/case/pallet/patient moves into the scanning range of the reader, the reader sends out electromagnetic waves that form a magnetic field when they "couple" with antenna on the RFID tag. The tag draws power from the magnetic field and uses it to power the microchips' circuits. The microchip then modulates the received signal in accordance with its identification or programmed code and transmits or reflects a radio frequency signal. The modulation is in turn picked up by the reader, which decodes the information contained in the transponder and depending upon the reader configuration, either stores the information, acts upon it, or transmits the information to the host computer via the communications port [25]
.

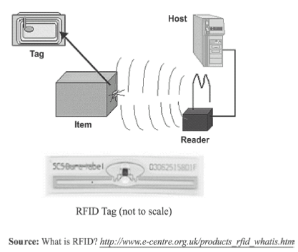

Figure 1: A typical RFID system and tag

3.2 Performance tradeoffs of RFID systems

The cost and performance of RFID tags are a function of the level of radio frequency waves produced by the reader. Low frequency tags require a larger antenna that increases the tag size and cost. High frequency tags can be smaller and cheaper, but require a more expensive reader. Reader range and speed of data transfer increase as frequency increases, but so does the health risk to workers due to radiation. Higher frequencies also have reflection problems and are negatively impacted by metal, liquid, glass and moist environments. Low frequencies are not impacted by the presence of metal and can even read through some non-ferrous metals [47].

Reader antenna shape and tag antenna design also affect RFID system performance. A circular polarized reader antenna should be used if the tag orientation within the radio frequency field is unknown, while a linear polarized reader antenna provides greater radio frequency penetration and longer read ranges. On a passive tag, the most important design characteristic is the antenna. A multi-directional antenna is less orientation specific and hence performs better than a single-directional antenna, but at a higher cost [45].

Another performance consideration in the current RFID systems is the read rate. Wal-Mart suppliers testing the RFID system have had mixed results. For example, Kimberly-Clark has achieved reads ranging from 85 to 94 percent for cases on a pallet (Kimberly-Clark produces paper based products which are RFID friendly) while Unilever (makers of shampoo and other personal hygiene products) has reported low readability rates for cases stacked on pallets and less than 100% readability for cases moving on a conveyor. Simon Ellis, supply chain futurist at Unilever mentioned that packaging redesign might be necessary to increase read rates [38].

3.3 Comparison of RFID with bar codes

Traditionally in the supply chain, bar-codes are used to track the movement of goods. Bar codes are "a series of alternating bars and spaces printed or stamped on parts, containers, labels or other media, representing encoded information that is read by electronic readers" [1]. Bar codes are used from the container level to the individual item level and though currently in widespread use, bar codes have limitations. Bar codes are the same for all instances of a unique stockkeeping unit (SKU) and hence do not differentiate between items. For example, tens cases of shampoo will all have the same bar code and each bottle of shampoo in all ten cases will have the same bar code. This same bar code for all SKUs makes it difficult to track and trace items that may need to be recalled due to quality or safety concerns. In contrast, RFID can be used to identify products at item level, can be read with no requirement for line of sight and can operate in harsh environments, where dirt, dust and moisture conditions can affect other types of Automatic Data Capture Systems such as bar codes. Moreover, multiple tags can be read simultaneously, and tags can also be programmed easily. Tags are capable of carrying more than 64 bits of information compared with 19 bits for bar-code technology, thus enabling RFID to store information such as location, move history, destination, expiration date and environmental conditions (temperature, moisture, etc.). RFID tags are tracking devices; bar codes provide no tracking capability. Bar codes require a higher print quality level that leads to greater scrap rates during packaging [18]; RFID does not require printing thus reducing one aspect of variation in the packaging process. Some RFID tags can be reprogrammed; bar codes are not reusable [18]. RFID tags promise many advantages over bar codes and have the potential to replace them in the supply chain. Bar-coding technology is cheaper but requires line of sight whereas RFID technology can scan full cartons of products without the need to open the carton. Labor time is also saved by not having to pick up the package and properly position the bar code for scanning. Table 1 in the Appendix shows the major advantages of RFID tags over bar codes.

4 Potential benefits of RFID technology in the Healthcare Industry

Benefits to the drug and healthcare industries not only include improved supply chain efficiency, but also can translate into saving lives or improving patient outcomes. The technology can increase patient safety, can speed critical treatments, and provide better tracking of patient drug treatment compliance that leads to better follow-up treatment. Benefits of RFID also include lower direct and indirect labor costs. The benefits of RFID can be summarized into the following four categories: cost reduction, patient treatment and safety improvement, supply chain efficiency, and the prevention of drug-based terrorist attacks.

