Benefits and Barriers of Implementation and Utilization of Radio-Frequency Identification (RFID) Systems in Transfusion Medicine

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Abstract

Radio-frequency identification (RFID) technology is used by hospital supply chains to track medical products and monitor inventories. Hospitals have also begun incorporating RFID technology as part of their transfusion processes. The purpose of this review was to analyze how healthcare organization supply chains can benefit from the utilization of RFID systems in transfusion service departments. The methodology for this study was a literature review following the steps of a systematic review with a total of 52 sources referenced. RFID technology is used to manage and track blood products from the initial donor phlebotomy to final disposition or product transfusion. RFID-enabled transfusion practices have successfully increased provider productivity and product quality through work-time reduction and error reduction. Findings of this research study suggest that RFID has provided improvements in quality of care and efficiency, while initial costs, security, and privacy appear to be the principal barriers to adoption.

Keywords: supply chain, blood bank, transfusion services, radio-frequency identification (RFID), benefits, barriers

Introduction

Supply chain management (SCM) in the healthcare setting is the practice of actively managing the flow of material and information within an organization to provide the highest level of customer service to end users while also maintaining a competitive advantage in overall business processes.[1] SCM within healthcare organizations entails data management, the procurement of organizational products, and logistical operations.[2] Additionally, SCM involves accurate day-to-day operations and efficient movement of goods throughout an organization.[3]

In maintaining and improving their SCM processes, hospitals have begun to incorporate radio-frequency identification (RFID) technology to control, monitor, and evaluate healthcare equipment, supplies, and products. RFID systems utilize radio-frequency electromagnetic fields to obtain data for tracking and identifying medical products and goods.[4] RFID tags are attached to supplies and products; scanning devices, or readers, are then used to identify specific information, including the contents, location, date manufactured, order number, batch number, dosage information, and shipping data. The data collected with the scanning device are then transferred through an interface to a computer or central workstation for review.[5] Examples of RFID use in healthcare organizations include tagging of patients, pharmaceuticals, mobile assets, and blood products. These items can be scanned using RFID reader

software and then tracked by potential end users.[6] The use of RFID technology has increased efficiency and improved inventory management in healthcare facilities.[7]

The integration of RFID technology into healthcare settings has been slow because of a lack of immediate payback in savings, and with continuous technological advancement, many providers do not want to invest in implementing and managing the technology.[8] Although integration has been slow, healthcare organizations have started utilizing RFID technology in several areas. An example of RFID implementation is the process of identifying, tracking, and monitoring the status of blood products from the point of collection to the final disposition, or transfusion, of the product to patients.[9] Through RFID, transfusion departments and supply chains are able to manage blood components to facilitate the delivery of the correct blood products to the correct patients.[10] RFID-enabled transfusion processes can increase efficiency by simplifying verification processes.

As RFID technology has been implemented in patient care areas, safety concerns have been raised because of the emission of low levels of radiation from the devices. Although no patient injuries have been reported, these devices could result in adverse reactions in patients with pacemakers or implantable cardiovascular defibrillators.[11] As a means of maintaining patient safety standards, continuous testing has assessed how these devices affect patients.[12] Studies have shown that exposure to the 13.56-MHz radio waves an RFID device emits shows no significant adverse effects to red blood cells up to the 25th day of holding blood products.[13] The authors of these studies concluded that RFID-enabled processes in transfusion services are a feasible option for future blood bank inventory management.

Research Purpose

The purpose of this research was to analyze how healthcare organization supply chains can benefit from the utilization of RFID systems in transfusion medicine.

Methodology

The approach for this research review followed an organized search pattern adapted from the conceptual framework of Yao et al. (2010).[14] The use of this conceptual framework in the current study is appropriate because the focus of both studies is to show how new technologies (RFID) can be applied to healthcare settings to enhance the care of patients. In addition, this approach has been successfully replicated in previous studies, increasing its internal validity.[15, 16] This framework was utilized to allow clear identification of the benefits of RFID and the barriers to the implementation of RFID in transfusion medicine. To research problems involving the current processes in transfusion medicine, it was first necessary to recognize the existing problems and issues that drive and impede adoption of RFID with regard to blood component processing and transfusion. Figure 1 illustrates the progression to implementation of RFID in transfusion services and includes the recognition of both benefits and barriers to adoption.

