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A literature review of RFID-enabled healthcare applications and issues

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ABSTRACT

Despite the rising implementation of RFID technology-based healthcare services, few empirical studies have been conducted to assess the potential of this technology within the healthcare sector. The purpose of this study is to help initiate and direct such empirical research by both conducting a review of the extant literature and using the findings to provide a discussion of current trends and future directions in this domain. In this paper, we develop a conceptual framework that can be used to classify publications on RFID applications and issues in the healthcare industry. We then use this framework to systematically summarize relevant articles. We conclude by highlighting future research directions where the deployment of RFID technology is likely to transform the healthcare sector.

1. Introduction

The healthcare industry is one of the largest sectors in many economies. In the United States (US) it represents a “multi-trillion dollar industry” (p. vi) (Payton et al., 2011). The sector created approximately 14.3 million jobs in 2008, and has the potential to create an additional 3.2 million jobs by 2018 (United-States-Department-of-Labor, 2010). Currently, this industry faces tremendous challenges, including an increase in operating costs, the high level of medical errors, and the ageing patient population. For example, US healthcare expenses represented about 5% of the country’s gross national product (GNP) in 1963 (Middleton, 2009), with a potential increase to almost 20% of the GNP by 2017 (Wurster et al., 2009). Likewise, Canada healthcare expenses are in the rise. The country’s total public health expenditure in 2000 accounted for about 6% of the country’s GNP, and is expected to increase to nearly 7.1% by 2020 (Brimacombe et al., 2001). In Australia, the overall private and public healthcare spending is estimated at about 10% of the country’s GDP, or an equivalent of about AUS$ 65,000 million in an annual spending (GS1-Australia, 2010). In parallel, approximately 1.5 million people in the USA suffer from medication errors each year, and this has brought about extra healthcare costs of roughly $ 2.3 billion in 1993 and $ 3.5 billion in 2006 (p. 5) (National-Academy-of-Sciences, 2007). Many Western societies are ageing, and analysts argue that the number of older people in the US will increase by 135% between 2000 and 2050 and that the “population aged 85 and over – probably the group needing health and long-term care services more than any other – should increase by 350%” (p. 776) (Wiener & Tilly, 2002), all of which therefore increases pressure on healthcare expenditure. At the same time, due to the economic crisis, several countries are facing critical challenges in providing healthcare services (Newell, 2011).

Despite the rising implementation of RFID technology-based healthcare services, few empirical studies have been conducted to assess the potential of this technology within the healthcare sector. The purpose of this study is to help initiate and direct such empirical research by both conducting a review of the extant literature and using the findings to provide a discussion of current trends and future directions in this domain. In this paper, we develop a conceptual framework that can be used to classify publications on RFID applications and issues in the healthcare industry. We then use this framework to systematically summarize relevant articles. This article is organized as follows: Following the description of the current state of the healthcare sector (Section 1) and of information technology (IT)-enabled healthcare opportunities (Section 2), we examine some samples of RFID-enabled healthcare pilot studies in Section 3. Section 4 introduces the research methodology; then Section 5 deals with the classification framework and method, followed by Section 6 which presents our results, while Section 7 discusses the implications, limitations and future research directions. Finally, Section 8 serves as the conclusion.

2. Information technology (IT)-enabled healthcare transformation: The case of RFID

The healthcare sector is currently taking advantage of strong institutional powers and policies for an effective use of

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information technologies (ITs), which should enable the sector to better support service delivery (Payton et al., 2011). Indeed, the adoption and effective use of ITs in the healthcare sector is "a critical goal of a 21st-century healthcare system" (p. 79) (Menachemi & Brooks, 2006). Information technologies offer many opportunities for healthcare transformation through business process reengineering. This includes minimizing unproductive data entry, real-time access of clinicians to patient data for improved decision making, improving clinical trials which fosters personalized medicine, enhanced monitoring of population in public health and in real-time research, streamlining processes to increase transparency and reduce administrative overhead (as it happened in other industries), creating new high-technology-based healthcare markets and healthcare-related jobs (p. 1) (PCAST, 2010) helping to reduce medical errors, improving on patient safety, facilitating the continuity of care, improving on patient—physician communication, enhancing information handoffs and hospital efficiency, as well as assistance in the overall healthcare management of individuals (p. 324) (Burkhard et al., 2010). Some studies suggest for example that the adoption and use of interoperable electronic medical records systems by U.S. healthcare organizations could lead to improved efficiency, which may lead to potential safety savings of about $ 142–371 billion (Sherer, 2010).

More recently, the radio frequency identification (RFID) technology, a wireless automatic identification and data capture (AIDC) technology (Fosso Wamba et al., 2008), and a disruptive and open innovation (Fosso Wamba, 2011), has been regarded as the next wave of IT innovation that will widen healthcare transformation (Ngai et al., 2009a,b; Oztekin et al., 2010a,b). For example, RFID technology can facilitate patient identification, tracking, and tracing within the healthcare value chain (Fisher & Monahan, 2008). The technology offers an improved means of reducing errors in patient care, including adverse drug effects, allergies, patient–medication mismatches and medication dosage errors (Thuemmler et al., 2007; Tu et al., 2009). It promotes better management of critical healthcare assets (e.g., infusion pumps, wheelchairs) by enabling real-time identification, tracking and tracing (Symonds et al., 2007; Bendavid et al., 2010). All these new capabilities enabled by RFID technology have the potential to facilitate new value creation in healthcare service innovation (Dominguez-Péry et al., 2011). For example, the technology can enable healthcare stakeholders to monitor all steps related to the patient blood collection and transfusion process, including the identification of blood bags at the collection point, the tracking and tracing of products from the collection point to the healthcare facility, and blood transfusion to a dedicated patient (Najera et al., 2011). Also, this technology makes it easier to manage patients with chronic conditions (Cresswell & Sheikh, 2008; Michael et al., 2008).