4.1 Cost reduction

It is well know rising health care costs are a major concern of the general public, politicians, and health care professionals. Health care organizations are actively seeking ways to reduce expenses in all areas of operations. Agility Healthcare Solutions CEO, Fran Dirksmeier, “estimates a 200-bed hospital can save US $600,000 annually from less shrinkage, fewer rentals, deferral of new purchases and improved staff productivity. A 500-bed hospital could save US $1 million annually” [18]. Advocate Good Shepherd Hospital, in Barrington Illinois, implemented RFID in 2003 to help manage inventory; annual inventory losses were cut about ten percent [18]. Many hospitals have a history of high costs related to lost, misplaced, or stolen equipment. For example, US $4 million worth of equipment was unaccounted for at Jackson Memorial Hospital, in Miami, Florida, in 2003; the hospital plans to implement RFID equipment tracking technology within two years [18]. Holy Name Hospital, a 361-bed facility in Teaneck, New Jersey, found that RFID-tagged equipment saved time in locating equipment and reduced rental costs since equipment was more fully utilized [18]. Cap Gemini Ernst & Young estimated that the five-year net present value of full adoption in the US drug system would result in savings of US $2.3 billion to manufacturers, US $8.2 billion to hospitals, and US $660 billion to distributors [29]. Medical equipment can also be tagged to monitor usage in order to improve the accuracy of billing patients and scheduling maintenance.

RFID technology can also reduce costs by preventing the theft of over-the-counter (OTC) drugs. OTC drugs are often distributed or sold in small, expensive packages that are prone to theft [5]. The RFID tag can trigger an alarm when thieves attempt to leave specified areas without paying for the drugs. This same system can be set up in hospitals to control drugs distributed to patients. Unauthorized removal or improper sign-out of medication could trigger an alarm or even lock exit doors.

4.2 The improvement of patient treatment and safety

As healthcare organizations seek to reduce costs, it is important that patient satisfaction is adversely affected. RFID can improve patient treatment and safety by reducing medical errors, reducing counterfeit drug production, improving the security of medicine and the facility, and improving patient compliance.

Reducing medical errors

The Institute of Medicine estimates that "tens of thousands of deaths and injuries [are] caused by medical mistakes every year" [32, p. 101]. The FDA estimates that number to be nearly 500,000 [32]. However, the FDA also estimates that half of the drug errors are preventable; and, the introduction of integrated information technology could greatly reduce that number. "In a paper-based environment, medical errors frequently approach 40%. Of those, 39% are made at the prescription point, 12% are caused by transcription errors, 11% in dispensing…Equipping pharmacists, doctors, and bedside nurse with wireless devices that incorporate bar codes or RFID will nearly eliminate all those errors" [28, p. 100]. For example, the RFID tag can be attached to patients and drugs. Nurses could electronically scan the patient's RFID tag and the drug's RFID tag to ensure that the correct drug and correct dosage are administered to the patient. The tags could alert the health care provider about possible patient allergies and potential drug interaction problems [33]. Tags also could be used to monitor the patient's environment and movement within the facility by attaching tags to the patient and all the patient's medical articles [21]. A wireless communication system could be used to monitor the environment and when tags indicators do not match the care pathway, an alarm would sound. RFID technology could also be used in the physician's office to scan in prescriptions and transmit them to the pharmacy; this would mean no more hand-written prescriptions, which will reduce prescription fill-rate errors [35]. In addition, the tags could be used to identify out-of-date products and hence reduce the possibility of a fatal or ineffective dose.

Reducing Counterfeit Drug Production

The FDA has identified drug counterfeiting as an emerging threat to the American public and has identified RFID tagging of products by manufacturers, wholesalers, and retailers as the most promising approach to reliable product tracking and tracing [16]. The real-time tracking features of RFID tags allow full visibility of drugs along the supply chain, making counterfeit drugs immediately apparent and thus protecting against counterfeit drug production, which will increase consumer safety. According to Kontnik and Dahod [29], "[t]he US drug system has embraced EPC/RFID and is betting most of its 'anticounterfeiting chips' on the expectation that a fully implemented system will be in place and operating (at the unit packaging level) by the year 2007 or earlier" (p. 60).

Improving the Security of the Medicine and the Facility

RFID is an effective technology for tracking and accounting for medicines because it gives a unique numerical identity to units of medicine (mass serialization) [29] and automates the reading and tracking of these numbers, thus adding security within the supply chain [29]. The technology enables "authorized users to automatically identify and account for each unit of authentic medicine in real times as it enters and moves through the distribution system" [29, p. 60].

RFID technology can also be used to improve the security of a hospital or treatment center by controlling access to different areas of the facility. Tags can be applied to employee identification tags and could indicate when an employee enters a restricted area. When such an event occurs an alarm could be triggered to alert security personnel of an unauthorized entry.