The methodology utilized in this literature review conformed to the principles of a systematic search. For the intent of this research query, a comprehensive and exhaustive review was not feasible because of the abundance of studies of heterogeneous quality. The literature review was conducted in three distinct stages including the following: (1) determining the search strategy, and identifying and collecting literature; (2) establishing inclusion criteria, scrutinizing text for relevancy, and analyzing the literature data; and (3) identifying appropriate categories.

Step 1: Literature Identification and Collection

The electronic databases PubMed, ScienceDirect, EBSCOhost, ProQuest, Academic Search Premier, and Google Scholar were searched for the following terms: “RFID” AND “supply chain” AND “blood bank” OR “transfusion services” OR “benefits” OR “barriers”. The *International Journal of Clinical Transfusion Medicine*, the *International Journal of Medical Informatics*, the *Journal of Health Information Management*, and other reliable healthcare websites, including those of the College of American Pathologists, the US Food and Drug Administration, the Red Cross, and the American

Association of Blood Banks, were also used. Citations and abstracts identified by the search were also assessed to identify relevant articles.

Step 2: Establishing Inclusion Criteria and Literature Analysis

Given the technology- and enterprise-oriented nature of the current study, literature was selected to include the technological and organizational impacts of the use of RFID. The search was limited to sources published since 2003 in an attempt to stay current in the research study. The search was also limited to sources attainable as full texts and written in the English language. The methodology and results of the identified texts were analyzed, and key papers were identified and included within the research query. References were reviewed and determined to have satisfied the inclusion criteria if the material provided accurate information about RFID in blood banks with a particular focus on the benefits of and barriers to its implementation. From a total of 94 references found, 52 references were selected for this research study. The literature search was conducted by B.C., P.M., E.W., and S.D. and was validated by A.C., who acted as a second reader and also double-checked that the references met the research study inclusion criteria.

Step 3: Literature Categorization

The results were structured following the conceptual framework, which employed subheadings including Background of RFID in Healthcare Organizations, Use of RFID in Transfusion Medicine, Benefits of RFID in Transfusion Medicine, and Barriers of RFID Adoption in Transfusion Medicine.

Results

Background of RFID in Healthcare Organizations

Efficient SCM systems within healthcare organizations are an important aspect of providing the best patient care while containing operating costs. RFID technology has become a $2.1 billion industry, so assessing which inventory management system to use is imperative for a particular healthcare organization's effectiveness.[17] Through RFID systems, medical product data entry is fast, automated, and contactless via radio waves.[18] As a result, goods can be moved faster and more cheaply while being tracked in a more accurate and timely fashion.[19] Implementing RFID technology in hospital supply chains has allowed healthcare organizations to operate more efficiently, improve organizational quality, and increase patient-level accessibility.[20]

The two key components of RFID systems are tags and readers.[21] Tags consist of silicon microchips and antennas that receive or emit radio frequencies depending on whether the tag is active or passive.[22] Passive tags, costing between $0.10 and $0.50 per tag, lack a power source, generally store less than 2 kilobytes of data, and are primarily used in short-range situations where tag reading is not important.[23] Active tags possess an internal power source and continuously transmit and receive signals farther than 3 meters. Active tags, which cost between $0.50 and $50 per tag, are able to store between 2 kilobytes and 128 kilobytes of data and are used in medium-distance and expensive situations where fast reading is needed.[24]

As RFID has become more prevalent in US industries, the processes to utilize these systems have also grown. In June 2003, Wal-mart required its top 100 suppliers to place RFID tags on each of their pallets and item cases by January 2005.[25] As a result, more than 300 suppliers were feeding RFID-tagged goods to 500 Wal-mart facilities as of March 2006.[26] Additionally, the US Department of Defense began enforcing new policies in which all government vendors would be required to use RFID passive tag technology when shipping pallets and cases to Department of Defense inventories throughout the country by January 2005.[27] The required policy allowed the Department of Defense to track more than 45 million line items from each of its 43,000 different suppliers.[28] Policies such as these have given other industries throughout the United States a foundation on which to base their RFID utilization practices.