Early studies show that RFID technology represents a viable means of checking, tracking, and tracing pharmaceutical products, while allowing a proper management of incident audit trails between the medical equipment and the healthcare staff (Booth et al., 2006). Indeed, counterfeit pharmaceutical products currently represent a major threat to patient safety for at least a couple of reasons: (a) they may contain hazardous ingredients (Fuhrer & Guinard, 2006); and (b) they may cause important financial losses to pharmaceutical firms (Dahiya, 2008). Some estimations indicate that in 2010, almost 10% of pharmaceutical products marketed worldwide were counterfeit (Lefebvre et al., 2011), and therefore accounted for about US$ 75 billion in financial losses by the pharmaceutical industry (Dahiya, 2008). Such a setback recently led the major US state and regulation (e.g., Food and Drug Administration, California State) to issue adoption mandates, which require pharmaceutical organizations to adopt a unique identifier (or e-Pedigree) for the tracking and tracing of pharmaceutical products as they move along the supply chain. As a result of such an action, the healthcare industry experienced a renewed interest in the adoption and use of RFID technology. Some studies have even suggested that "RFID is an enabling technology that saves lives, prevents errors, saves costs and increases security. It removes tedious procedures and provides patients with more freedom and dignity" (p. 1) (IDTechEx, 2006). In short, RFID-enabled healthcare transformation projects could lead to tremendous benefits, including improved patient care, improved patient security and safety, and finally improved organizational performance (Reyes et al., 2011), thereby enabling "new work practices to develop higher order capabilities for improving cost management, enhancing patient safety, and enabling regulatory compliance in hospital settings" (p. 8) (Lewis et al., 2009).

The high operational and strategic potential of the technology is effective in the healthcare market, as the value of the RFID market rose from about $ 5.63 billion in 2010 to almost $ 5.84 billion in 2011 (Das & Harrop, 2011). Consequently, the global market turnover for RFID readers and RFID tags alone is expected to reach the impressive amount of $ 8.9 billion by 2015 (MarketResearch.com, 2011). In 2011, almost 150 million RFID tags were in use in the healthcare supply chain (Pleshek, 2011), and the forecasts show the sales of RFID tags and systems will reach almost $ 1.43 billion in 2019, up from the nearly $ 94.6 million of 2009. Such a jump will be mainly due to the widespread of RFID-enabled healthcare applications, including the item-level tagging of drugs and various medical disposables, real-time locating systems for healthcare staff, patients and assets for improved efficiency and reduced losses, the compliance with safety requirements, and the availability of assets(Harrop et al., 2009).

However, the principle behind RFID technology is not that complicated. A basic RFID system includes RFID tags (active, passive, or semi-passive), which are also called RFID chips or transponders, serving as a digital data store that can be embedded or attached to a physical item to be identified and tracked. RFID readers or interrogators communicate with the tags and retrieve the information to be sent to a host computer or RFID middleware to ensure communication between the RFID infrastructure and the different intra- and inter-organizational systems. This process initiates and supports business transactions (Asif & Mandviwalla, 2005). When compared to similar AIDC technologies (e.g., bar-coding), RFID technology presents a vast range of advantages including: a unique item/product level identification, no need for line of sight, multiple tags reading, more data storage capability and data read/write capabilities (Asif & Mandviwalla, 2005). However, the high implementation costs of the technology remains a major inhibitor for its widespread adoption and use, as well as the substantial gap between the technology implementation costs and the RFID-enabled benefits (Bensel et al., 2008). Furthermore, the lack of common standard and the low operational performance level of RFID in a harsh environment continue to hamper its adoption.

3. RFID-enabled healthcare: Sample pilot studies

Recently, several pilot studies have been conducted to assess the real potential of RFID-enabled healthcare. For example, the Seoul National University Bundang Hospital is using RFID technology to enhance the workflow for better patient management (Kim et al., 2010). As for the Texas Health Presbyterian Hospital in Dallas, its current use of RFID is to track and trace over 7000 items (including IV poles, wheelchairs, and hospital beds) throughout the hospital, and this is generating tremendous benefits such as the nurses saving about 15% of their time for searching for critical assets, as well as about $ 30,000 of monthly savings from rental equipment (Pleshek, 2011). The Royal Wolverhampton Hospitals National Health Service Trust in England is also using a real-time RFID-enabled location system to manage three different functions throughout its facility: tracking the movements of patients and staff members, managing the locations of tagged assets, and ensuring hand-hygiene compliance. The hospital is planning to use the solution to track patients as they are registered, moved through various wards and then discharged, to improve the level of staff utilization by better directing staff members as to which services each patient requires next, and so forth (Swedberg, 2012a,b). Similarly, the Toronto University Health Network is currently testing an real-time RFID-enabled location system in order to prevent the transmission and spread of new infections, and control any existing infections, by tracking equipment, patients and employees (Swedberg, 2012a,b). Another user of RFID technology is the University Hospital of Jena. The only 200-year-old university clinic in the German state of Thuringia is using the technology in combination with a SAP NetWeaver platform to identify, track and match medication accurately and in real time from the hospital's pharmacy to the patients. Undoubtedly, this leads to improved treatment process, increased service quality in medical care, and improved safety of patients (e.g., reduction of undesired medication effects) (SAP, 2006).

Nevertheless, despite this high operational and strategic potential of RFID technology-enabled healthcare transformation, few empirical studies have been conducted to assess the potential of this technology within the sector. For example, a review by Ngai et al. (2008) on RFID technology shows that only 3.6% of the papers dealt with applications and issues related to the healthcare sector, while almost 17.8%, the highest frequency of peer-reviewed articles on RFID technology, tackled application and issues related to the retail sector. In addition, even if there is currently a real emergence of literature reviews on RFID technology (Ngai et al., 2008), RFID technology in the supply chain (Sarac et al., 2010) and RFID-enabled healthcare (review within a single journal) (Fosso Wamba, 2012), a comprehensive review of articles dealing with RFID applications and issues in the healthcare is still to come. Therefore, this paper is an initial effort towards bridging the existing knowledge gap in the literature. More specifically, this study draws on prior studies on RFID technology research agendas (Curtin et al., 2007; Ngai et al., 2008), as well as on the extant literature on RFID technology to achieve the following objectives:

(1) Develop a conceptual framework for the classification of articles dealing with RFID applications and issues in the healthcare.
(2) Use the conceptual framework to classify and summarize all relevant articles.
(3) Develop future research directions where the deployment and use of RFID technology is likely to transform the business processes in the healthcare sector.

4. Methodology

In this study, a methodology that has been adopted is similar to the one used by Ngai and Wat (2002) when studying electronic commerce and by Ngai et al. (2009b) when studying CRM and data mining. It consists in developing a classification framework and a comprehensive review of journal articles dealing with RFID-enabled healthcare applications. This choice falls in line with (Ngai & Wat, 2002), who believe that "academics and practitioners alike use journals most often for acquiring information and disseminating new findings and represent the highest level of research" (p. 416). Therefore, master and doctoral dissertations, conference articles, unpublished working papers and textbooks were excluded for this review.