Improving Patient Compliance

Mediary Corp. has invented the Med-ic Electronic Compliance Monitor, a technology that embeds RFID tags into blister packs of prescription packages. The "new blister packaging system…can monitor electronically the date and the time a patient opens a package of medicine and takes out a pill" [36, p. 26]. The patient must return the used packaging to the health care provider, the package is scanned, and the scanner plots out patient usage patterns. The blister packaging system will enable health care providers to more effectively evaluate patient compliance with prescription medication therapy since the doctor or pharmacist can see if the patient skipped or doubled up on doses [36]. The dosage patterns can help the physician and/or pharmacist understand why the patient is not improving or why the patient's condition is worsening. The technology can also be extended to "alert the patient when it is time to take a pill" [36, p. 26]. The RFID tag "can be tailored to specific clinical requirements, such as monitoring the temperature, vibration, humidity, radiation, light or shock to which the package might be exposed" [36, p. 28]. The cost of this new technology is about $15 per blister pack and approximately $600 for the scanner and software [36]. However, as demand increases, production costs are expected to drop below $5 per blister-packaging tag [36].

4.3 Supply chain efficiency

Though healthcare organizations are part of the service industry, they do utilize tangible products in the delivery of services to patients. Hence, the efficient management of the supply chain for tangible products is important in reducing costs and improving patient satisfaction. Safety and security issues can be addressed efficiently and effectively since the technology can be implemented with minimal increases in staffing and packaging costs [29]. The entire supply chain is more efficient. Boxes of drugs can be scanned without opening the cartons [3]. Overall, improvements in tracking and visibility are crucial to the long-term success for the pharmaceutical and medical product industries "to ensure that consumers are protected, product integrity is maintained, and shrinkage is minimized to maximize revenue" [29, p. 60]. Out-of-date stock and product returns should be reduced, further improving profitability. RFID technology can also increase efficiency and visibility within the supply chain by improved tracking of the blood supply and by improved tracking of physical items, better recall management, and improved supply chain planning and patient treatment.

Improved Tracking of the Blood Supply

Managing blood distribution is a nightmare, "the stuff of supply chain nightmares, the kind that keep logistic professionals awake at 3a.m…." [38, p. 15], because you are dealing with a highly perishable, highly sensitive product that is always in short supply and is always difficult to procure

[38]. The blood supply has a life of 35 days after preservatives are added; the life of platelets is only five days [38]. Blood must be treated with preservatives and kept under specific conditions; variation from the standard will result in death. In addition, the blood donor rate has consistently hovered around 7 percent while demand never decreases, creating a constant shortage [38]. Accurate tracking is imperative since the correct type of blood must be delivered to the right place at the right time.

RFID technology can provide accurate tracking, in real time. Since blood must be kept at specific temperatures, temperature sensitive tags would ensure that blood that was stored at other than optimal temperatures would not be distributed to a patient. Other benefits include the ability to track tainted blood, an issue that arose in Great Britain after the mad cow disease outbreak and arose in America after the AIDS epidemic.

Improved Tracking of Physical Items

RFID tags could be used for identification, tracking and locating in healthcare facilities for any applications involving patients, clinicians, equipment, supplies and controlled drugs [34]. Tags could be used to determine whether supplies and instruments had been sterilized [34]. Miller [34] also addresses other issues such as tracking residents in long-term care facilities, monitoring access to restricted areas, identifying implantable medical devise, and scanning information from implanted equipment.

RFID tagging would allow for product tracking without infringing on required federal government labeling space. The government agencies have passed numerous labeling regulations, including the Federal Food, Drug, and Cosmetic Act of 1938, the Fair Packaging and Labeling Act of 1967, the Poison Prevention Packaging Act of 1970, and various other Federal Drug Administration rules and regulations [16]. The requirements for stringent and numerous labeling regulations on often quite small packaging has created problems for the pharmaceutical industry. RFID tagging would solve this problem since the tag could be placed inside the package and thus not obscure any portion of the exterior label. If the tag replaces the bar-code then more space would be freed up on the outside of the package to meet labeling regulations.

Better Drug Recall Management

RFID tagging will make drug recall activities faster and more efficient since the drugs will be visible along the supply chain [3]. Accurate tracking means that specific drug batches can be located quickly and effectively in the event of a product recall, and facilitates the disposal of damaged and out-of-date product [29]. This improved efficiency in recall management will also lower the costs associated with recalls.

