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ABSTRACT

This research first conceptualizes, develops, and validates four new constructs for studying RFID in health care, including Drivers (Internal and External), Implementation Level (Clinical Focus and Administrative Focus), Barriers (Cost Issues, Lack of Understanding, Technical Issues, and Privacy and Security Concerns), and Benefits (Patient Care, Productivity, Security and Safety, Asset Management, and Communication). Data for the study were collected from 88 health care organizations and the measurement scales were validated using structural equation modeling. Second, a framework is developed to discuss the causal relationships among the above mentioned constructs and the established construct Performance. The research also compares perception differences regarding RFID implementation among the non-implementers, future implementers, and current implementers of RFID. It is found that both future implementers and current implementers consider RFID barriers to be lower and benefits to be higher compared to the non-implementers.

Subject Areas: Health Care, Radio Frequency Identification, Structural Equation Modeling, Technology Adoption

1. INTRODUCTION

Prior to the Wal-Mart (June 2003) and the U.S. Department of Defense (July 30, 2004) mandates, radio frequency identification (RFID) had been flying below the business innovation radar. Since then, RFID empirical studies have been dominated by case studies and survey papers focused on adoption, benefits, and challenges of RFID implementations. Scholars in support of RFID have argued its potential to improve supply chain operational effectiveness and efficiency. These scholars propose RFID as a new alternative to existing tracking methods and a means to a wide range of previously cost-prohibitive internal control and supply chain coordination innovations (Bendoly *et al*., 2007; Reyes *et al.*, 2007; Bottani and Rizzi, 2008; Rekik et al., 2008; Uckun et al., 2008). Regardless, given the external pressures to adopt coupled with the potential benefits of RFID, the adoption decision is for the most part based on managerial opinion (Vijayaraman and Osyk, 2006; Angeles, 2007; Bendoly *et al.*, 2007; Reyes *et al.*, 2007; Cannon *et al.*, 2008; Angeles, 2009).

Yet, given the aforementioned research, empirical studies on the use of RFID in the health care industry have been limited. For example, a review of the academic literature on RFID from 1995-2005 by Ngai *et al*. (2008) identified only 1 health care article out of 85 articles analyzed. Ferrer et al. (2010) presented 21 cases studies on the application of RFID in services, yet there was only one health care case. Tzeng *et al*. (2008) studied 5 health care providers in Taiwan and created 7 propositions on how RFID can deliver business value to health care providers. However, these propositions need to be validated through empirical evidence.

Our research is further motivated by the U.S. Food and Drug Administration (FDA) strong recommendation for the pharmaceutical and health care industries to adopt RFID (FDA, 2004) and the increasing pressure to deliver high-quality patient care while controlling costs (LaGanga and Lawrence, 2007). Unfortunately, health care systems across the globe appear to be overwhelmed by spiraling costs, continuing quality concerns, increasing patient dissatisfaction, and shrinking resources (e.g., qualified doctors, nurses, and staff; space, budgets) (Athanassopoulos and Gounaris, 2001; Tucker, 2004; Goldstein, 2005; Wright *et al*., 2006; Umble and Umble, 2006; Liberatore and Nydick, 2008). However, some early RFID studies in the health care industry have shown or suggested that RFID implementations can reduce or mitigate these negative issues. For example, Advocate Good Shepherd Hospital, in Barrington, Illinois, was able to reduce annual inventory losses by ten percent through an RFID enabled inventory system (Glabman, 2004). In a successful "proof of application" study at the Elvis Presley Memorial Trauma Unit in Memphis, Tennessee Janz *et al*. (2005) found that RFID could assist in the control of workflow processes through the automatic capture of data on patient movements. Numerous RFID health care applications to improve patient treatment and safety have been proposed including: 1) tagging patients and their medications to ensure the correct drug and dosage are administered to the patient (McGee, 2004); 2) tracking the patients' care pathway to ensure the patient receives the correct procedures (Rogoski, 2006); 3) using RFID tagged blister packs to monitor patient compliance in taking their medication (Parks, 2003); 4) tracking blood to ensure its' usability in regards to perishability and accuracy (Roberts, 2003); and 5) identifying whether supplies and instruments had been sterilized before patient use (Miller, 1999). For additional overviews on health care applications of RFID see Wicks *et al*. (2006) and Correa *et al*. (2007).

Given the importance of RFID implementation in health care, more empirical studies are needed to understand the costs, benefits and challenges of RFID implementation so that useful guidance can be provided to health care organizations that are increasingly under pressure to implement RFID. However, there is no valid measurement instrument available in the literature to guide empirical research. This study develops four new constructs (Drivers, Implementation Level, Barriers and Benefits) and validates one existing construct (Performance) for studying RFID in health care. The findings from our analysis of 88 health care organizations provide strong support for the validity and reliability of most of our proposed constructs. In addition, this study develops a framework to discuss the causal relationship among the key constructs in RFID implementation in health care. This research also compares the perception differences regarding RFID Drivers, Barriers, Implementation Level, Benefits and Performance among the non-implementers, future implementers and current implementers of RFID in health care.

The reminder of this paper is organized as follows. We first review previous literature for developing our constructs and framework. Next, we describe our methodology and data collection followed by our validation of constructs using structural equation modeling. We then present our data analysis. Finally, we offer implications and our conclusion to the study, followed by limitations of this study and future research.

2. RESEARCH FRAMEWORK AND CONSTRUCTS DEVELOPMENT

Figure 1 presents our research framework discussing the antecedents and outcomes of RFID implementation in health care. We identified major constructs in the RFID implementation including Drivers, Implementation Level, Barriers, Benefits and Performance (See Table 1). Drivers is defined as the level of pressure internally and externally to adopt RFID in order to improve a wide range of hospital process outcomes. Implementation Level is defined as the process areas within the hospital that RFID is implemented. RFID Barriers are the extent to which possible obstacles reject or delay the implementation of RFID and benefits refer to the level of benefits that hospitals can receive from RFID implementation. Finally, Performance is defined as the performance position of the hospital with respect to their competitors.

Drivers is conceptualized as including Internal Drivers and External Drivers; Implementation Level includes Clinical Focus and Administrative Focus; Barriers includes four dimensions: Cost Issues, Lack of Understanding, Technical Issues and Privacy Concerns; Benefits has five dimensions: Patient Care, Productivity, Security and Safety, Asset Management and Communication; and Performance includes three dimensions: Cost, Quality and Financial.

Our construct development and the relationships between the constructs for the proposed model were based on three streams of research. The first research stream focused on empirical survey papers that tested relationships between the factors of quality, technology, leadership, and performance in the health care environment. The second research stream centered on RFID research in health care, while the third stream of research covered RFID review papers and empirical survey papers in the area of supply chain management. We first identified the measurement items for each proposed construct and discussed relationships between the constructs. We then developed a survey instrument that was designed to solicit feedback on the deployment of RFID in the health care environment. See Appendix A for the survey questions for each construct and subconstruct. We next discuss the supporting literature for each of the constructs and subconstructs, and we summarize our findings in Table 1. Then we discuss the relationships between the dimensions and present our research framework.