Using RFID-enabled medical assets in inventory management and product tracking throughout hospitals has become an important part of providing patient care in a timely and effective manner.[29] It has been estimated that a typical hospital is unable to locate about 15 to 20 percent of its assets, which can

lead to increased purchasing, increased expenditures, and lack of control throughout the network.[30] In placing RFID devices on medical assets, employees can use RFID software to locate items needed for patient care throughout the hospital by searching for their location, the RFID devices can transmit specific location and product information to the user, and use can be monitored accurately.[31]

Use of RFID in Transfusion Medicine

Providing transfusion services to patients involves a multistep process of transferring blood products from donation or supply centers to medical facilities. More than 15.7 million blood donations are collected and approximately 30 million transfusions are performed yearly in the United States.[32] The primary steps involved in the transfer of blood products are identification, screening, and labeling.[33] According to Dzik (2006), the root causes of transfusion errors occur in the stages of identification of the blood drawn at the time of donation, identification of the intended recipient at the bedside, laboratory testing and screening, and labeling of blood samples.[34] Goodnough et al. (2009) claimed that these errors are due to human error and suggested that electronic technologies, such as RFID, can reduce the errors associated with blood ordering and patient/specimen identification.[35] In a study of RFID implementation in multiple blood centers, Davis et al. (2009) concluded that RFID-enabled transfusion practices were successfully performed and increased provider productivity and product quality.[36]

Transfusion medicine is in the beginning stages of adopting RFID technology to support blood collection as well as the processing, labeling, inventory, and distribution of blood products.[37] RFID has been used to regulate and monitor smaller samples of red cells, plasma, platelets, and other blood-related products. In the process of tracking blood samples, the blood bag and the containers used for product transport are equipped with RFID tags to monitor the precise location of the blood products and to account for missing and unused samples.[38] A packing slip is included in the transport container, and contents are verified by the receiving blood center or healthcare facility.[39] Once the tagged products arrive, they are recorded as received in an RFID-enabled database at the receiving facility.[40] In the event of medical emergencies, such as severe blood loss in trauma patients, blood donation and processing centers and hospital transfusion services departments are able to utilize RFID technology to locate and track the closest available compatible blood products to treat these patients.[41]

As medical error–related deaths continue to rise, the Institute of Medicine has made it a priority to find ways to reduce the number of these deaths.[42] In 2013, preventable medical errors accounted for an estimated 210,000 to 400,000 deaths per year.[43] Throughout transfusion-related services, human errors are bound to occur as a result of high patient volumes and other external factors.[44] Integrating RFID systems into transfusion supply chains allows for the opportunity to provide safer transfusions and improve the quality of blood products.[45] According to Briggs et al. (2009), RFID has been able to reduce morbidity and mortality of patients receiving transfusions.[46] RFID utilization in transfusion services will be able to improve transfusion medicine workflow processes, resulting in increased productivity, positive patient outcomes, and significant cost savings.[47]

Progress has been made toward the adoption of RFID in recent years. The Transfusion Medicine RFID Consortium was formed to research the use of RFID methods and devices to identify and track blood products from the point of collection and distribution to final disposition or transfusion. The consortium included representation from hospitals and blood collection and processing facilities as well as RFID industry consultation from middleware and information system companies.[48] In May 2013, the Food and Drug Administration approved the use of iTrace, an RFID device, to store and track the manufacturing data of blood products including the collection, processing, and labeling of components.[49]