Improving Supply Chain Planning and Patient Treatment

The Navy is experimenting with using passive tags as tracking devices for patients in the battlefield. Wounded soldiers are provided with an RFID tag; a healthcare worker can then scan the tag, upload the information into a hand-held scanner, and make entries about the patient's condition and care [39, p. 65]. The system was field tested in Iraq in a 116-bed hospital in an operational environment. Implementation results included: increased casualty accountability and documentation; increased situational awareness; and maximized use of resources [10]. The system easily could be leveraged to an emergency response system where the patient is tagged in the field by the emergency team, and the patient's condition and treatment data scanned onto the tag and uploaded at the hospital. The impact would be to speed treatment and improve accuracy. In addition to the benefits previously mentioned, such a system can provide more planning information to the hospital, such as requirements for emergency room staffing and for usage requirement for x-rays and other ancillary services.

4.4 The prevention of drug-based terrorist attacks

RFID will protect the drug industry against terrorist attacks using tainted medicine. The real-time tracking features allow authorized law enforcement agencies full visibility along the supply chain, thus making counterfeit drugs immediately apparent [29]. Such RFID capability will make this country less vulnerable to drug-based terrorist attacks.

Congress has acted to open the borders of the United States to drugs from other countries [29]. In addition to the elevated threat of terrorist acts imported into the United States from these other countries, the increased length of the supply chain increases the risk of terrorist attacks and the less stringent manufacturing processes in these countries could lead to increased instances of health and safety problems that would require recalls. RFID tracking would play an essential role in tracking foreign drugs in this country. The issue has become so important that during the 2004 US presidential election campaign, President Bush and his opponent, John Kerry, both vowed to implement electronic health record systems within four to ten years [33]. Not only would RFID reduce the risk of terrorist attack but it would also eliminate "tens of thousands of deaths and injuries caused by medical mistakes every year" [33, p. 101] and according to Health and Human Services Secretary Tommy Thompson "a good health-information system could save our economy $140 billion a year. That's about 10% of our total health-care spending, and that's a conservative estimate" [46]. RFID will be a key component of the health-information system.

5 AN OVERVIEW OF RFID APPLICATIONS

RFID will protect the drug industry against terrorist attacks using tainted medicine. The real-time tracking features allow authorized law enforcement agencies full visibility along the supply chain, thus making counterfeit drugs immediately apparent [29]. Such RFID capability will make this country less vulnerable to drug-based terrorist attacks.

Congress has acted to open the borders of the United States to drugs from other countries [29]. In addition to the elevated threat of terrorist acts imported into the United States from these other countries, the increased length of the supply chain increases the risk of terrorist attacks and the less stringent manufacturing processes in these countries could lead to increased instances of health and safety problems that would require recalls. RFID tracking would play an essential role in tracking foreign drugs in this country. The issue has become so important that during the 2004 US presidential election campaign, President Bush and his opponent, John Kerry, both vowed to implement electronic health record systems within four to ten years [33]. Not only would RFID reduce the risk of terrorist attack but it would also eliminate "tens of thousands of deaths and injuries caused by medical mistakes every year" [32, p. 101] and according to Health and Human Services Secretary Tommy Thompson "a good health-information system could save our economy $140 billion a year. That's about 10% of our total health-care spending, and that's a conservative estimate" [46]). RFID will be a key component of the health-information system.

6 IMPLEMENTATION CHALLENGES

Currently the costs associated with implementing and managing the tagging systems are the major problems associated with RFID. These costs include obtaining tags, applying tags to equipment or patients, purchasing tag readers, developing software programs and database systems, integration with existing systems and system maintenance. In such environments, tags would have to be attached to everything; and, for a 1000-bed hospital that could mean tagging 20,000 items per day [21]. The tags would have to be quite small and cost effective before such a system could be implemented, and decisions would have to be made regarding who would apply the tags. Hosaka [21] suggests that the tags originate at hospital registration; the patient's information and tag numbers would be stored in a database, and the tags sent to the nursing station. Staff members could attach tags directly to larger items and attach tags to packaging for small items such as syringes [21]. The number of tags would be determined by the patient's estimated length of stay. Unused tags could be reprogrammed. If tags were coated with medical silicon, they can be sterilized and reused until such a protective coating begins to deteriorate [21]. According to a recent HDMA Healthcare Foundation Study, integration costs are estimated to range from $10 to $16 million for large manufacturers and from $3 to $16 million for large distributors [3]; these costs do not include the costs of hardware, data-processing software, or operating expenses. The tags are also relatively expensive; passive RFID tags cost approximately 10 cents per tag whereas bar codes cost approximately 3 cents per sticker [3]. The difference in total costs can be substantial. For example, a typical 800-bed hospital administers approximately 15,000 doses of medication a day [3]; that equates to $1,050 per day difference in medication tagging costs alone.