Insert Figure 1 Here

Insert Table 1 Here

2.1 Drivers

The recent rapid growth in the interest and development of RFID technology was spurred by the tagging mandates made by Wal-Mart (O'Connor, 2005) and the United States (U.S.) Department of Defense (Collins, 2004). Under these mandates, suppliers were required to tag cases and pallets sent to distribution centers and supply depots. A survey by Vijayaraman and Osyk (2006) found that meeting the Wal-Mart compliance was the top reason supply chain firms were deploying RFID technology. No health care organization has an external mandate to implement tagging: however, the FDA recommendation does create adoption pressure (FDA, 2004). In order to assess whether or not health care organizations are under external pressure, we created a subconstruct to measure the impact external entities have in influencing a health care provider to implement RFID technology. From a review of the FDA report and papers by Wicks *et al*. (2006) and Correa *et al*. (2007) we identified patients, suppliers, the FDA, insurance companies and health maintenance organizations, regulatory groups, and competitors as External Drivers.

Since health care providers are not under a mandate to deploy RFID and there are numerous health care providers that have implemented RFID in their operations, it is reasonable to assume that these providers have deployed RFID for reasons that are internal to the organization. We reviewed the three empirical supply chain surveys conducted by Vijayaraman and Osyk (2006), Reyes *et al*. (2007) and Li *et al*. (2010) to identify internal reasons companies' implemented RFID technology. An analysis of the survey items identified several categories including visibility, efficiency, asset management, security, customer service, collaboration and cost reduction. We then used these categories to develop measurement items for the Internal Drivers.

2.2 Implementation Level

Implementation Level is a new construct we develop to identify how RFID is used by the health care provider. Wicks *et al*. (2006) described several application areas for RFID, such as tracking physical items, controlling drug distribution to patients, tracking patient medication compliance, monitoring the patient's environment and movement in the facility, and tracking blood. Correa *et al*. (2007) identified health care specific uses of RFID, like patient identification and tracking, asset management and tracking, drug counterfeiting, inventory management, spare parts for surgery, blood and specimen bags, and tracking patient files. The use of RFID to track and monitor emergency room patients is discussed by Janz *et al*. (2005) and by Chao *et al*. (2007), while Schwaitzberg (2006) discussed RFID applications for surgery.

Based on the above discussion on the various uses of RFID in health care, we separate the Implementation Level of RFID into two subconstructs we name Clinical Focus and Administrative Focus. Clinical Focus refers to RFID implementations that have a direct impact on the patient's health and well being, while Administrative Focus refers to RFID implementations that have an indirect impact on patients.

2.3 Barriers

Table 2 lists barriers to the successful implementation of RFID that have been identified in the supply chain and health care literature. Universal standards refer to a lack of global standards for radio frequencies and protocols that will facilitate data exchange between various RFID users. Standards will also help to lower technology costs. Costs associated with RFID include the tags and readers, tag placement, facility/equipment redesign, training, and system maintenance. Software application issues refer to a lack of software to integrate and synchronize RFID data with the existing technology infrastructure, the filtering of noisy data (i.e., multiple reads of the same item), and analysis of that data. RFID technology problems include interference issues with metal, liquid, glass and moist environments which affects read rates and read accuracy, and the overall performance of the tags and readers. Privacy issues focus on the misuse of the tag to collect information on the person buying the tagged item or wearing a tag as an identification device. Privacy in health care is a very important issue and is regulated by the U.S. Department of Health & Human Services Health Insurance Portability and Accountability Act (HIPAA) of 1996. The HIPAA Privacy Rule created national standards to protect the privacy of patients' medical records (HHS, 2006). Security issues deal with spoofing and hacking attacks to change the data on the tag. In the health care environment, unauthorized changes to a patients' tag might result in health complications or even death. Only two studies (Li & Visich, 2006; Li et al., 2010) discussed the environmental problems of RFID readers and tags. Readers emit radiation when they transmit a signal creating a health risk to workers, and tags are non-biodegradable and may contain toxic metals. A lack of understanding about how RFID works, the possible benefits, and how to make the business case for RFID implementation were also found to be barriers. This category also includes calculating the return on investment and the payback period. Finally, the issue of labeling is important in health care because medication containers have little if any exterior space for tag placement.

Insert Table 2 Here

Vijayaraman and Osyk (2006) found that the top three RFID concerns were cost, a lack of understanding of the benefits, and integration issues. The top three RFID barriers identified by Reyes *et al*. (2007) were not applicable in our business, initial costs are too high, and expected benefits are not enough. The survey results of Li *et al*. (2010) were similar to Vijayaraman and Osyk (2006), where financial concerns was rated highest, followed by lack of a business case, and technology. Interestingly, privacy and environmental impact were the two lowest rated barriers. Therefore, for Barriers to implementing RFID, we developed the following four new subconstructs: Cost Issues; Lack of Understanding; Technical Issues; and Privacy Concerns.

2.4 Benefits

Table 3 lists benefits from the successful implementation of RFID that have been identified in the supply chain and health care literature. Track depicts knowing where an item is in the supply chain or for the health care profession knowing where a patient or employee is located. Trace is the ability to identify what went into a product (manufacturing inputs) and then knowing where the product has been. This facilitates recall management and the identification of unofficial 'grey' supply chains as well as the detection of counterfeit drugs. Inventory benefits cover a wide range of issues including control of inventory and expiration dates, the reduction of inventory, stock outs and shrinkage. In a health care environment, the control of inventory used to support surgical operations is critical so that all necessary items are available and none are left in the patient (Chao *et al*., 2007). Efficiency includes process automation, productivity improvements, and the reduction of labor costs. Communication is a key element in the supply chain and in health care for collaboration and planning, as well as the sharing of information between patients and health care providers. Asset management within the facility and the supply chain is critical for keeping asset costs down and yet still keep operations running. In the health care industry, assets used to provide services to patients are often expensive and need to be shared by providers. Error reduction is facilitated by the availability of accurate information. In the supply chain literature, this can help in the reconciliation of shipments, while in health care it can prevent the wrong medication being given to a patient. Finally, patient care aspects include customer service, patient safety, level of treatment, and compliance with medical practices.

Insert Table 3 Here

Vijayaraman and Osyk (2006) found that the top three sources of RFID cost savings (benefits) were reduced out-of-stocks, minimized inventory losses, and reduced labor cost due to less material handling. The top three RFID realized improvements identified by Reyes *et al*. (2007) were accuracy and availability of information, level of process automation, and level of customer service. In the survey by Li *et al*. (2010) those respondents who were pilot testing, implementing, or had implemented RFID indicated their top three motives as competitive decision, inventory management, and cost reduction in processes. For the construct Benefits we developed five new subconstructs: Patient Care; Productivity; Security & Safety; Asset Management; and Communication.

2.5 Performance

Constructs for performance have been well established in the health care literature. In our research we measure the construct Performance with the three subconstructs Cost Performance, Quality Performance and Financial Performance. Cost Performance is related to holding down patient costs, and attaining high labor productivity and capacity utilization. Quality Performance is measured by indicators for clinical quality, patient satisfaction, and response to patient requests and complaints. Financial Performance focuses on market share growth, return on assets and investment, and operating profit.

Li (1997) explored the relationships between hospital management practices and service quality performance, whereas Li and Collier (2000) investigated the role of technology and quality on hospital financial performance. Li and Benton (2003) measured the impact of hospital management decisions on cost performance and quality performance, while Li and Benton (2006) investigated the impact of hospital technology and nurse staffing management decisions on cost performance and quality performance. Patient satisfaction was measured as an outcome by Meyer and Collier (2001) and by Marley *et al*. (2004). All three performance constructs were used in a structural model by Li *et al*. (2002) who found that hospital quality performance indirectly affected hospital financial performance and that cost performance directly affected hospital financial performance.