The research timeframe for this study covers the literature on the applications and issues related to RFID-enabled healthcare that was published between January 2000 and December 2011. This 11-year period is considered to be representative of the applications and issues of RFID-enabled healthcare since the research on this topic is relatively new. More specifically, a comprehensive search using a combination of a descriptor, "RFID technology", RFID, "Radio Frequency Identification", and "healthcare" was realized within the following databases:

- ABI/Inform Complete
- Academic Search Complete
- ACM Digital Library
- Business Source Complete
- Elsevier (SCOPUS)
- Emerald
- IEEE Xplore
- Science Direct
- Taylor & Francis.

Our selection of databases is an extension of the databases used by Ngai et al. (2009b) to study customer relationship management (CRM) and data mining. This deliberate choice allows us to obtain a comprehensive review of the academic articles on RFID-enabled healthcare applications and issues. The search articles was performed between 18 December 2011 and 5 January 2012 and resulted in 1548 articles (Fig. 1). The reference of all these articles and their abstracts was downloaded into a reference management software package called Endnote. Afterward, a screening of the abstract of each article was performed by one co-author to assess its fit with our research objectives and identify duplicated articles between 5 January 2012 and 22 February 2012. At the end of this process, 88 articles were identified as duplicates and 972 articles were excluded based on the abstract analysis.

Then, from the 25 February 2012 to 8 March 2012, the remaining 488 articles were thoroughly analyzed by one co-author in order to eliminate those which were not related to RFID-enabled healthcare applications and issues. The analysis showed that 258 articles were inappropriate for our research objectives, and that 15 articles rather had anonymous authors. Between the 9 March and 8 April 2012, the two co-authors took on independently analysing and classifying each of the remaining 215 articles. Then a comparison of the two classifications was realized and where there was a discrepancy, verification was jointly conducted by the two authors to reach a consensus. The final classification was verified by the last co-author for consistency with regard to the dimensions of our classification framework. This analysis ended on the 13 April 2012.

5. Classification framework

For this study, a classification framework was developed based on early studies on RFID technology (Fosso Wamba & Chatfield, 2009) in general, with a focus on this technology in the healthcare industry (Van Oranje et al., 2009; Fosso Wamba & Ngai, 2011) (Fig. 2). According to Fosso Wamba and Chatfield (2009), the level of RFID-enabled business value realization depends on several factors, one of the most important being the costs (e.g., costs associated to the level of electronic integration and organizational integration, human resource training costs, RFID infrastructure costs). Fosso Wamba and Ngai (2011) demonstrate that RFID has the tremendous potential of transforming patient management-related processes, in line with Van Oranje et al. (2009) for whom the same technology is capable of transforming not only patient management-related applications, but also asset management and staff management-related applications. Drawing on Van Oranje et al. (2009), Fosso Wamba and Ngai (2011), Fosso Wamba and Chatfield (2009), we developed a classification framework that identifies three broad categories of RFID-enabled applications that influence the creation

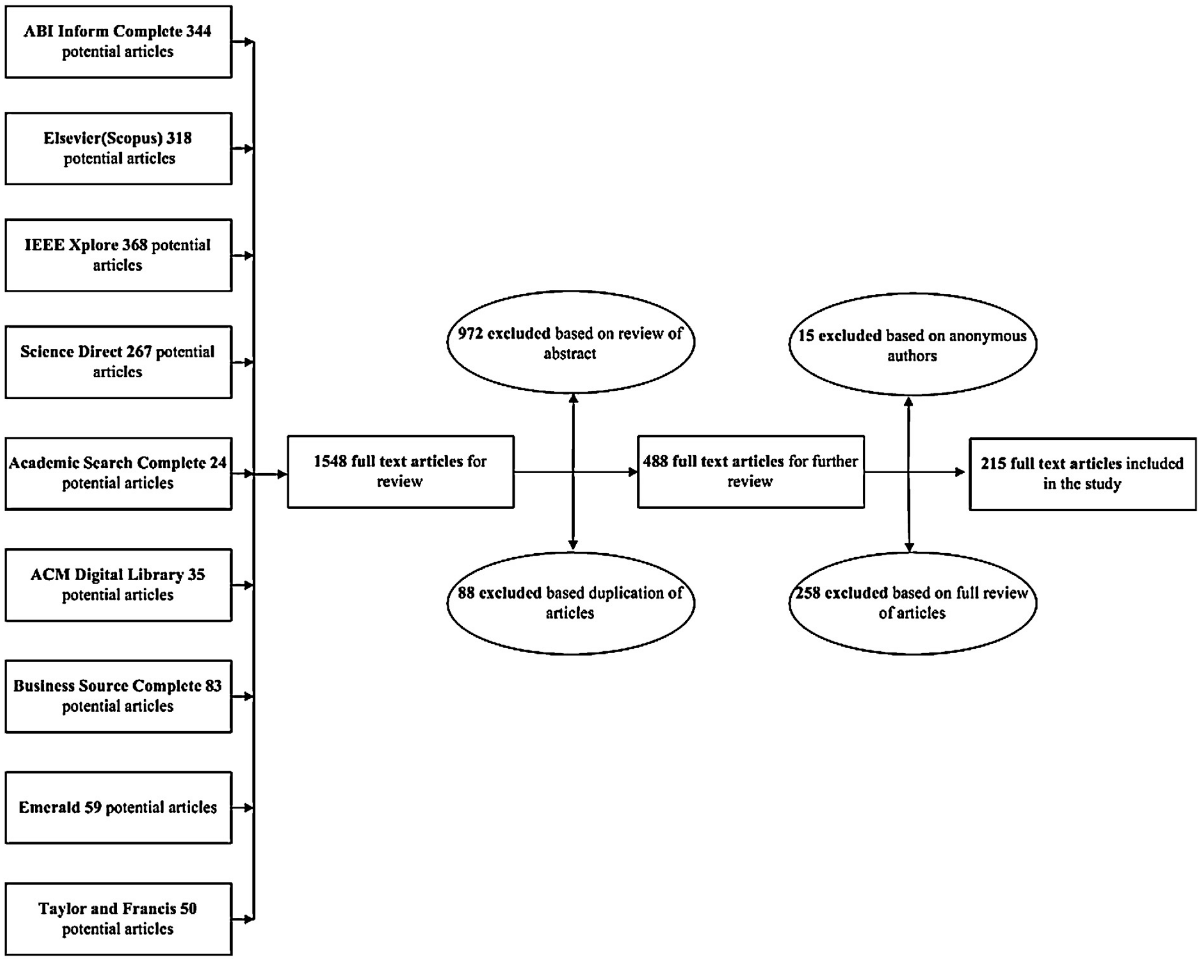

Fig. 1. Selection process framework.

of benefits by means of RFID technology in the healthcare sector: asset management, patient management, and staff management-related applications. This model posits that the realization of the benefits from RFID-enabled healthcare applications is moderated by key RFID issues (e.g., technological, data management, security and privacy, and organizational and financing issues) (Van Oranje et al., 2009). We argue that when exploring RFID-enabled applications, the firms that are increasingly become aware of RFID-enabled issues and are taking proper actions to deal with them will be the greatest recipients of benefits related to these applications. For example, we suggest that the greater amount of RFID-enabled benefits will fall in the hand of the firms that will have carried out proper management changes in the course of the RFID project. Similarly, the firms which will have adequately trained their staff to support emerging RFID-enabled healthcare applications will come out with great benefits.