Although cost is a major impediment to RFID implementation, increased demand for RFID tags and supporting systems will drive technology to improve the system and lower associated costs. Alien Technology Corp. has patented a manufacturing and packaging process called fluidic self-assembly. The new processes are purported to greatly reduce the price of RFID tags; Alien's goal is to reduce the cost to 5 cents or less per tag. In 2003, Gillette ordered 500 million tags from Alien, the largest RFID sale to date [42]. Smartcode Corp. has also patented a new technology that could produce tags at a cost of five to ten cents per tag; however, that price is for volume orders of at least a billion tags. Companies can also outsource. Bon Secours has contracted with Agility Healthcare Solutions; Agility tags the medical equipment, installs the scanning equipment, and monitors the systems for a monthly fee. Bon Secours estimated a cost of $750,000 to perform these services in-house; the company is expecting an annual savings of $200,000 from outsourcing and a conservative savings of $203,000 from its ability to track equipment, thus preventing theft and loss [18]. Companies can also take advantage of the research from the newly created FedEx Institute of Technology; the institute's mission is to bring an interdisciplinary approach to supply-chain research so that "RFID tags can track goods or the progress of patients through a health care facility" [11, p. 1].

Labeling is another issue that must be addressed. RFID tags must not cover other required over-the-counter drug labels [5]. As previously mentioned, drug manufacturers must comply with numerous legislative and regulatory requirements when labeling drugs. Bix, et al., [5] found that problems exist related to where to place RFID tags on small packages that require multiple labels and found that most companies lack application training so that employees comply with government regulations. The study found that of the 849 packages evaluated, 34.51% of the RFID tags partially or completely obscured required governmental labels.

Problems with labeling could be solved by reserving space for the tag, using real bar-codes instead of dummy bar-codes on product packaging, and affixing the tags inside cartons [5]. These ideas would provide the room for the RFID tags. And, technology is already at work to reduce the size of the RFID tags; size reduction would mitigate the labeling problems.

The cleansing and analysis of RFID-generated data is also a big issue. Janz et al. [24] reported the results of the implementation of an RFID patient tracking system at the Elvis Presley Memorial Trauma Unit of the Shelby County Regional Medical Center (the MED), located in Memphis, Tennessee. They found that a significant amount of noise and "dirty data" are generated from an RFID-based system.

Unique implementation problems centering on patient confidentiality exist in healthcare industries. How can products be named so that each product has a unique identifier yet still maintain patient confidentiality? If the tags are unique, anyone scanning the tags will know the patient's drug therapy program and the patient's disease, illness, or perhaps even type of injury.

These issues relate to data sharing and consumer/patient privacy concerns, and present greater costs and challenges in the healthcare industry than in other industries adopting RFID technology [9]. Privacy advocates are concerned that third parties might be able to determine what medicines a person was taking by scanning pill bottles carried by the patient. To prevent snooping, the tags would need either a random number that can be looked up in a secure database to identify the medicine or a security code to access the data stored on the chip. Either security option would increase the cost of chips and readers [29]. In addition, healthcare providers need to be compliant with the U.S. Department of Health and Human Services Health Insurance Portability and Accountability Act (HIPAA). The HIPAA is a security rule that requires an organization to take "reasonable" measures to safeguard electronic health data [17].

Other major problems exist with RFID implementation. According to Kontnik and Dahod [29], a recent Product Safety Task Force identified 26 major problems and at least 60 more minor problems, including how to: name the products (the EPC); construct the track-and-trace database; determine the economic, legal, and regulatory implications of each method; determine what needs to be done to ensure full and accurate records are kept along the entire supply chain; determine how the system should handle expectations and inconsistencies; determine who bears the risk of loss; determine who has the obligation to correct problems; integrate e-mail, scanning, and other print functions within the system; determine what is the best frequency at which to operate; and determine how stable the products are going to be after prolonged exposure to radio frequency waves.

The potential healthcare applications and benefits to the healthcare industry, together with the many unique implementation problems in the healthcare industry faces, has prompted the formation of the Healthcare EDI Coalition (HEDIC), working within the Health Industry Business Communication Council, to work to overcome the various implementation issues. "The workgroup's key objectives are to identify the issues involved with the use of RFID in healthcare applications, to work proactively with technology providers and other standards organizations in developing a response to those issues and to develop guidance and specification for implementing RFID technologies in healthcare applications" [34]. Major topics at the 1999 National Conference & Technology Exposition sponsored by HEDIC included seminars on transition, integration, and implementation of RFID technology; according to the conference program, "the future is here for most stakeholders" [34, p. 59]. The FDA and the Joint Commission on Accreditation of Healthcare Organizations are encouraging bedside bar-coding by the beginning of January 2007; but according to Becker 2004) perhaps RFID could do a better job of tagging patients, workers, and medications, and organizations could move directly to RFID instead of implementing bar-coding and then having to move to RFID.