2.6 Research Framework

Based on the above discussion of the constructs, we propose that Internal Drivers and External Drivers will have a positive impact on the Implementation Level of RFID, which in turn will have a positive impact on RFID Benefits, leading to a positive impact on Performance. In addition, RFID Barriers are proposed to be negatively related to RFID Implementation Level in health care. The following section will provide a brief literature support for the proposed research framework.

External drivers of change in the health care industry include shifts in demand and customer expectations, dynamic markets and advances in technology, particularly in the area of information technology (Abernethy and Lillis, 2001; Carmen *et al*., 1996, and Bouwens and Abernethy, 2000). And, it is well known that there is intense pressure on health care organizations from outside agencies, such as regulatory groups and insurance companies, to lower costs and improve performance. For example, medical errors cost the U.S. Medicare program more than $8.8 billion annually (Business Wire, 2008). In order to secure the pharmaceutical supply chain from counterfeit drugs and terrorist attacks the FDA has identified several implementation areas for RFID technology including the tracking of drugs through the supply chain, the management of drug inventory, and the correct dispensement of drugs to the patient (FDA, 2004). Based on these trends and events we propose that External Drivers will have a positive impact on RFID Implementation Level.

The Institute of Medicine has estimated that between 44,000 to 98,000 patients die from medical errors annually in the U.S. These errors are usually are drug-related but also include incorrect patient diagnostics, equipment failures, and misinterpretation of medical orders (Crane and Crane, 2006). Medical errors are also caused by a lack of communication among and between all levels within the health care organization (Tang and Lansky, 2005), and hospital residents cited overwork, inadequate supervision and handoff problems as the most common causes for medical errors (Jagsi *et al*., 2005). The implementation of RFID technology can help to reduce medical errors by automatically ensuring patients receive the correct drug and dosage (McGee, 2004), are on the correct care pathway (Murphy, 2003), and RFID can be used to monitor the patients environment and movement within the facility (Hoska, 2004). Health care organizations use a systems approach to promote patient safety, reduce medical errors, and increase patient satisfaction Kohn *et al*. (2000) and physicians utilize a variety of quality programs as their primary approach to improve quality (Martin, 2007). Therefore, Internal Drivers will have a positive impact on RFID Implementation Level.

The implementation of RFID in a health care facility poses numerous challenges. For example, Hoska (2004) estimated that a 1000-bed hospital would need to tag 20,000 items per day, while Becker (2004) estimated that an 800-bed hospital would need to tag approximately 15,000 doses of medication daily. Janz et al. (2005) found that an RFID system to track patients in an emergency room created a significant amount of noise and 'dirty data' that needed to be filtered before the data could be used for analysis. And, health care organizations need to be complaint with HIPPA in order to ensure the privacy rights of patients (Fenner, 2004). Clearly, the number and severity of obstacles encountered will affect the implementation level of RFID and we propose that Barriers will have a negative impact on Implementation Level.

Numerous benefits have been reported from the implementation of RFID in health care. Holy Name Hospital in Teaneck, New Jersey found that RFID-tagged of equipment could be located quicker and was more fully utilized, which reduced equipment rental costs (Glabman, 2004). Patient care can be improved through higher accuracy in medicine dispensement (Klein, 2003), in patient compliance (Parks, 2003), and in the reduction of medical errors (Klein, 2003). Approximately 70% of the respondents to a BearingPoint Study (Editorial, 2006) identified patient safety as the most important RFID implementation benefit. Therefore, Implementation Level will have a positive impact on Benefits.

The Li et al. (2010) survey found that organizations with RFID experience (piloting, implementing, implemented) rated competitive decision as the highest of six categories for the motivation to implement RFID technology, while respondents considering RFID implementation within two years rated competitive advantage the third highest motivation. Competitive advantage was measured using the survey items strategic initiative and competitive advantage. Visich et al. (2009) conducted a review of empirical evidence of RFID in the supply chain, and using the business process framework of Mooney et al. (1996) proposed that for managerial processes RFID has the potential to facilitate transformational effects when the process is reengineered to significantly improve competitive capability. And, Spekman and Sweeny (2006) noted that "the early adopters will reap a strategic benefit from deploying RFID" (p.750). Based on this discussion we hypothesize that Benefits from RFID deployment will have a positive impact on organizational Performance.

3. RESEARCH METHODOLOGY AND DATA COLLECTION

The research methodology used is based on empirical data collected through a web-based questionnaire survey of health care professionals. We focused on the health care industry first to eliminate perplexing results across industries, second because the U.S. Food and Drug Administration has strongly recommended that the pharmaceutical and health care industries adopt RFID, and finally because of the innovative opportunities (both patient focus and economic focus) that RFID can provide to the health care industry.

Guided by our literature review, we developed a survey instrument to measure and test the relationships between the constructs. These survey items were reviewed by five health care professionals and five academics. Based on their feedback we made minor changes to the survey instrument. We then e-mailed the survey to 1,000 health care professionals. Approximately 900 e-mails were successfully sent to top-level managers at hospitals across the United States asking them to access the survey link. Between March and July 2008, and after three e-mail requests, a total of 88 useable responses were collected giving a response rate of 9.8%. We also received more than 100 e-mail replies stating: their company is not considering RFID; that company policy forbids participation in such surveys; respondent did not have time to complete the survey; or requesting to be removed from the e-mail list.

4. INSTRUMENT DEVELOPMENT AND VALIDATION

4.1 Item Generation

The basic requirement for a good measurement is content validity, which means that the measurement items in an instrument cover the major content of a construct (Churchill, 1979). Content validity is usually achieved through a comprehensive literature review and interviews with practitioners and academicians. The items for Drivers, Implementation Level, Barriers, Benefits and Performance were generated based on previous literature as discussed in Section 2 Research Development and Constructs Development. Items that measure Performance were adopted from Li *et al*. (2002). The items for these five instruments are listed in Appendix A. All survey items were measured using a 7-point Likert scale.

4.2 Large-scale Data Analysis

While the number of useable responses (88) and the response rate (9.8%) were less than desired, the makeup of respondent pool was considered excellent. As seen in Table 4, a majority of the respondents are top level managers, with 30% (27) of the respondents CEOs and 19% (17) of them vice presidents. A few respondents identified themselves as COO, CNO, CFO or CIO (8%, 7) and 28% (25) are at the director level. These individuals are expected to have a broad view of RFID implementation in their organization and this meets our objective of collecting information at the organizational level. Hospital location (urban (47%, 40) and rural (53%, 46)) as well as affiliation (system affiliated (56%, 49) and stand-alone (44%, 38)) are represented about equally. In addition, 66% (58) of the respondents work at large hospitals (>500 employees) and a significant majority are not-for-profit (93%, 79) and are not teaching hospitals (76%, 66).

Insert Table 4 Here

4.3 Instrument Assessment Methodology

Following the guidelines of Bagozzi (1980) and Bagozzi and Phillips (1982), the following measurement properties are considered important for assessing the measures developed in this paper: (1) content validity, (2) internal consistency of operationalization (unidimensionality and reliability), (3) convergent validity, and (4) discriminant validity.

4.3.1 Content Validity

Content validity depends on how well the researchers create measurement items to cover the domain of the variable being measured (Nunnally, 1978). The evaluation of content validity is a rational judgmental process not open to numerical evaluation. The usual method of ensuring content validity is an extensive review of literature for the choice of the items and the solicitation of inputs from practitioners and academic researchers on the appropriateness, completeness, etc. The content validity of the constructs in this paper was established through extensive review and input from health care professionals and academicians.