Benefits of RFID in Transfusion Medicine

As part of implementing RFID technology in transfusion services, Massachusetts General Hospital has taken the opportunity to utilize this technology to prevent blood transfusion errors.[50] First, the patient is assigned an identification number in the form of an RFID-enabled wristband, which is used to track all patient information throughout the entire transfusion process. The patient is then taken to the treatment area, where an RFID-enabled mobile point-of-care trolley initially verifies the patient's identity and the procedure to be performed. Staff members then scan the patient's wristband into the RFID blood data

system, and once the transfusion is complete, the staff member again scans the tagged blood bag into data system to complete the process.[51] A similar RFID transfusion system implemented in four Italian hospitals during a 2008 pilot study has shown significant improvement in work-reduction times and error reduction of 100 percent.[52] The goal of that study was to record data in order to improve on future systems and processes.[53]

The use of RFID technology in hospital supply chains can provide multiple benefits to a healthcare organization's business operations. RFID technology can increase patient safety, speed critical treatments, reduce supply chain costs, and provide better tracking of patient drug-treatment compliance, which leads to better follow-up treatment. Benefits of using RFID in hospitals not only include improved supply chain efficiency, but also translate into saving lives or improving patient outcomes.[54]

As outlined in Table 1, the benefits of utilizing RFID systems in transfusion medicine have ranged from improved identification of patients and blood components to long-term savings and increased productivity. A cost-benefit assessment by Davis et al. (2009) showed a five-year return on investment of 2 percent, with an approximate payback period of four years.[55] From a patient safety standpoint, RFID implementation has also been proven as a valid and logical method of increasing positive patient outcomes. Lou et al. (2011) reported that passive RFID allows for increased positive identification of recipients and thereby a decrease in fatal transfusion reactions.[56] Porcella and Walker (2005) described that a pilot study in one Iowa hospital system yielded a 3–10 percent reduction in misidentification of patients and/or blood products during transfusion.[57] In addition, the Transfusion Medicine RFID Consortium (2012) noted a 33 percent reduction in misidentification in addition to total elimination of delivery errors and an 87 percent reduction in product loss.[58] (See Table 1.)

Barriers of RFID Adoption in Transfusion Medicine

Although RFID technology offers healthcare facilities an opportunity to increase productivity, improve efficiency, provide higher-quality care, and enhance safety standards, it has risks involving the privacy and security of patient information. The use of lower-quality tags results in an increased probability that patient information can be accessed by unauthorized sources.[59] Through such uses of low-quality RFID technology, the privacy and anonymity of patients is susceptible to Health Insurance Portability and Accountability Act (HIPAA) violations.[60] Low-quality tags do not possess the ability to verify if readers have permission to access the chosen information. This inability to verify permission in turn jeopardizes the tag's programmed identification, including protected health information (PHI) such as patient preferences and behaviors as well as confidential health records.[61] This information can fall victim to eavesdropping if not properly protected through proper high-quality RFID tag systems.

Although the benefits of RFID implementation in transfusion service management are numerous, barriers that hinder adoption are shown in Table 2. Yao et al. (2012) examined the start-up costs of RFID implementation in an 800-bed hospital and found that the initial investment can range from $20,000 to $1 million, depending on the magnitude of implementation and desired usage.[62] Also, according to the College of American Pathologists, in 2005 RFID tags were 10–15 times more expensive than barcode systems.[63] Perhaps one of the most significant barriers to RFID utilization is the issue of patient confidentiality, as identified by Juels (2006) and Lahtela and Hassinen (2009).[64, 65] In a session conducted at the 2011 Annual Meeting of the American Association of Blood Banks, concerns of RFID safety and morphological and biochemical effects on blood components were discussed.[66] (See Table 2.)

Solutions to security and privacy issues in RFID technology involve deactivating a tag after a patient is discharged from a facility, which prevents the tag from being interoperable with any system after that point.[67] Security of RFID-enabled medical products is a potentially serious matter when PHI is involved and must be approached cautiously. A hash-lock security approach can be used so that PHI can be accessed only when a password or key is entered to verify that the reader has permission to access the designated tag information.[68] A silent tree-walking algorithm can also be utilized, which prevents eavesdropping from unauthorized readers.[69]

Discussion

RFID technology is not considered to be a new technology, but integration of this technology into health-related practices is new. The skepticism that leaders in US healthcare have expressed toward RFID is reflected in the low adoption levels. As RFID technology has continued to develop and emerge as a practical way to efficiently manage goods, some large organizations and government agencies, including Wal-Mart and the Department of Defense, have required their top suppliers to utilize RFID. Wal-Mart's and the Department of Defense's mandates have led the way in developing SCM RFID system models for other industries, but healthcare organizations are still lagging behind.[70] It appears that the majority of healthcare organizations have been hesitant to adopt RFID technology as part of their SCM operations because of high start-up and maintenance costs, interoperability issues, and data security standards.