5.1. RFID-enabled asset management

RFID-enabled asset management is considered as one of the most important avenues offered by the technology for healthcare cost saving. For example, analysts estimate that the costs generated by the theft of healthcare equipment and supplies within US hospitals can reach $ 4000 per bed annually, thus accounting for a

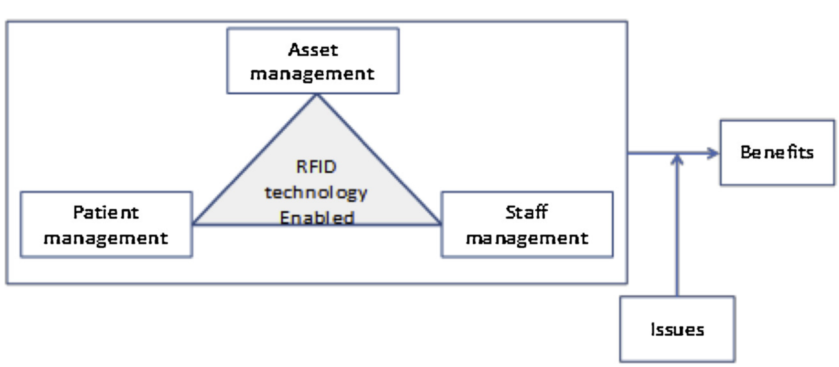

Fig. 2. Classification framework.

Table 1
RFID-enabled healthcare asset management applications.

Asset identification	Asset tracking and tracing for access control and inventory shrinkage decrease	Asset tracking and tracing for expiration date and restocking
Blood bags identification in hospitals to ensure blood type matching	Detection of tampered or unacceptable drugs	Asset tracking and tracing to avoid procedure delays
Proper equipment servicing	Inventory utilization	Inventory management
Materials tracking to avoid left-ins	Real-time inventory counting	Maintenance of medical equipment
Medicine tracking	Provision of e-Pedigree	Location tracking and tissue bank operations

total potential loss of about $ 3.9 billion for an average of 975,000 staffed beds (Lieshout et al., 2007). The adoption and effective use of RFID technology to track and trace healthcare assets can help healthcare firms reduce this loss. More precisely, RFID-enabled healthcare asset management applications (Van Oranje et al., 2009; Fosso Wamba & Ngai, 2011) include the following (see Table 1).

5.2. RFID-enabled patient management

RFID technology holds tremendous potential in terms of improving the management of patients within the healthcare supply chain. The technology is regarded as a viable means to eliminate various inefficiencies related to patient management, such as medication errors. For example, by using an RFID-enabled electronic patient identification where all patient history is stored, healthcare stakeholders can in real time recover patient information and discover potential drugs incompatibilities, which will enable them to avoid adverse drug effects which constitute a major problem in the healthcare sector (Lieshout et al., 2007). In the USA, analysts estimate that roughly 11 to 15 of every 1000 Americans annually seek advice from a healthcare provider on grounds related to adverse drug effects (The-Commonwealth-Fund, 2011). More precisely, RFID-enabled patient management covers the following applications (Van Oranje et al., 2009) (p. 73): accurate patient identification for medication safety, critical information to the patient, dementia outpatients tracking and tracing, elimination of wrong procedure for patient surgery, RFID-driven medical record, infant hospitals identification to avoid mismatching, tracking and tracing of infant hospitals for security against theft, intelligent medication monitoring for the elderly at home, automated care intervention pathways, procedures for audit management, monitoring of patient location tracing, patient identification for blood transfusion, patient identification to avoid wrong drug dose, time procedure, tracking and tracing of hospitals for patient flow monitoring, patient tracking to ensure safety access and control dementia psych, portable, current and comprehensive health records, provision of real-time information on health indicators and vital signs (by means of RFID ingestion or implantation), and tracking of drugs supplies and procedures performed on each patient.

5.3. RFID-enabled staff management

RFID-enabled staff management covers the following applications (Van Oranje et al., 2009) (p. 72): better staff time utilization, improved error prevention, improved labour productivity, reduced processing time, staff identification, staff monitoring, staff tracking, and workflow optimization in hospitals.

5.4. RFID-enabled healthcare issues

The emerging literature on RFID-enabled healthcare applications enables the identification of three categories of issues: technological, data management, security and privacy, and organizational and financial issues (Van Oranje et al., 2009) (p. 16).

- Technological issues: These are issues such as the lack of required wireless infrastructure within healthcare facilities to support RFID-enabled healthcare projects, the potential interference of RFID systems with medical equipment, the difficulty to clearly define the scope of RFID-enabled healthcare projects, and the technical realization of such projects (e.g., integration of RFID systems with healthcare infrastructure, identification of common standards) (Van Oranje et al., 2009).
- Data management, security and privacy issues: They cover issues such as security and privacy issues, RFID data integrity and reliability, management of huge amounts of data generated by RFID systems, RFID-enabled business intelligence (Van Oranje et al., 2009).
- Organizational and financing issues: They cover issues such the difficulty to conduct a cost-benefit analysis of RFID-enabled healthcare projects, the cost of RFID system, change management, training, skills to support emerging RFID-enabled healthcare processes, integration of RFID with healthcare organizational complexity, culture and norms (Van Oranje et al., 2009).

5.5. RFID-enabled healthcare transformation benefits

The adoption and effective use of RFID technology in the healthcare sector has the potential to provide tremendous benefits in terms of efficiency, quality and management (Van Oranje et al., 2009) (p. 54).