4.3.2 Unidimensionality

Unidimensionality can be defined as the existence of one latent trait or construct underlying a set of measures (McDonald, 1981; Hattie, 1985). This research will thus use structural equation modeling (SEM) to test unidimensionality of each construct. We use multiple fit criteria to test for unidimensionality and reduce any measuring biases inherent in different measures. Two goodness of fit indices were used: goodness-of-fit (GFI) and comparative fit index (CFI). The values of those fit indexes above 0.90 or higher suggest no evidence of a lack of unidimensionality.

RFID Drivers was represented by 2 dimensions and 16 items (see Appendix A). A single factor LISREL measurement model is specified for each dimension of RFID Drivers. Following Sethi and King (1994), iterative modifications were made for each of the constructs by observing modification indices and coefficients to improve key model fit statistics. Further, as recommended by Joreskog and Sorbom (1989), only one item was altered at a time to avoid over-modification of the model. This iterative process continued until all model parameters and key fit indices met recommended criteria. If the constructs have less than 4 items, model fit statistics could not be obtained. In these cases, a two-factor model was tested by adding the items of another construct. The items of another construct are added only to provide a common basis for comparison and to keep items in sufficient number so that model fit statistics could be obtained. The same methodology was applied to the other four constructs, including Implementation Level, Barriers, Benefits, and Performance. The final results are summarized in Table 5. The table presents the number of items measuring each construct, and statistics for assessing the goodness of fit of the measurement model. It can be seen that half the GFI values are above 0.90 and the other half a little below 0.90. This may be caused by the small sample size. All CFI values are 0.90 or above indicating the unidimensionality of all constructs. The items removed in the final instrument are identified by an asterisk in Appendix A.

Insert Table 5 Here

4.3.3 Reliability

Traditionally, the Cronbach α coefficient (Cronbach, 1951) has been used to evaluate reliability. A scale is found to be reliable if α is 0.70 or higher (Nunnally, 1978). However, it has been noted that Cronbach α uses restrictive assumptions regarding equal importance of all indicators and the measure of reliability can be biased. An alternate composite reliability measure has been suggested (Werts *et al*., 1974). This reliability measure ρ_c for an underlying theoretical dimension A, can be calculated as follows:

$$\rho_c = (\sum_{i=1}^{p} \lambda_i)^2 \text{Variance(A)} / ((\sum_{i=1}^{p} \lambda_i)^2 \text{Variance(A)} + \sum_{i=1}^{p} \theta_\delta)$$

where ρ_c is the composite measure reliability, p is the number of indicators, λ_i is the factor loading which relates item *I* to the underlying theoretical dimension *A*, and θ_δ is error variance. When ρ_c is greater than 0.50 it implies that the variance captured by the factor is more than that captured by the error components (Bagozzi, 1981). Bagozzi (1981) and Werts *et al*. (1974) suggest using ρ_c in conjunction with Cronbach alpha. The calculated values for Cronbach's alpha were very similar to Werts-Linn-Jorsekog coefficient (ρ_c). In Table 6 we report ρ_c and Cronbach's alpha for each subconstruct. Note that all coefficients are 0.85 or greater, indicating good construct reliability of all the subconstructs.

Insert Table 6 Here

4.3.4 Convergent and Discriminant Validity

A factor analysis was conducted for each of the five constructs using principal components as means of extraction and varimax as method of rotation. Factor analysis is useful in providing some evidence of discriminant and convergent validity of measurement items (Segars and Grover, 1993). Items with good measurement properties should exhibit high factor loadings on the latent factor of which they are indicators (convergent validity), and small factor loadings on the factors that are measured by differing sets of indicators (discriminant validity). The results of the factor analysis for each of the five constructs are shown in Tables 7-11. For simplicity, only loadings above 0.40 were displayed. It can be seen that all items loaded on their respective factors and there were no items with cross-loadings greater than 0.50. The results of factor analysis provide primitive support for convergent and discriminant validity of the constructs.

Insert Table 7 Here

Insert Table 8 Here

Insert Table 9 Here

Insert Table 10 Here

Insert Table 11 Here

5. DATA ANALYSIS

The respondents were asked to indicate the state of RFID deployment in their organizations in the survey. The surveyed organizations were then classified into three groups: non-implementers, future implementers and current implementers. Non-implementers include organizations who do not have plans to implement RFID within the next two years, future implementers plan to implement RFID within the next two years and current implementers are organizations that are currently pilot testing, implementing or have completed implementation of RFID technology. Among all the organizations, 50% (44 respondents) are non-implementers, 35% (31 respondents) belong to future implementers and the rest (15%, 13 respondents) are current implementers.

This section will first test the causal relationship proposed in Figure 1, followed by the comparison of RFID Implementation Level between future and current implementers and then comparison of RFID Drivers, Barriers, Benefits and Performance among non-implementers, future implementers and current implementers.

5.1 Results for the Proposed Research Framework

Structural equation modeling was used to test the proposed relationships in Figure 1. We split Drivers into two constructs in order to better understand what motivates health care providers to adopt RFID technology. We removed the non-implementers from the analysis since they do not plan to implement RFID and are thus irrelevant in the analysis.

Figure 1 displays the path diagram resulting from the structural modeling analysis using AMOS. The model fit measures are: GFI= .91, CFI= .85, NFI= .80 (normed fit index), and RMSR=.122 (root mean square residual). GFI is above the recommended value of .90; CFI and NFI are at or above .80. However, RMSR is above the suggested maximum value of .05 and this result may be due to the very small sample size (44) since RMSR tends to increase as the sample size decreases (Anderson & Gerbing, 1984). The results show that except for the link between External Drivers and Implementation Level, the other relationships are found to be significant.

The lack of a significant link between External Drivers and Implementation Level indicates that health care organizations are not under pressure from external entities to adopt RFID technology. The significant positive link between Internal Drivers and Implementation Level shows that health care organizations are implementing RFID on their own initiative to improve hospital process outcomes. This is a good outcome as it indicates hospitals are being proactive in the deployment of RFID. In contrast to the proposed negative relationship, Barriers are found to be positively related to the Implementation Level. This was an unexpected result as we hypothesized that the greater the barriers the lower the likelihood of RFID implementation. There are several possible explanations for this result. First, barriers may not discourage the implementation of RFID because organizations feel the anticipated or derived benefits will be worth the effort to overcome the barriers. Even though organizations are aware of various barriers to the RFID implementation, they still want to implement it because of anticipated benefits from the implementation. Second, our respondent pool consisted of a significant number of high level managers and there could be an expectation that even though barriers are high, the employees tasked with implementing RFID will find a way around the barriers. Third, it is possible that higher levels of multiple RFID implementations create higher levels of barriers. Future research may validate this finding.

The results support our propositions that Implementation Level has a positive relationship with Benefits, and that Benefits has a positive impact on Performance. Both of these paths are significant, supporting our propositions regarding them. This makes sense as hospitals would most likely implement RFID in processes where they expect to receive benefits from the deployment, and these benefits should improve overall performance.

5.2 Comparison of RFID Implementation Level between Current and Future Implementers

For the current and future implementers, the respondents were asked to indicate the actual or anticipated level of RFID implementation in various areas in their organizations. The results are show in Table 12.

Insert Table 12 Here

Table 12 shows that top five RFID applications for the current implementers are track: medical equipment (4.75); medication dispensing (3.49); MRO inventories (maintenance, repair, operating) (3.45); hospital beds (3.31); and emergency room patients (3.23). For the future implementers, the top five applications are track: infants (4.16); medical equipment (3.97); medication dispensing (3.77); patient medication usage (3.61); and surgical operations (tools, sponges etc) (3.48). It can be seen that tracking medical equipment and track medication dispensing belong to the top five in these two groups. In addition, the current implementers group focused on both clinical and administrative areas by using RFID to track emergency room patients, MRO inventory, and hospital beds. The future implementers focused primarily on clinical areas and plan to use RFID to track infants, patient medication usage and surgical operations. The only administrative focus implementation to be in the top ten for future implementers was track hospital beds, which was ranked 8th.