RFID possesses several positive aspects in terms of patient care and employee efficiency. RFID has allowed healthcare organizations to gain access to accurate and timely PHI in order to treat patients efficiently and effectively. RFID has permitted transfusion service professionals to accurately draw blood from a donor, perform tests on blood samples, and quickly return lab results to treating physicians. RFID can aid in the reduction of clerical errors involving pretransfusion testing and positive patient identification. The more efficient tracking mechanisms provided by RFID systems allow for ease of inventory management and reduce product outdating because processing centers can monitor hospital inventories and transfer short-date products to a facility where the products are more likely to be utilized prior to expiration. The ability to readily track component availability can increase positive patient outcomes in situations requiring emergency release of blood products by streamlining inventories and transfer of products between facilities. RFID systems also make it easier to perform "lookbacks" when the final disposition information for a blood product is required because of component, processing, or donation issues that arise either prior to or after transfusion. Additionally, the chances of blood being lost within or between organizations are significantly reduced. As a result, patients are treated quickly, accurately, and effectively, reducing the amount of wasted or unnecessary treatment.

In the past decade, healthcare organizations have begun to implement RFID technology as part of improving their overall transfusion service processes. In the use of RFID systems, the tags are placed on blood products after going through the identification verification processes, beginning at the initial phlebotomy or donation and ending with the transfusion of the product to a compatible recipient. The primary purposes of implementing RFID as part of providing transfusion services are to increase the provider's work efficiency and, most importantly, improve patient outcomes. The majority of research regarding RFID implementation in transfusion medicine has suggested that the positive implications outweigh the negative implications, and therefore this technology should be adopted by healthcare organizations.

RFID is currently being employed in several areas of the healthcare delivery system. RFID is used in areas including patient and staff identification, pharmaceutical management, magnetic resonance imaging departments, and information technology. This technology has also been used to activate HEPA ventilation systems that reduce energy consumption and nosocomial infections. For RFID to work seamlessly, hospitals must adopt information and communication technologies that support the use of RFID and can streamline administrative and clinical processes. The healthcare industry is expected to invest heavily in RFID implementation in the future; however, technical issues including signal propagation, interference with other medical devices or clinical systems, privacy, and a lack of industry governance standards may slow adoption rates. In addition, hospitals and providers will need to implement several costly health information technologies in a short time, including electronic medical records, computerized provider order entry, and the mandated change from ICD-9 to ICD-10 coding by October 1, 2015.

One of the most significant benefits of utilizing RFID in transfusion services is the impact on positive patient identification by aiding in the elimination of human error. By utilizing RFID to identify recipients, the risk of misidentification of blood products and patients is significantly decreased. It is possible that many incidents of misidentification go undetected during transfusions, if the products transfused are

inadvertently compatible with the recipient. RFID would make it possible to better track product and patient information and to ensure that such incidents do not occur.

The two major negative implications of RFID systems in healthcare organizations are the privacy of PHI and system implementation. Once medical products encrypted with patient data become RFID-enabled, the data associated with the products are susceptible to privacy and accessibility issues. Though RFID tags are capable of being secured with passwords and access codes to protect encrypted data, the cost of doing so comes at the organization's expense. The expense of ensuring that patient privacy is maintained at the highest level is a major concern for healthcare organizations attempting to control costs.

In addition to the cost of maintaining PHI privacy, the costs of implementing, operating, and maintaining RFID systems can be significant. RFID systems in healthcare organizations' supply chains can become extremely complex to the point that healthcare organizations believe that RFID would not be a feasible technology to adopt within their organization. For a healthcare organization to realize the positive effects of a fully implemented RFID system, its managers must be willing to invest significant resources toward the implementation and maintenance of the system.