- Efficiency gains: Cover the following benefits: capital expense reduction, inventory reduction, operating cost reduction, labour cost savings, increased patient management.
- Quality gains: Cover all benefits related to the improvement of patient care quality (e.g., elimination of wrong patient and wrong medication errors, elimination of wrong patient and wrong procedure errors), improved coordination between healthcare stakeholders, improved patient satisfaction, improved infection control capacity, improved asset preventive and corrective maintenance.
- Management gains: Cover all benefits related to the capacity of healthcare stakeholders to comply with various regulations, the reduction of insurance premiums, the improvement of process and event audit capacity as well as of forecasting capacity.

6. Results

We now present and discuss the results of the review of past peer-reviewed articles dealing with RFID-enabled healthcare. In the first place, we highlight the distribution of articles by year, topic, benefits, issues, approach and journal.

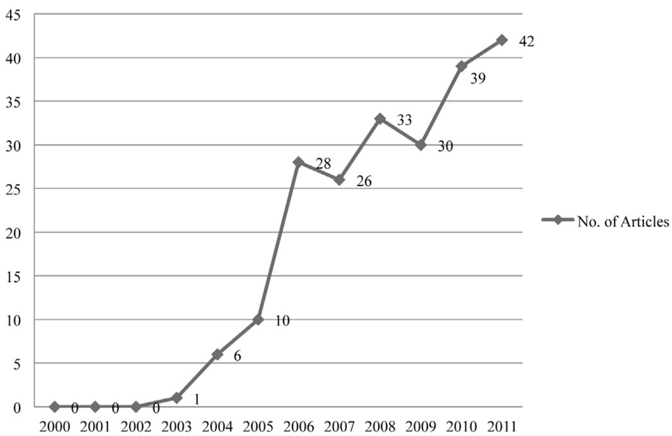

Fig. 3. Classification of articles based on year.

Table 2
Classification of articles based on the distributions by applications.

Dimension	Number of articles	Percentage
Asset management	116	45.5
Patient management	105	41.17
Staff management	34	13.33
Total	255	100

Note: Some articles are counted more than once because they cover more than one application.

6.1. Distribution of articles by the year of publication

Based on the literature we reviewed, there were no publications for the years 2000, 2001 and 2002. There was only 1 publication in 2003, 6 in 2004 and 10 in 2005. The year 2006 witnessed a steep increase resulting in 28 publications, and thereafter this bullish trend was maintained: from 33 publications in 2008 to 42 publications in 2011 (Fig. 3), with only little variations in 2007 (26 publications) and 2009 (30 publications). One of the reasons may be the fact that the retail giant Wal-Mart issued an adoption mandate in 2003, thereby triggering more interest for RFID technology. Clearly, the amount of publications on RFID-enabled healthcare has exploded since the first review by (Ngai et al., 2008) where only one peer-reviewed article on RFID-enabled healthcare were found (or 3.6%, compared to five articles of 17.8% in the retailing).

6.2. Distributions of articles by topics

Table 2 shows the distribution of articles by topics. It clearly appears that the vast majority of articles covered areas related to asset management (116 articles, 45.5%) and patient management (105 articles, 41.17%), followed by staff management (34 articles, 13.33%).

Table 3 presents the distribution of articles by RFID-enabled healthcare benefits. Clearly, the most highly published RFID-enabled healthcare benefits are related to efficiency gains (86 articles, 43.43%), followed by RFID-enabled healthcare quality gains in the second position with 67 articles (33.83%), and RFID-enabled healthcare management gains in the last position with 45 articles (22.72%). RFID-enabled healthcare transformation is expected to have significantly impacts on healthcare's business processes, patient care quality and coordination with healthcare stakeholders, thus leading to tremendous impacts on healthcare efficiency and effectiveness.

Table 3
Classification of articles based on the distributions by benefits.

Dimension	Number of articles	Percentage
Efficiency gains	86	43.43
Quality gains	67	33.83
Management gains	45	22.72
Total	198	100

Note: Some articles are counted more than once because they cover more than one benefit.

Table 4
Classification of articles based on the distributions by issues.

Dimension	Number of articles	Percentage
Technological issues	97	39.27
Organizational and financing issues	92	37.24
Data management, security and privacy issues	58	23.48
Total	247	100

Note: Some articles are counted more than once because they cover more than one issue.

Table 4 shows the classification of articles based on the distribution by RFID-enabled healthcare issues. So far, the highest number of published articles on RFID issues is concerned with technological issues (97 articles, 39.27%), followed by organizational and financing issues (92 articles, 37.24%) and then data management, security and privacy issues (58 articles, 23.48%). This low level of articles on data management, security and privacy came as a surprise as these issues are among current key concerns related to RFID adoption and use (Halamka et al., 2006).

6.3. Classification of articles based on the most used approaches

The distribution of article by approach used is presented in Table 5. The vast majority of articles (109, 44.30%) are review articles, followed by experiments/models (43 articles, 17.47%) and case studies (39 articles, 15.85%). Most of the articles, apart from the articles adopted as reviews, employed multiple approaches (for example, a case study and survey, experiments and simulation). Further, the results also indicate that there is a shortage of analytical (15 articles, 6.09%) and survey studies (16 articles, 6.5%) covering the topics on RFID in healthcare. Other approaches such as simulation (24 articles, 9.75%) also need to be looked into.

6.4. Distribution of articles per journal

Table 6 lists journals containing two or more articles. We can notice that this represents 126 articles out of 230 articles or 58.54%. Clearly, the most popular journal publishing articles related to RFID-enabled healthcare is "Healthcare Purchasing News" with 30 articles (13.95%), followed far behind by "IEEE Transactions on Information Technology in Biomedicine" with 7 articles (3.25%), "Decision Support Systems" journal and the "International Journal of Medical Informatics", each of which has 6 articles (2.79%).

Table 5
Classification of articles based on the most used approaches.

Most used approaches	No of journals	Percentage
Reviews	109	44.30
Experiments/models	43	17.47
Case studies	39	15.85
Simulation approach	24	9.75
Survey studies	16	6.5
Analytical approach	15	6.09
Total	246	100

Note: Some articles are counted more than once because they cover more than one approach.

Table 6
Classification of articles per journal (with minimum of two publications).