Table 12 also show that except for track medical equipment, track administrative equipment, track doctor, and track administrative personnel, the future implementers have a higher perceived implementation level in most areas than the actual implementation level rated by the current implementers group. This may reflect a gap between perception and reality. Companies may have a higher expectation for the level of RFID implementation than what will be actually implemented later. It is interesting to note that current implementers scored track medical equipment the highest implementation level for both groups of implementers.

5.3 Comparison of RFID Drivers, Barriers, Benefits, and Performance

Analysis of Variance (ANOVA) tests were used to compare the perception difference among the non-implementers, future implementers, and current implementers regarding RFID Drivers, Barriers, Benefits and Performance. The results are shown in Table 13 and Table 14.

Insert Table 13 Here

Insert Table 14 Here

The results show that significant differences exist in the respondents' perception regarding RFID Barriers (Cost, Lack of Understanding, and Technical Issues) and Benefits (Patient Care and Productivity) among the three groups. T-tests were conducted to see where differences between the three groups existed in each construct and the results are shown in Table 15. For the Barrier Cost, non-implementers have a significantly higher mean than future implementers, and future implementer have a significantly higher mean than the current implementers. Regarding the Barrier Lack of Understanding, current implementers have a significantly lower mean than non-implementers and future implementers. For the Barrier Technical Issues, non-implementers have a significantly higher mean than current implementers and future implementers. For the Benefit Patient Care, future implementers consider Patient Care as a greater benefit of RFID implementation than non-implementers. In term of the Benefit Productivity, non-implementers have a significantly lower mean than current and future implementers. In sum, it can be seen that there exists more similarity regarding RFID Barriers and Benefits between current implementers and future implementers, and more difference between non-implementers and current/future implementers. Compared to non-implementers, future and current implementers consider RFID Barriers to be lower and Benefits to be higher (See Chart 1). In addition, no significant differences were found in RFID Drivers and Performance among the three groups.

Insert Table 15 Here

Insert Chart 1 Here

Finally we note two items of interest in Table 13. First, non-implementers have the highest mean for External Drivers while current implementers have the lowest mean. The opposite occurs for Internal Drivers where current implementers have the highest mean and non-implementers have the lowest mean. Second, for each of the four subconstructs for Barriers the mean declines from non-implementers to future implementers to current implementers. This indicates that non-implementers have a pessimistic perception regarding the actual barriers to RFID implementation.

6. IMPLICATIONS AND CONCLUSIONS

In this research we utilized three research streams to design a research framework and survey instrument to measure and study RFID in health care. For our survey instrument we developed four new constructs (Drivers, Implementation Level, Barriers and Benefits) and we utilized one existing construct from the literature (Performance). Next, we conducted a small pilot test with practitioners and academicians and based on their appraisal we refined the survey instrument. We distributed the survey instrument to health care professionals and we then completed a rigorous statistical analysis to determine the validity and reliability of the constructs.

The results of our data analysis provide strong support for content validity, unidimensionality, reliability and convergent validity for all five constructs. This research represents a first attempt to develop and validate a set of constructs for studying RFID implementation in health care at the organizational level using a rigorous methodology. The instrument developed in this paper will be of use to researchers for further studies of RFID implementation in health care.

The results of our research also show the importance of RFID implementation to the health care organization. The research indicates that managers believe the implementation of RFID in health care could lead to many benefits including improved patient care, improved patient security and safety, and finally improved organizational performance. The results also show that RFID deployment in health care is driven by internal factors, not external pressure. This result is expected since health care organizations are not under a mandate to implement RFID; their decision to adopt RFID must be driven by internal factors, such as visibility, efficiency, asset management, security, patient service, collaboration and cost reduction.

The results also indicate that perception differences exist between the non-implementers, future implementers and current implementers regarding RFID. Non-implementers consider RFID barriers to be higher and benefits to be lower than the other two groups. This may be caused by a lack of understanding of RFID technology. To increase the adoption of RFID, more studies on RFID in health care need to be done to help health care organizations better understand the drivers, benefits, barriers and implementation issues of RFID.

While these results appear exciting in that our analysis provides a strong assessment of the antecedents and outcomes of RFID implementation in health care, the study suffered from a small sample size because of the early stage of RFID development. In addition, these 88 responses were divided into three categories, where non-implementers were the largest group (44 responses), while there were 31 future implementers and only 13 implementers. As with all survey studies, our scope limitation prevents a complete story (for our sample set).

While RFID technology is being pushed by retail giants like Wal-Mart and touted as having great potential for reducing costs and improving customer service - the focus has been mostly on the supply chain. Because of this supply chain focus, health care professionals were not aware of the applications that could be used in service operations. Hence, the numerous e-mail replies stating: "our company is not considering RFID". We believe this lack of awareness in the field led to the limited sample size. Future research should validate the constructs developed in this paper using a larger sample size.

RFID adoption in health care is still in the early stages. Future study can also include additional constructs in the implementation of RFID in health care. For example, how does top management support and workforce development impact the implementation level of RFID? Future study can also look at the impact of contextual factors (organization size, culture, geographic location, etc.) on RFID implementation or how the various items for a construct impact a linked construct. For example, does substantial tracking implementation lead to improvements in patient care and security and safety. If a larger survey sample can be obtained, it would be possible to develop separate structural models for future implementers and current implementers. Another area of study is the impact of barriers on implementation level to help explain why our results showed an unexpected positive relationship between Barriers and Implementation level.

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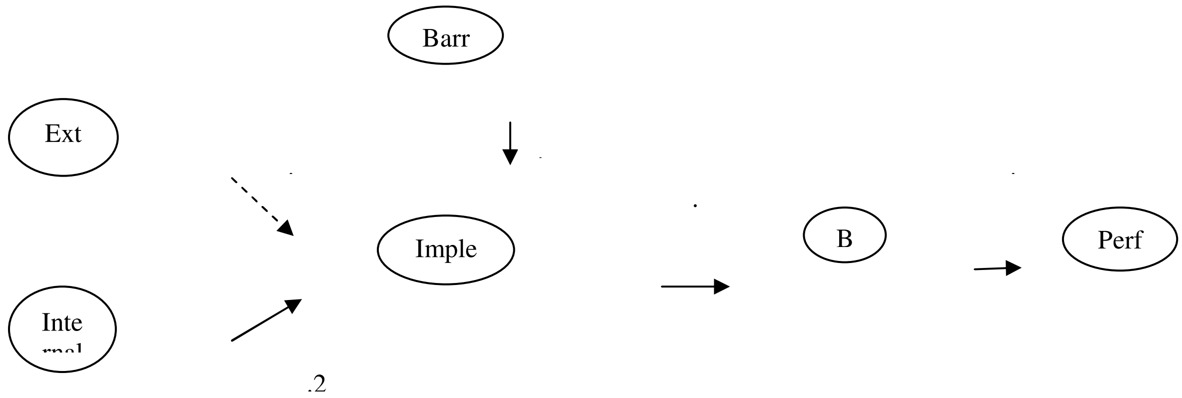

Figure 1: Antecedents and Consequences of RFID Implementation in Health Care Organizations

Note: Solid lines are for significant paths; dashed lines indicate insignificant paths; t-values are in parentheses.