Other ideas include adopting the EPC standard. Florida already requires this for some products, so the industry could leverage off what Florida is already doing [5]. The industry could establish common business practices to handle exceptions and set consistent best practices; this could be addressed by applying Malcolm Baldrige healthcare criteria standards.

Companies could also set up security infrastructures and set up partnerships along the supply chain to facilitate implementation and lower to costs such as the Blue Cross/Tufts partnership. And, The Department of Homeland Security could provide funding for the tracking of prescription and OTC drugs to protect against terrorist attack.

7 CONCLUSION

The same benefits and problems of RFID implementation that exist in the healthcare industry also exist in other industry sectors. This paper attempts to focus on the issues more specific to the healthcare industry. However, it should be noted that the real benefit of RFID technology comes from going above and beyond compliance and investigating other applications of RFID to improve healthcare marketing efforts, operational effectiveness and efficiency, and patient satisfaction. The mandates from the government and the major retailers will drive the adoption of RFID technology in health care, and companies will have no choice but to implement RFID systems. And, as the old saying goes, "the early bird catches the worm." Even if the true benefits will not be realized for several years, establishing the base RFID infrastructure today is the key driver for total supply chain adoption and benefit realization tomorrow.

REFERENCES

1. *APICS Dictionary, Ninth Edition*, 1998, edited by Cox, J. and Blackstone, J., APICS-The Educational Society for Resource Management, Falls Church, VA.

2. Bacheldor, B., and Sullivan, L., 2004, "RFID Kick-Start, *Information Week,* May 24, p. 20.

3. Becker, C., 2004, "A New Game of Leapfrog?" *Modern Healthcare,* 34(28): pp. 38.

4. Berthiaume, D., 2004, "RFID Boosts Customer Satisfaction at Tesco," *Chain Store Age*, January, p. 24A.

5. Bix, L., Sansgiry, S., Clarke, R., Cardoso, F., and Shringarpure, G.,2004, "Retailers' Tagging Practices: A Potential Liability?," *Packaging Technology and Science*, 17(10): p. 3-11.

6. Brewer, A., and Sloan, N., 1999, "Intelligent tracking in manufacturing," *Journal of Intelligent Manufacturing,* 10: 245-250.

7. Brewin, B., 2004, "FDA Backs RFID Tags for Tracking Prescription Drugs," *Computerworld,* 38(8): pp. 4.

8. Collins, J. (2004a), "Purdue Pharma Tags OxyContin," *RFID Journal,* November 16, www.rfidjournal.com/article/articleprint/1241/-1/1/, accessed December 3, 2004.

9. Collins, J. (2004b) "Pharma Groups Work on EPC Issues", *RFID Journal*,

Deleted: ¶

September 30, www.rfidjournal.com/article/articleprint/1143/-1/1/, accessed October 20, 2004.

10. Collins, P. (2004), "RFID: The next killer app?", *Management Services*, May, pp.20-22.

11. Cottrill, K., 2003, "Grossing Frontiers," *Traffic World,* November 24, 2003, p. 1.

12. Editorial, "VeriSign tools integrate EPC global network," *Journal of Commerce,* September 29, 2004, p. 1.

13. Dinning, M. and Schuster, E., "Fighting friction", *APICS - The Performance Advantage*, February, pp. 26-31, 2003.

14. Editorial, "VeriSign tools integrate EPC global network, *Journal of Commerce,* September 29, 2004.

15. Emery, G., 2004, "IT execs prepare for an RFID revolution," *Washington Technology,* June 29, http://www.washingtontechnology.com/news/1_1/industry/23875-_1.html, accessed August 12, 2004.

16. FDA (2004), "Combating Counterfeit Drugs: A Report of the Food and Drug Administration", U.S. Department of Health and Human Services, Food and Drug Administration, Rockville, Maryland, February.

17. Fenner, M. (2004), "Health Care Goes High Tech," *Card Technology*, July/August, pp. 38-45.

18. Glabman, M., "Room for Tracking: RFID technology finds the way," *Materials Management in Health Care,* May, 2004, p. 26-38.

19. Handfield, R., 2004, "The RFID powerplay: An offer that top suppliers can't refuse," *APICS-The Performance Advantage,* January.

20. Hickey, K., 2004, "RFID Grew in 2002, *Traffic World,* May 5, 2003, p. 20-21.

21. Hosaka, R., 2004, "Feasibility Study of Convenient Automatic Identification System of Medical Articles Using LF-Band RFID in Hospital," *Systems and Computers in Japan,* 35(10): 571-578.

22. Industrial Engineer, 2004.

23. Jansen, R., and Krabs, A., 1999, "Automatic identification in packing-radio frequency identification in multi-way system" *Packing Technology and Science,* 12: p. 229-234.