Journal	No.	Percentage
Healthcare Purchasing News	30	13.95
Information Technology in Biomedicine, IEEE Transactions on	7	3.25
Decision Support Systems	6	2.79
International Journal of Medical Informatics	6	2.79
Mobile Networks and Applications	5	2.32
Pharmaceutical Technology Europe	4	1.86
Communications Magazine, IEEE	4	1.86
Assembly Automation	4	1.86
European Journal of Information Systems	3	1.39
Health Marketing Quarterly	3	1.39
Journal of Medical Systems	3	1.39
IEEE Wireless Communications	3	1.39
Pervasive Computing, IEEE	3	1.39
Journal of Network and Computer Applications	3	1.39
The American Journal of Bioethics	3	1.39
Hospital Topics	3	1.39
Business Process Management Journal	2	.93
Proceedings of the IEEE	2	.93
IEEE Engineering in Medicine and Biology Society	2	.93
International Journal of Physical Distribution & Logistics Management	2	.93
American Journal of Business	2	.93
Nursing Management	2	.93
Industrial Engineer: IE	2	.93
Journal of Healthcare Management	2	.93
American Journal of Health-System Pharmacy	2	.93
Personal and Ubiquitous Computing	2	.93
Progress in Biophysics and Molecular Biology	2	.93
Telemedicine and e-Health	2	.93
Sensor Review	2	.93
Engineering in Medicine and Biology Magazine, IEEE	2	.93
IT Professional Magazine	2	.93
Technovation	2	.93
International Journal of Production Economics	2	.93
Information Systems Management	2	.93
Total	126	58.54

Our review revealed only one journal from the IS Senior Scholars Basket of Eight journals. Given the importance of healthcare IT and RFID to the IS discipline, it is surprising that more premier outlets have not published papers that integrate the two. This may highlight the need for special issues on healthcare related RFID to encourage more authors to explore this topic. Over the last decade there has been a huge increase in the number of articles published on this topic (see Fig. 3). We posit that IS journals should become more involved in this revolution. IS is after all an important referent discipline for healthcare related RFID technologies.

7. Discussion

Using the classification framework as a conceptual guide, we have performed an analysis of 215 peer-reviewed articles identified from 9 databases: ABI/Inform Complete, Academic Search Complete, ACM Digital Library, Business Source Complete, Elsevier (SCOPUS), Emerald, IEEE Xplore, Science Direct and Taylor & Francis. Based on the results of our analysis, RFID technology is mostly used for the purposes of: (a) asset management (116 articles, 45.5%), due to its potential to track item-level products such as medical devices, laboratory specimens and surgical instruments automatically and in real time and (b) patient management (105 articles, 41.17%), given its capacity to hold patient information in the attached RFID tags and enabling in tracking their movements. It also appears that based on the articles dealing with benefits, the highest number of them are related to RFID-enabled healthcare efficiency gains (86 articles, 43.43%), followed by articles tackling the issue of RFID-enabled healthcare quality gains (67 articles, 33.83%), and of RFID-enabled healthcare management gains (45 articles, 22.72%). Further, the article highlights the fact that the most common issues related to RFID-enabled healthcare are technological issues (97 articles, 39.27%), followed by organizational and financial issues (92 articles, 37.24%), and finally, data management, security and privacy issues (58 articles, 23.48%). These results are consistent with the review conducted by Ngai et al. (2008), who found that RFID technological issues were among the most issues discussed by the peer-reviewed articles identified in their study.

With regard to the research methodology, the results show that the vast majority of articles (109 articles, 44.30%) are review articles, followed by articles using experiments/models (43 articles, 17.47%), and case studies (39 articles, 15.85%). At the bottom of the list, are the articles using simulation approach represent the fourth largest segment of articles found (24 articles, 9.75%), the articles using survey approach (16 articles, 6.5%) and those using analytical approach (15 articles, 6.09%). Finally, this study indicates that the journals with two or more articles on RFID-enabled healthcare published 126 articles out of 230 articles, i.e., 58.54%. In this category, the most popular journal is Healthcare Purchasing News with 30 articles (13.95%), which is followed far behind by IEEE Transactions on Information Technology in Biomedicine with 7 articles (3.25%), the Decision Support Systems journal, and the International Journal of Medical Informatics, with 6 articles each (2.79%).

7.1. Implications for research and practice

This review of the literature allows us to assess the level of knowledge development on RFID-enabled healthcare, explore the implications for practice and theory and to recommend some future research directions. In addition to highlighting the potential benefits (efficiency gains, quality gains and management gains) of RFID-enabled healthcare projects, this article also provides the frequent concerns and issues (technological issues, data management, and security and privacy issues, organizational and financial issues) affecting the level of business value realization from the said projects. Such information may assist managers in the implementation of RFID-enabled healthcare projects so as to direct resources and more attention to potential issues that may negatively affect the business realization of such projects. The same results may serve as a baseline for future research to be carried out by healthcare informatics academics. For example, future research may explore the RFID network externalities, which requires an assessment of the impact of RFID technology on the interdependency of the healthcare value chain activities, as well as the key business and technical issues of implementing RFID-enabled projects for a high level of business value realization. More precisely, future research should look at how RFID investments within the healthcare sector can be linked to other organizational resources in order to create higher order capabilities to transform the industry through innovative business processes, enhanced business strategies and improved business models (Lewis et al., 2009).

The analysis of articles on RFID applications in the healthcare shows that the highest number of published articles is concerned with the "asset management" areas (45.5%), followed by "patient management" (41.17%), and "staff management" (13.33%). These results indicate that there are significant opportunities for future research in the areas of RFID-enabled staff management. For example, exploring the impact of RFID technology on staff (nurses, doctors) job characteristics and performance is an interesting question for future research. Another interesting question for future research will be: how RFID-enabled healthcare will transform the relationships between patients–nurses, nurses–doctors, patients–doctors? Also, investigating the cost of integrating RFID technology into "asset management", "patient management" and "staff management" processes should also be included in future research. Furthermore, future research should assess the acceptance of

RFID-enabled patient management and staff management applications and healthcare applications using current dominant theoretical models (e.g., diffusion of innovation, technology acceptance model), and eventually propose emerging theories to better explain the adoption and use of the said technology in the healthcare sector. How RFID technology facilitates the reduction of patient-related transaction costs is an interesting area for future research.