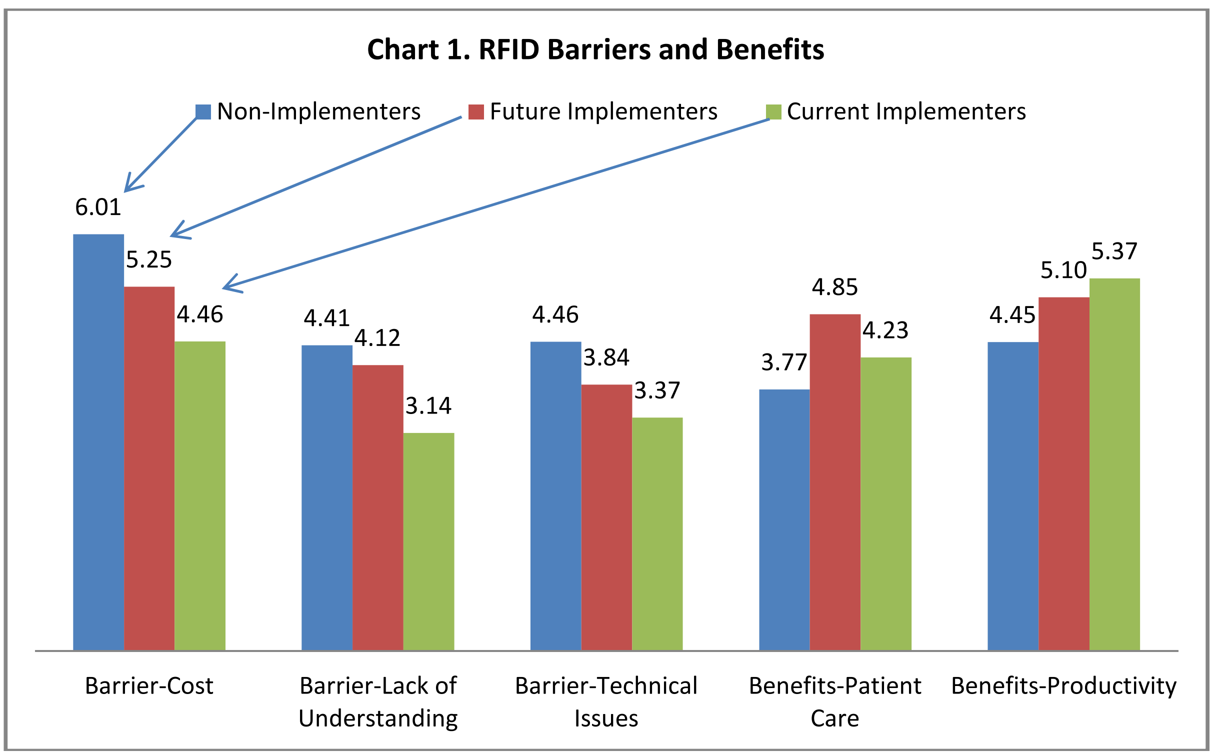

Table 1: Constructs for RFID in Health Care

Constructs	Definitions	Literature
Drivers	The level of pressure externally and internally to adopt RFID in order to improve a wide range of hospital process outcomes.	FDA (2004), Vijayaraman and Osyk (2006), Wicks *et al*. (2006), Reyes *et al*. (2007), Correa *et al*. (2007), Li *et al*. (2010)
Implementation Level	The process area within the hospital that RFID is implemented. This includes clinical processes that directly impact the patient and administrative processes that indirectly impact the patient.	Li and Collier (2000), Marley *et al*. (2004), Wicks *et al*. (2006), Correa *et al*. (2007), Schwaitzberg (2006), Janz *et al*. (2007), Chao *et al*. (2007)
Barriers	The extent to which possible obstacles reject or delay the implementation of RFID including cost, a lack of understanding, technical issues, and privacy concerns.	Srivastava (2004), Li and Visich (2006), Vijayaraman and Osyk (2006), HHS (2006) Wicks *et al*. (2006), Reyes *et al*. (2007), Li *et al*. (2010), Reyes and Frazier (2007), Correa *et al*. (2007)
Benefits	The level of benefits that hospitals can receive from RFID implementation including the areas of patient care, productivity, security and safety, asset management, communication, and employees.	Srivastava (2004), Li and Visich (2006), Vijayaraman and Osyk (2006), HHS (2006) Wicks *et al*. (2006), Reyes *et al*. (2007), Li *et al*. (2010), Reyes and Frazier (2007), Chao *et al*. (2007), Correa *et al*. (2007)
Performance	The performance position of the hospital with respect to their competitors in the areas of cost, quality, and finances.	Li (1997), Li and Collier (2000), Meyer and Collier (2001), Li *et al*. (2002), Li and Benton (2003, 2006), Marley *et al*. (2004),

Table 2: Barriers to the Implementation of RFID

	Paper Type*	Universal Standards	Cost	Software Applications	Technology Problems	Privacy	Security	Environmental	Lack of Understanding	Labeling
Srivastava (2004)	SCO	X	X	X	X	X				
Li & Visich (2006)	SCO	X	X	X	X	X	X	X		
Reyes & Frazier (2007)	SCO	X	X		X	X				
Vijayaraman & Osyk (2006)	SCS	X	X	X		X	X		X	
Reyes *et al*. (2007)	SCS	X	X		X		X			
Li *et al*. (2010)	SCS	X	X	X	X	X	X	X	X	
Wicks *et al*. (2006)	HCO	X	X	X	X	X	X			X
Correa *et al*. (2007)	HCO	X	X	X	X	X	X			

*SCO: supply chain overview; SCS: supply chain survey; HCO: health care overview

Table 3: Benefits from the Implementation of RFID

	Paper Type*	Track/ Trace	Inventory	Efficiency	Communication	Asset Mgmt.	Error Reduction	Patient Care
Srivastava (2004)	SCO	X	X	X	X	X		
Li & Visich (2006)	SCO	X	X	X	X	X		
Reyes & Frazier (2007)	SCO	X	X	X				
Vijayaraman & Osyk (2006)	SCS	X	X	X		X		
Reyes *et al*. (2007)	SCS	X	X	X	X	X	X	X
Li *et al*. (2010)	SCS	X	X	X			X	
Wicks *et al*. (2006)	HCO	X	X	X	X	X	X	X
Correa *et al*. (2007)	HCO	X	X	X	X	X		X
Sarac et al. (2010)	SCO	X	X	X			X	

*SCO: supply chain overview; SCS: supply chain survey; HCO: health care overview

Table 4: Demographic Data for the Respondents (sample size 88)

	Number	Percentage
Job Title (88)		
CEO	27	30.7%
VP	17	19.3%
Director	25	28.4%
Manager	10	11.4%
CFO	1	1.1%
CNO	1	1.1%
CIO	3	3.4%
COO	2	2.3%
Other	2	2.3%
Number of Employees (86)		
Under 100	2	2.2%
101 and 250	13	14.8%
251 and 500	13	14.8%
500 and 1000	19	21.6%
Above 1000	39	44.3%
Number of Beds Available (87)		
Under 100	28	32.2%
101 and 250	28	32.2%
251 and 500	12	13.8%
500 and 1000	12	13.8%
Above 1000	7	8.0%
Hospital Location (86)		
Urban	40	46.5%
Rural	46	53.5%
Teaching Hospital (87)		
Yes	21	24.1%
No	66	75.9%
For Profit or not-for-profit (85)		
For Profit	6	7.1%
Not-for-profit	79	92.9%
System-affiliated or stand-alone (87)		
System affiliated	49	56.3%
Stand-alone	38	43.7%