This study was limited as a result of the restrictions in the search strategy used, such as the key terms searched, and researcher and publication bias may have limited the availability and quality of the research identified for review.

RFID technology in the US healthcare industry could potentially change the way health services are delivered for years to come. The lack of control of healthcare costs in the United States continues to be a growing concern, and this review suggests that utilizing RFID systems may be a way to control healthcare expenditures. The adoption of RFID systems in transfusion services may appear to be only a small solution to a major problem, but it could change the way healthcare is delivered. Much more research still needs to be done to evaluate whether the implementation of RFID technology in transfusion medicine is a feasible option for use in healthcare organizations' supply chains.

RFID systems have been proven to provide a benefit in several areas of the healthcare delivery system; however, research on the governance and standardization of RFID utilization is lacking. Future research in these areas would be beneficial to the healthcare sector. Research on health information technology and big data management in relation to RFID would also be valuable to the healthcare community. More in-depth knowledge regarding connectivity and interoperability of RFID systems with hospitals' and providers' health information systems will be essential to the continued implementation of RFID systems in the healthcare environment.

Conclusion

The implementation of RFID in transfusion medicine offers many benefits over the current procedures utilized in the tracking of blood products from the time of donation to transfusion or final disposition. RFID technology is not without risks, with specific concerns noted regarding security and patient confidentiality. The high implementation costs involved with RFID systems are also a concern. Further research on the benefits of RFID is anticipated to lead to its widespread utilization in transfusion medicine. As RFID gains acceptance in the field of blood banking, it is expected to have a significant impact with regard to patient safety and cost savings.

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Table 1

Benefits of Implementation and Utilization of Radio-Frequency Identification (RFID) Systems in Transfusion Medicine

Source	Benefits
College of American Pathologists (2005)	• RFID allows for accurate identification of blood products and recipients. • RFID tags eliminate transfusion error due to patient misidentification.
Porcella and Walker (2005)	• Pretest and posttest of RFID in transfusion medicine, first in a pilot of five units in an Iowa hospital system and then in a systemwide implementation • In pilot, the rate of detection of misidentified patients or blood products increased between 3 and 10 percent, and in the systemwide implementation, the rate increased 30 percent.
Chang et al. (2008)	• Pretest and posttest of RFID implementation in a blood center • Detection of misidentified blood products improved 19 percent.
Davis et al. (2009)	• Literature review of comprehensive assessment with a cost-benefit model • Found a 2 percent return on investment over a five-year planning horizon with an approximate four-year payback period.
Kumar (2009)	• Pilot study of RFID implementation and utilization • Found an inventory savings of $150,000 through the pilot program
Revere et al. (2010)	• Overview of hospitals that have instituted RFID within the organization • Wayne Memorial Hospital in North Carolina reported a savings of more than $300,000 due to RFID initiatives.
Lou et al. (2011)	• Passive RFID tags decrease fatal blood transfusions by linking all specimens and procedures during hospitalization. • Higher data storage than barcodes • Temperature sensing potential is important in component storage.
Pustkova et al. (2011)	• Examination of the implementation of RFID to assist with visual examination and identification of blood specimens in a single hospital setting • Increased job performance in transfusion medicine processes
Poshywak (2012)	• Examination of implementation and realization in

	facilities that have already implemented new technology • Return on investment, in a five-year projection, showed annual impact of more than $10 million.
Transfusion Medicine RFID Consortium (2012)	• Pilot study of RFID implementation and utilization in a blood donation center and hospital setting • RFID reduced donation site misidentification and lost products by 33 percent, reduced final destination loss of product by 87 percent, increased efficiency by 63 percent, and had zero delivery errors.
Hohberger et al. (2013)	• Pretest and posttest of RFID implementation in a large 700-bed academic hospital emergency room and blood and marrow transplant units • Found the system payback period to be 2–5 years, and found an increase in employee performance of 10 percent with the implementation and utilization of RFID
Kotzen (2013)	• Review of Virtua Health System's implementation of RFID, saving an estimated $1.2 million through error prevention and employee job performance