With regard to RFID-enabled healthcare issues, the review shows that the highest number of published articles is concerned with the "Technological issues" (39.27%), followed by "Organizational and financing issues" (37.24%), then "Data management, security and privacy issues" (23.48%). These results confirm the fact that in the early adoption phase of RFID technology, the vast majority of articles are more centred on technological issues and organizational and financing issues and less on data management, security and privacy issues. This finding highlights significant opportunities for future research in the areas of RFID-enabled healthcare issues. For example, exploring the best approach to analyze the explosion of RFID-enabled healthcare data should be included in future research. An interesting question for future research is: How to analyze big data generated by RFID-enabled healthcare applications for improved healthcare service delivery? Exploring the best mechanism to solve security and privacy issues related to RFID-enabled healthcare applications should also be explored by future researchers. Indeed, early studies on RFID technology show that consumers' privacy concerns have a negative effects on the adoption and use of the technology (Smart & Bunduchi, 2010). Finally, analysing the best RFID-enabled healthcare architecture should be included in future research (e.g., data-on-the tag vs. data-on-the network). Also, future research topics may include: an investigation of the network effect of RFID technology within all healthcare value chain; and a study of the key technical and business challenges of integrating RFID technology within the entire healthcare value chain.

When dealing with RFID-enabled healthcare transformation benefits, our analysis shows that the highest number of published articles is concerned with the "Efficiency gains" (43.43%), followed by "Quality gains" (33.83%), then "Management gains" (22.72%). Clearly, future research needs to focus more on how to assess benefits enabled by RFID technology when complying with healthcare law and regulations. An interesting question for future research is: How can RFID technology enable the reduction of healthcare insurance premiums?

7.2. Suggestions for future research

There are a plethora of opportunities for future studies in this area. Future research needs to focus on how the management of these new RFID-enabled healthcare capabilities should be realized to enhance healthcare performance. Indeed, prior research on IT-enabled firm performance suggests that "the role and articulation of 'the underlying mechanisms' through which IT capabilities improve firm performance remain unclear" (p. 238) (Mithas et al., 2011). In the context of logistics and manufacturing (Fosso Wamba & Chatfield, 2009) found that business value creation and realization from RFID projects were contingent to strong leadership, second-order organizational learning, resources commitment, and organizational transformation. Future research needs to investigate the extent to which these contingency factors still exist in the healthcare sector, given that "the healthcare context provides high levels of complexity and nuance that can support information systems (IS) theory extension and innovation" (p. 670) (LeRouge et al., 2007). Also, future research needs to investigate technological, organizational and environmental factors that may have an impact on the adoption and use of RFID-enabled healthcare applications by applying current dominant IS adoption theories (Fichman, 2000), and develop new theories when required.

Other areas for future research regarding the use of RFID in the healthcare value chain include: assessing the business value of RFID-enabled item level tagging within the healthcare value chain in order to evaluate the impact of this item level tagging on the healthcare outcome and costs. Indeed, one of the key challenges of the healthcare sector is the difficulty of measuring the exact healthcare delivery costs to each patient, which allows a comparison of the costs with the outcomes. In this context, some scholars believe that technologies such as RFID may play an important role in resolving these challenges (Kaplan & Porter, 2011).

Researchers should consider juxtaposing the business value realized from the current RFID-enabled healthcare projects and compare the real value realized. Indeed (Davern & Kauffman, 2000) highlight the fact that "few authors would contend that the search for value has reached a point where practitioners and theoreticians are satisfied with its outcomes" (p. 121). Therefore, developing new frameworks and/or using existing frameworks to "understand where potential value lies and how best to relate it contextually to the measurement of the firm's realized value across multiple levels of analysis" (p. 121) (Davern & Kauffman, 2000) should also be included in future research.

Furthermore, to understand the influence of different healthcare stakeholders on their peers, it would be interesting to examine the business value from the co-adoption of RFID technology and other healthcare ISs (e.g., ERP, electronic medical records (EMR) systems, computerized clinical decision support (CCDS), computerized physician order entry (CPOE), picture archiving and communication system (PACS), automated dispensing machines (ADM) and electronic materials management (EMM)), and applying new theories (e.g., social network theory).Indeed, a recent study by Sykes et al. (2009) shows that social network theory and social network constructs may improve our "understanding of employees' system use", by going beyond behavioural intention and capturing the informal interactions that complement the formal infrastructure (p. 387).

Prior studies on IT adoption (Riggins & Mukhopadhyay, 1994) show a positive correlation between the level of business process reengineering and the use of and value gained from ITs. This trend was noticed in the emerging literature on RFID adoption in logistics and manufacturing (Fosso Wamba & Chatfield, 2009). Therefore, additional research is needed to empirically investigate how to reengineer healthcare-related processes (patient, asset and staff) to achieve higher levels of business value from RFID-enabled healthcare projects. For example, Najera et al. (2011)) found that RFID technological issues (e.g., RFID tags reading accuracy and performance) have a negative impact on RFID-enabled patient management applications. And Michael et al. (2008) found that privacy and security issues are among key inhibitors of RFID-enabled healthcare applications. Future research should also look at better strategies to incorporate RFID into healthcare processes and operations. Future studies need for example to identify the scope of the RFID-enabled healthcare project, then assess the potential impact of the technology in terms of incremental and/or process transformation. This assessment should also include the cascade effect that can be created by applying RFID at certain parts of the organization and/or operations. For example, McNulty and Ferlie (2004), when studying the implementation of business process reengineering in a UK National Health Service hospital, discovered that the impact of "reengineering within a UK hospital was limited by managers and clinicians operating within an organizational form that embraced new public management (NPM) and vertical principles of organizing and which made it difficult to adopt a coherent process-based logic of organization" (p. 1406). Therefore, exploring the importance of key healthcare stakeholders in facilitating or inhibiting the execution of RFID-enabled healthcare projects should be included into future research. Developing a holistic performance measurement and management system to assess the value generated by RFID-enabled healthcare operations should be also included into future research. Indeed, within healthcare settings, "performance measurement and management takes place around distinct units which report up the line" (p. 1406), thus lacking the holistic view of the impacts of transformational initiatives within the sector. Also, early studies from Fosso Wamba (2012), Fosso Wamba et al. (2008) showed that the impacts of RFID are not only incremental and/or transformational, but may include new emerging processes called "smart or intelligent" processes (that are triggered without any human intervention). Assessing the impacts of such processes within the healthcare settings should be included into future research.

7.3. Limitations

In addition to the diverse implications of this study, we should mention some of its limitations. We utilized nine major databases and followed a published methodology to conduct our literature review; however, the search was not exhaustive. Another limitation is that only articles written in English were included in this review. Future research should consider expanding the size of databases and include non-English speaking journal articles. Finally, although we employed a systematic approach to classify the articles, the inclusion of articles into our final selection was based on our subjective judgment. Future studies should be conducted to corroborate our classifications.