Table 5: Assessment of Unidimensionality

Construct	Sub-Construct	Indicators	χ^2	P value	GFI	CFI
Drivers	External Drivers (ED)	6	30.05	.00	.89	.95
	Internal Drivers (ID)	8	75.38	.00	.83	.90
Implementation Level	Clinical Focus (CF)	8	32.00	.00	.85	.95
	Administrative Focus (AF)	6	37.36	.00	.88	.94
Barriers	Cost Issues (CI)	5	29.18	.00	.88	.90
	Lack of Understanding (LU)	8	66.30	.00	.86	.93
	Technical Issues (TI)	4	1.07	.58	.99	.99
	Privacy and Security Concerns (PSC)	5	41.71	.00	.87	.94
Benefits	Patient Care (PC)	5	19.78	.00	.91	.95
	Productivity (PD)	4	7.45	.02	.96	.98
	Security and Safety (SS)	4	67.10	.00	.99	.99
	Asset Management (AM)	4	26.90	.00	.87	.95
	Communication (COM)	3	11.67	.55	.96	1.00
Performance	Cost Performance (CP)	3	30.83	.00	.91	.97
	Quality Performance (QP)	4	15.47	.00	.92	.95
	Financial Performance (FP)	4	2.89	.24	.99	.99

Note: the model fit statistics could not be obtained for the constructs with three items. In these cases, a two-factor model was tested by adding the items of another construct.

Table 6: Assessment of Reliability

Sub-Construct	Indicators	Reliability (ρ_c)	Reliability (α)
External Drivers (ED)	6	.92	.92
Internal Drivers (ID)	8	.93	.92
Clinical Focus (CF)	8	.96	.96
Administrative Focus (AF)	6	.94	.93
Cost Issues (CI)	5	.85	.86
Lack of Understanding (LU)	8	.95	.95
Technical Issues (TI)	4	.91	.90
Privacy and Security Concerns (PSC)	5	.97	.97
Patient Care (PC)	5	.92	.92
Productivity (PD)	4	.92	.92
Security and Safety (SS)	4	.94	.94
Asset Management (AM)	4	.97	.97
Communication (COM)	3	.95	.95
Cost Performance (CP)	3	.88	.87
Quality Performance (QP)	4	.91	.91
Financial Performance (FP)	4	.94	.93

Table 7: Factor Analysis for Drivers

Item	Internal Drivers	External Drivers
ID9	.880	
ID7	.872	
ID2	.861	
ID8	.859	
ID3	.785	
ID1	.757	
ID4	.735	
ID10	.706	
ID5	.700	
ED3		.921
ED5		.908
ED4		.868
ED2		.797
ED1		.779
ED6		.715
Eigenvalue	7.19	3.16
% of Variance	47.93	21.06
Cumulative % of variance	47.93	69.00

Table 8: Factor Analysis for Implementation Level

Item	Clinical Focus	Administrative Focus
CF3	.860	
CF4	.825	
CF7	.812	
CF2	.802	
CF9	.798	.422
CF6	.797	.454
CF5	.796	
CF10	.762	.407
AF5	.421	.535
AF4		.884
AF3		.874
AF2		.839
AF6		.818
AF1	.488	.604
Eigenvalue	9.95	1.18
% of Variance	71.06	8.46
Cumulative % of variance	71.06	79.52

Table 9: Factor Analysis for Barriers

	Lack of Understanding	Privacy and Security Concerns	Cost Issues	Technical Issues
LU5	0.849			
LU2	0.814			
LU4	0.807			
LU3	0.787			
LU1	0.765			
LU6	0.764			
LU7	0.728			
LU8	0.702			
PSC5		0.922		
PSC4		0.915		
PSC6		0.889		
PSC2		0.872		
PSC1		0.850		
CI1			0.880	
CI2			0.862	
CI3			0.832	
CI6			0.764	
CI4			0.487	
TI2				0.901
TI1				0.836
TI3				0.833
TI7				0.602
Eigenvalue	10.23	2.72	2.47	1.65
% of Variance	46.48	12.34	11.22	7.49
Cumulative % of variance	46.48	58.82	70.04	77.53

Table 10: Factor Analysis for Benefits

Item	Security and Safety	Asset Management	Productivity	Patient Care	Communication
SS1	.847				
SS4	.830				
SS5	.802				
SS3	.777				
AM2		.950			
AM3		.948			
AM1		.926			
AM4		.881			
PD3			.870		
PD1			.862		
PD4			.746		
PD2			.651		
PC2				.792	
PC1				.755	.416
PC7				.728	
PC3				.678	
COM1					.785
COM2					.777
COM3					.742
Eigenvalue	10.20	3.12	1.44	1.08	0.80
% of Variance	19.95	19.94	17.09	15.98	14.59
Cumulative % of variance	19.95	39.89	56.98	72.96	87.55

Table 11: Factor Analysis for Performance

	Financial Performance	Quality Performance	Cost Performance
FP2	.907		
FP3	.875		
FP4	.824		
FP1	.820		
QP2		.901	
QP4		.879	
QP3		.832	
QP1		.801	
CP1			.891
CP2			.887
CP3	.477		.748
Eigenvalue	5.829	1.955	1.292
% of Variance	31.311	29.165	22.036
Cumulative % of variance	31.311	60.476	82.512

Table 12 RFID Applications between Future Implementers and Current Implementers

	Future Implementers	Current Implementers
Clinical Focus - direct impact on patient		
Track infants	4.16	3.20
Track surgical patients	3.39	3.06
Track emergency room patients	3.29	3.23
Track other patients	3.16	2.83
Track medical equipment	3.97	4.75
Track the blood supply	3.22	2.60
Track patient medication usage	3.61	3.17
Track medication dispensing	3.77	3.49
Track lab specimens	3.42	2.77
Track surgical operations (tools, sponges etc)	3.48	3.08
Administrative Focus - indirect impact on patient		
Track administrative equipment	2.45	3.19
Track nurses	2.42	2.26
Track doctors	1.81	2.00
Track administrative personnel	1.74	1.84
Track hospital beds	3.35	3.31
Track uniforms	2.03	1.92
Track MRO inventories (maintenance, repair, operating)	2.84	3.45

Table 13 ANOVA tests on RFID Drivers and Barriers

	Group	Number	Mean	F Value	Significance
External Drivers	Non-Implementers	44	3.16	.71	.49
	Future Implementers	31	3.11		
	Current Implementers	13	2.58		
Internal Drivers	Non-Implementers	44	5.40	1.01	.37
	Future Implementers	31	5.65		
	Current Implementers	13	5.94		
Barriers-Cost	Non-Implementers	44	6.01	8.97	**.00**
	Future Implementers	31	5.25		
	Current Implementers	13	4.46		
Barriers-Lack of Understanding	Non-Implementers	44	4.41	3.95	**.02**
	Future Implementers	31	4.12		
	Current Implementers	13	3.14		
Barriers-Technical Issues	Non-Implementers	44	4.46	3.65	**.03**
	Future Implementers	31	3.84		
	Current Implementers	13	3.37		
Barriers-Privacy & Security Concern	Non-Implementers	44	3.95	1.04	.36
	Future Implementers	31	3.80		
	Current Implementers	13	3.20		