24. Janz, B., Pittts, M., and Otondo, R. (2004), "Back to Future with RFID, Lessons Learned-Some Old, Some New", Workshop, the 35th Annual

Meeting of the Decision Sciences Institute, Boston, Massachusetts, November 20-23.

25. Jones, P., Clarke-Hill, C., Shears, P., Comfort, D., and Hillier, D., 2004, “Radio frequency identification in the UK: Opportunities and challenges,” *International Journal of Retail & Distribution Management*, 32(3): p. 164-171.

26. Käkkäinen, M., 2003, “Increasing efficiency in the supply chain for short shelf life goods using RFID tagging,” *International Journal of Retail & Distribution Management,* 31(10): p. 529-536.

27. Käkkäinen, M. and Holmström, J., 2002, “Wireless product identification: enabler for handling efficiency, customization and information sharing,” *Supply Chain Management: An International Journal, 7(4): p. 242-252.*

28. Klein, P., 2003, “It’s Innovation That Counts,” *Optimize,* October 2003, p. 99-102.

29. Kontnik, L., and Dahod, S., 2004, “Safe and Secure,” *Pharmaceutical Executive,* 24(9): p. 58-70.

30. Landt, J. (2001), “Shrouds of Time: The History of RFID”, *AIM Publications*, Pittsburgh, PA, USA.

31. Lapide, L., 2004, “RFID” What’s in it for the forecaster?” *The Journal of Business Forecasting*, 23(2): 16-19.

32. McGee, M., 2004, “E-Health Revives Health-Care IT,” *InformationWeek,* September 20, p. 1006.

33. McGee, M., 2004, “Health-Care I.T. Has a New Face,” *InformationWeek,* May 10, p. 16.

34. Miller, M., 1999, “Tuning into future healthcare use of RFID,” *Automatic I.D. News,* 15(2): p. 58.

35. Murphy, C., 2003, “Deciding how to work with competitors,” *InformationWeek*, Nov., Issue. 962, p. 73.

36. Parks, L., 2003, “New microchip watchdog could boost patient compliance,” *Drug Store News,* 25(7): p. 26.

37. *RFID Journal,* 2004, “Wal-Mart details EPC rollout plan,” June 17 www.rfijournal.com/article/articleprint/992/-1/1/, accessed July 15, 2004.

38. Roberts, S., 2004, "When the supply chain becomes a matter of life and death," *Frontline Solutions (Pan-european Edition),* 12(2): p. 14-16.

39. Schwartz, K., 2004, "Tag Team," *Government Executive,* 36(7): p. 65.

40. Seideman, T., 2004, "The race for RFID," *The Journal of Commerce,* 4(48): p. 16-18.

41. Smäros, J., and Holmström, J., 2000, "Viewpoint: Reaching the consumer through e-grocery VMI," *International Journal of Retail and Distribution Management,* 28(2): 55-61.

42. Stackpole, B., 2003, "RFID finds its place," *Electronic Business*, 29(9): p. 42.

43. *UsingRFID.com,* 2004, "How consumers really feel about RFID tags at item level." Cap Gemini Ernst & Young, February, http://www.usingrfid.com/features/read.asp?is+6, accessed August 16, 2004.

44. Ward, S., 2004, "Making Waves," *Barron's,* 84(22): p. 31-32.

45. Weil, M. (2004), "Confusion and Possibility: The Meaning of the Wal-Mart Mandate," APICS - The Performance Advantage, February, pp. 51-54.

46. Whiting, R., 2004, "MIT = RFID + Rx," *Information Week*, May 10, p. 16.

47. Wilding, R. and Delgado, T. (2004), "The story so far: RFID demystified", *Logistics and Transport Focus*, April, pp. 26-31.

Deleted: **Removed byJohn¶**
These groups are concerned with the surveillance measures used to track consumers (Bix, et al., 2004). However, Metro, in Germany, opened an "electrified" store, one that RFID-tags 100% of shelf items to track sales and inventory; no protests were lodged against the company (Kanellos zdnet.com.com/2100-11-3-998138.html).¶
The following are the materials I do not know how to incorporate in the article (Suhong?):¶
BCBS of Massachusetts and Tufts Health Plan now require PDA transmission of prescriptions, and organizations could leverage from this initial plan, and also being able to incorporate the federal government mandated RFID technology. The costs for such an e-prescription plan cost $3M for 3,400 BlackBerry or Pocket PC devices with Xiz's PocketScript E-prescription software and services for Massachusetts doctors, but there are 30% fewer calls between doctors and pharmacists, 35% of doctors report they could check accuracy and drug interactions more easily, pharmacists saved almost an hour of time per pharmacist per day, and drug costs are lower. Half of the doctors changed to Tufts plan-preferred drug, which lowered pharmaceutical costs by 2% or more (Murphy, 2004).¶
¶
Consumers are also drivers for RFID implementation in health care. Internet purchases are increasing (Kontnik and Dahod). Internet purchases create another supply chain vulnerable to terrorist attack and problems associated with purchases from foreign drug manufacturers. ¶
0% of shelf items to track sales and inventory; no protests were lodged against the company (Kanellos zdnet.com.com/2100-11-3-998138.html).¶
The following are the materials I do not know how to incorporate in the article (Suhong?):¶
BCBS of Massachusetts and Tufts Health Plan now require PDA transmission of prescriptions, and organizations could leverage from this initial plan, and ... [1]