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Table 2

Barriers of Implementation and Utilization of Radio-Frequency Identification (RFID) Systems in Transfusion Medicine

Source	Barriers
College of American Pathologists (2005)	• RFID tags can be 10–15 times more expensive than barcode systems.
Juels (2006)	• Literature review identified threats to security as rogue scanning, "eavesdropping" on either tag-to-scanner or scanner-to-tag communications.
Chao et al. (2007)	• Literature review identified cost to implement and security concerns as barriers to RFID use.
Lahtela and Hassinen (2009)	• Review of the structure and infrastructure of several RFID systems • Threat to patient-level data security was identified as a risk.
Yao et al. (2012)	• Examination of cost to implement RFID in an 800-bed hospital • Found the start-up cost to be $20,000 to $1 million with $1,050 per day in medication tagging
American Association of Blood Banks (2011)	• Analysis of safety issues related to the use of RFID • Studies are required to test the ability of RFID tags to survive centrifugation, freezing, and gamma radiation procedures involved in the processing and storage of blood components. • Noted possible morphological and biochemical effects of RFID tags on blood components
Lou et al. (2011)	• Additional costs involved with RFID system implementation include readers, middleware, and software applications. • RFID readers can cost $50 to $3,000 each. • Software applications can range in cost from $25,000 to more than $100,000 for facility-wide implementation.

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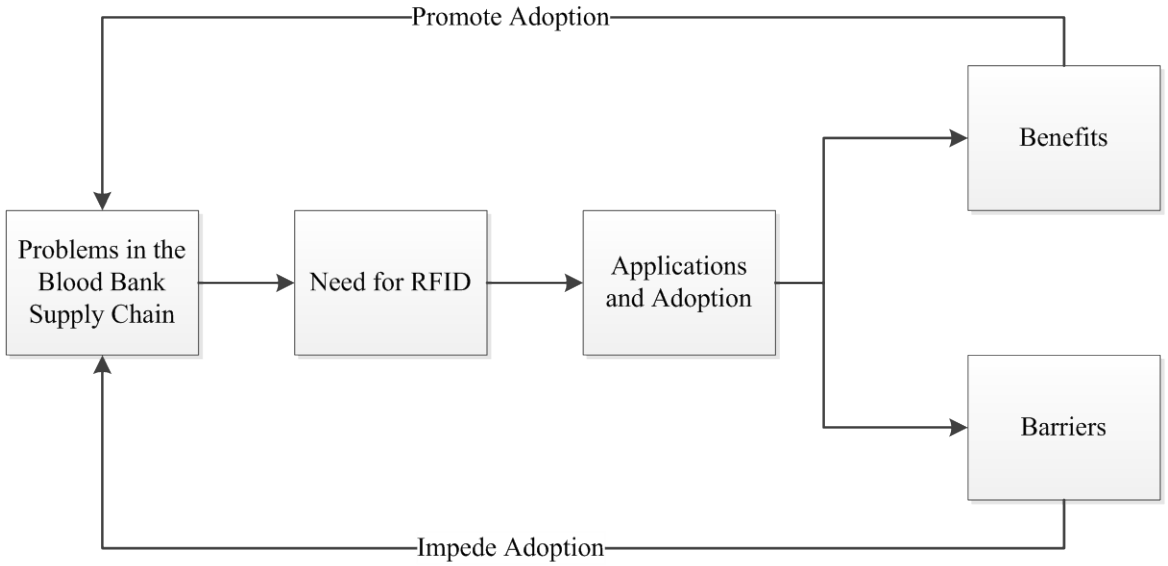
Figure 1

Conceptual Framework



Source: Adapted from Yao, W., C. H. Chu, and Z. Li. "The Use of RFID in Healthcare: Benefits and Barriers." *Proceedings of the 2010 IEEE International Conference on RFID Technology and Applications* (RFID-TA) (2010): 128–34.