Table 14 ANOVA tests on RFID Benefits and Performance

	Group	Number	Mean	F Value	Significance
Benefits-Patient Care	Non-Implementers	44	3.77	4.13	**.02**
	Future Implementers	31	4.85		
	Current Implementers	13	4.23		
Benefits-Productivity	Non-Implementers	44	4.45	2.89	**.06**
	Future Implementers	31	5.10		
	Current Implementers	13	5.37		
Benefits-Security and Safety	Non-Implementers	44	4.06	1.80	.17
	Future Implementers	31	4.91		
	Current Implementers	13	4.46		
Benefits-Asset Management	Non-Implementers	44	4.84	2.40	.10
	Future Implementers	31	5.76		
	Current Implementers	13	5.37		
Benefits-Communication	Non-Implementers	44	3.47	1.98	.14
	Future Implementers	31	4.29		
	Current Implementers	13	4.12		
Performance-Cost	Non-Implementers	44	4.48	1.47	.23
	Future Implementers	31	4.60		
	Current Implementers	13	3.97		
Performance-Quality	Non-Implementers	44	5.01	.10	.91
	Future Implementers	31	4.98		
	Current Implementers	13	5.12		
Performance-Financial	Non-Implementers	44	4.33	.62	.54
	Future Implementers	31	4.64		
	Current Implementers	13	4.46		

Table 15. T-tests on RFID Barriers and Benefits

Group	Construct	t-Value	Significance
Between Non-Implementers and Future Implementers	Barriers-Cost	2.76	**.01**
	Barriers-Lack of Understanding	.85	.40
	Barriers- Technical Issues	1.87	**.07**
	Benefits-Patient Care	-2.93	**.00**
	Benefits-Productivity	-1.87	**.07**
Between Non-Implementers and Current Implementers	Barriers-Cost	3.72	**.00**
	Barriers-Lack of Understanding	2.64	**.01**
	Barriers- Technical Issues	2.23	**.03**
	Benefits-Patient Care	-.83	.41
	Benefits-Productivity	-1.82	**.07**
Between Future Implementers and Current Implementers	Barriers-Cost	1.95	**.06**
	Barriers-Lack of Understanding	2.31	**.03**
	Barriers- Technical Issues	1.16	.25
	Benefits-Patient Care	1.30	.20
	Benefits-Productivity	-.68	.50

Appendix A. Items for Drivers, Implementation Level, Barriers, Benefits, and Performance

(Items marked by an asterisk were removed in the final instrument)

Drivers

Please rate the importance of the following drivers of implementing RFID. (1 = not important; 4 = somewhat important; 7 = very important)

Drivers-External Drivers (ED)

ED1 Pressure from patients.
ED2 Pressure from suppliers.
ED3 Pressure from FDA.
ED4 Pressure from insurance companies and HMOs.
ED5 Pressure from external regulatory groups.
ED6 Keep up with competitors.

Drivers-Internal Drivers (ID)

ID1 Improve patient care.
ID2 Improve hospital productivity.
ID3 Improve hospital and patient security and safety.
ID4 Improve hospital asset management.
ID5* Improve hospital and patient communication.
ID6 Improve hospital employee job satisfaction.
ID7* Improve hospital cost performance.
ID8 Improve hospital quality performance.
ID9 Improve hospital financial performance.
ID10 Improve hospital supply chain performance.

Implementation Level

Please indicate the level of RFID implementation in your hospital in the following areas. (1 = no implementation; 4 = moderate implementation; 7 = strong implementation)

Implementation Level-Clinical Focus (CF)

CF1* Track infants.
CF2 Track surgical patients.
CF3 Track emergency room patients.
CF4 Track other patients.
CF5 Track medical equipment.
CF6 Track the blood supply.
CF7 Track patient medication usage.
CF8* Track medication dispensing.
CF9 Track lab specimens.
CF10 Track surgical operations (tools, sponges etc).

Implementation Level-Administrative Focus (AF)

AF1 Track administrative equipment.
AF2 Track nurses.
AF3 Track doctors.
AF4 Track administrative personnel.
AF5 Track hospital beds.
AF6 Track uniforms.
AF7* Track MRO inventories (maintenance, repair, operating).

Barriers

Please indicate the significance of the following barriers to implementing RFID in your hospital. (1 = no a barrier; 4 = minor barrier; 7 = major barrier)

Barriers-Cost Issues (CI)

CI1 Cost of tags.
CI2 Cost of readers.
CI3 Initial cost of implementation.
CI4 Return on investment.
CI5* Payback period.
CI6 Lack of funds for the RFID implementation.

Barriers-Lack of Understanding(LU)

LU1 Your hospital's lack of knowledge/understanding about RFID.
LU2 Difficulty in understanding potential benefits.
LU3 Developing/integrating new process.
LU4 Determining potential costs.
LU5 Determining potential ROI.
LU6 Training problems.
LU7 Security/regulation issues.
LU8 Large number of stakeholders in the decision.

Barriers-Technical Issues (TI)

TI1 Technical issues with hardware.
TI2 Technical issues with software.
TI3 Analysis & utilization of information generated from the RFID system.
TI4* Usage difficulties for patients.
TI5* Usage difficulties for suppliers.
TI6* Uncertainty of technology standards.
TI7 Database integration difficulty

Barriers-Privacy and Security Concerns (PSC)

PSC1 Privacy concerns that patients may have.
PSC2 Privacy concerns that employees may have.
PSC3* Privacy concerns of external entities.
PSC4 Security concerns about patient data integrity.
PSC5 Security concerns about employee data integrity.
PSC6 Security concerns about external entity data integrity.

Benefits

Please indicate the level of benefit your hospital may receive from implementing RFID. (1 = weak benefit; 4 = moderate benefit; 7 = strong benefit)

Benefits-Patient Care(PC)

PC1 Improve patient satisfaction with clinical processes.
PC2 Improve patient satisfaction with clinical outcomes.
PC3 Improve patient satisfaction with dispensing of medication.
PC4* Improve patients' compliance with medication prescriptions.
PC5* Improve patient safety.
PC6 Improve patient tracking.
PC7 Improve patient satisfaction with administrative processes.

Benefits-Productivity(PD)
PD1 Improve efficiency of nurses.
PD2 Improve efficiency of physicians.
PD3 Improve support staff productivity.
PD4 Improve the efficiency of the treatment process.

Benefits-Security and Safety(SS)
SS1 Improve drug-handling safety.
SS2* Improve the safety of surgery.
SS3 Improve the security of medicine (theft prevention).
SS4 Reduce medical errors.
SS5 Improve the safety of the blood supply.

Benefits-Asset Management(AM)
AM1 Improve the tracking of medical equipment.
AM2 Improve the utilization and management of medical equipment.
AM3 Improve the preventive maintenance of equipment.
AM4 Reduce equipment rental costs and deferral of new purchases.

Benefits-Communication(COM)
COM1 Improve communication between hospital and patient.
COM2 Improve communication between hospital and patient's family.
COM3 Improve internal communication among hospital staff.

Performance

Please indicate the position of your hospital with respect to your competitors on the following dimensions of performance. (1 = significantly lower; 4 = equal; 7 = significantly higher)

Performance-Cost Performance(CP)
CP1 Holding down inpatient costs.
CP2 Attaining high labor productivity.
CP3 Maintaining high capacity utilization.

Performance-Quality Performance(QP)
QP1 Clinical quality.
QP2 Patient satisfaction.
QP3 Responding to patient requests.
QP4 Responding to patient complaints.

Performance-Financial Performance(FP)
FP1 Market share grow.
FP2 Return on assets.
FP3 Return on investment.
FP4 Operating profit.