APPENDIX

	RFID Tags	Bar Codes
Direct line of sight to reader	not required	Required
Multiple item reads	yes - multiple items can be read simultaneously	no - only one code can be read at a time
Human intervention	not required, though for some products (metal, liquids) package must be oriented	required in most cases to scan the bar code and to orient packages
Labor requirements	lower - the tag is read as it passes through the reader	higher - automated bar code scanners require proper package orientation
Communication	two-way, through the use of a read-write tag	one-way
Information currency	real-time - data is entered into the computer system as the item is read	seldom real-time - data is entered into the computer system when the scanner is uploaded (typically for hand-held scanners)
Missed reads	no - a poka-yoke light system can be utilized to indicate an item has been read	yes - items not scanned have no way to indicate a mis-read or a no-read (theft)
Multiple reads of an item	no - an item with an RFID tag can only be read once since the item has a unique code, its EPC	yes - the same item can be read multiple times with no way of prevention or detection
Robustness	more robust since RFID tags can be embedded in the item	bar code can be damaged (water, abrasion, tear) and be unscannable
Reader range	higher	Lower
Security	can be used as a security device	cannot be used as a security device
Reading speed	higher - due to automation and multiple item reads	lower - limited by the ability of the human operator
Long-term system costs	lower due to tag reuse, cheaper maintenance costs and lower labor requirements	Higher
Data Storage	higher, ≥ 64 bits and growing	lower, 19 bits

(Dinning and Schuster, 2003; Wilding and Delgado, 2004a)

Page 20: [1] Deleted **Angela M. Wicks** **2/8/2005 7:24:00 PM**

Removed byJohn

These groups are concerned with the surveillance measures used to track consumers (Bix, et al., 2004). However, Metro, in Germany, opened an "electrified" store, one that RFID-tags 100% of shelf items to track sales and inventory; no protests were lodged against the company (Kanellos zdnet.com.com/2100-11-3-998138.html).

The following are the materials I do not know how to incorporate in the article (Suhong?):

BCBS of Massachusetts and Tufts Health Plan now require PDA transmission of prescriptions, and organizations could leverage from this initial plan, and also being able to incorporate the federal government mandated RFID technology. The costs for such an e-prescription plan cost $3M for 3,400 BlackBerry or Pocket PC devices with Xiz's PocketScript E-prescription software and services for Massachusetts doctors, but there are 30% fewer calls between doctors and pharmacists, 35% of doctors report they could check accuracy and drug interactions more easily, pharmacists saved almost an hour of time per pharmacist per day, and drug costs are lower. Half of the doctors changed to Tufts plan-preferred drug, which lowered pharmaceutical costs by 2% or more (Murphy, 2004).

Consumers are also drivers for RFID implementation in health care. Internet purchases are increasing (Kontnik and Dahod). Internet purchases create another supply chain vulnerable to terrorist attack and problems associated with purchases from foreign drug manufacturers.

0% of shelf items to track sales and inventory; no protests were lodged against the company (Kanellos zdnet.com.com/2100-11-3-998138.html).

The following are the materials I do not know how to incorporate in the article (Suhong?):

BCBS of Massachusetts and Tufts Health Plan now require PDA transmission of prescriptions, and organizations could leverage from this initial plan, and also being able to incorporate the federal government mandated RFID technology. The costs for such an e-prescription plan cost $3M for 3,400 BlackBerry or Pocket PC devices with Xiz's PocketScript E-prescription software and services for Massachusetts doctors, but there are 30% fewer calls between doctors and pharmacists, 35% of doctors report they could check accuracy and drug interactions more easily, pharmacists saved almost an hour of time per pharmacist per day, and drug costs are lower. Half of the doctors changed to Tufts plan-preferred drug, which lowered pharmaceutical costs by 2% or more (Murphy, 2004).

Consumers are also drivers for RFID implementation in health care. Internet purchases are increasing (Kontnik and Dahod). Internet purchases create another supply chain vulnerable to terrorist attack and problems associated with purchases from foreign drug manufacturers.