8. Conclusion

This paper presents a comprehensive review of articles dealing with RFID applications and issues in the healthcare. More specifically, we developed and implemented a classification framework with three categories of RFID-enabled applications influencing benefits creation from RFID technology in the healthcare sector: asset management, patient management, and staff management-related applications. This study analyzes the extant literature to highlight the usefulness and relevance of the proposed framework. This study also posits that the realization of the full business benefits from RFID-enabled healthcare applications will depend on three categories of issues, namely: technological, data management, security and privacy, and organizational and financing issues. The framework we developed and the analysis we conducted provide an overview of extant literature in the healthcare RFID domain. This review also highlights several avenues for future research on healthcare RFID. Based on the results of this study, we posit that there is a need for more healthcare RFID research in IS journals. Also, given the sensitive nature of medical information, there is a need for more research on data management, security and privacy issues.

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Appendix A.

See Tables A1–A3.

Table A1
RFID-enabled applications.

Dimension	Number of papers	Percentage	References
Asset management	116	45.5	Kapoor et al. (2009), Brading (2009), Wyld (2008a,b), Curtin et al. (2007), Bose et al. (2009), Chaveton (2006), Forcinio (2007), Harrop (2007), Parkinson (2008), Zhou and Shi (2009a,b), Kumar et al. (2008), Enyinda and Szmerekovsky (2008), Attaran (2006), Pei Ran et al. (2008), Britton (2007), Roark and Miguel (2006a,b), McGrady et al. (2010), Jeppsson (2011), Smith (2006), Zalucki (2010), Wicks et al. (2006), Thompson (2004), Roark and Miguel (2006a,b), Crooker et al. (2009), Lavine (2008), Revere et al. (2010), Kumar et al. (2010), Kennedy (2011), Agarwal et al. (2007), Schiefen (2007, 2008), Barlow (2004, 2005a,b, 2006a,c,d,e, 2007b, 2008a,d,c, 2009a,b,c, 2010), Brooks (2010), Christianson (2008), Philippe and Beaulieu (2011), Janz et al. (2005), Endicott (2007), Kaufman (2007), Reiner and Sullivan (2005), Acharyulu (2007), Raviprakash et al. (2009), Carr et al. (2010), Perrin and McAndrew (2006), Neuwirth (2005), Liu et al. (2011a,b), Francis et al. (2009), Petro et al. (2009), Booth et al. (2006), Degaspari (2011), Ting et al. (2011), Ngai et al. (2009a,b), Chen et al. (2008), Mehrjerdi (2008, 2010, 2011a,b), Carrasco and Jackson (2010), Bendavid et al. (2010), Bouet and Pujolle (2010), Nagy et al. (2006), Ahlund (2005), Kumar et al. (2009), Potyrailo et al. (2011), Schwaitzberg (2006), Davis et al. (2009), Symonds and Parry (2008), Kwok et al. (2010), Mehrjerd (2010), Barjis (2010), Li et al. (2006), Attaran (2007), Spekman and Sweeney (2006), Bassen et al. (2007), Sheng et al. (2008), Subramoniam and Sadi (2010), Panescu (2006), Chao et al. (2007), Hohberger et al. (2011), Kranzfelder et al. (2011), Van der Togt et al. (2011), Tzeng et al. (2008), Çakıcı et al. (2011), Ustundag et al. (2010), Bunduchi et al. (2011), Qu et al. (2011), Yao et al. (2011), Oztekin et al. (2010a,b), Tu et al. (2009), Bendavid and Boeck (2011), Meiller et al. (2011), Najera et al. (2011), John (2007), Ilie-Zudor et al. (2011), Reyes et al. (2011), Alemdar and Ersoy (2010), Regenbogen et al. (2009), Ian (2006), Oztekin et al. (2010a,b), Foster and Jaeger (2008), Bernstein et al. (2007), Enyinda and Tolliver (2009), Coustasse et al. (2010), Poston et al. (2006), Singh et al. (2008)

Table A1 (*Continued*)

Dimension	Number of papers	Percentage	References
Patient management	105	41.17	Wang et al. (2010), Jaska et al. (2010), Bose et al. (2009), Harrop (2007), Parkinson (2008), Zhou and Shi (2009a,b), Attaran (2006), Rhodes and Resnick (2005), Pei Ran et al. (2008), Roark and Miguel (2006a,b), Scheeres (2010), Yu-Lee et al. (2009), McGrady et al. (2010), Smith (2006), Sensmeier (2005), Wicks et al. (2006), Roark and Miguel (2006a,b), Crooker et al. (2009), Revere et al. (2010), Kumar et al. (2010), Coronato et al. (2009), Siegemund et al. (2005), Schiefen (2007, 2008), Barlow (2008a), Christianson (2008), Janz et al. (2005), Reiner and Sullivan (2005), Acharyulu (2007), Raviprakash et al. (2009), Carr et al. (2010), Perrin and McAndrew (2006), Williamson (2006), Fanberg (2004), Gibson (2009), Chen et al. (2010), Liu et al. (2011a,b), Chung-Chih et al. (2008), Shuenn-Yuh et al. (2010), Swartz et al. (2010), Shih et al. (2008), Yu et al. (2008), Ku et al. (2011), Booth et al. (2006), Degaspari (2011), Isella et al. (2011), Ting et al. (2011), Ngai et al. (2009a,b), Ju-Young et al. (2010), Biffi Gentili et al. (2010), Chen et al. (2008), Mehrjerdi (2011b), Bendavid et al. (2010), Bouet and Pujolle (2010), Censi et al. (2010), Nagy et al. (2006), Kumar et al. (2009), Al-Safadi and Al-Sulaiman (2011), Mehrjerdi (2010), Xiao et al. (2006), Schwaitzberg (2006), Chien et al. (2011), Barjis (2010), Li et al. (2006), Attaran (2007), Mehrjerdi (2011a), Spekman and Sweeney (2006), Mehrjerdi (2008), Fei et al. (2009), Sheng et al. (2008), Panescu (2006), Philipose et al. (2004), Cangialosi et al. (2007), Rodriguez et al. (2004), Yonglin et al. (2010), Nath et al. (2006), Pei-Hsuan et al. (2011), Occhiuzzi and Marrocco (2010), Chung-Chih et al. (2006), Chao et al. (2007), Peris-Lopez et al. (2011), Ohashi et al. (2010), Tzeng et al. (2008), Ustundag et al. (2010), Bunduchi et al. (2011), Huang et al. (2008), Yao et al. (2011), Liu et al. (2011a,b), Najera et al. (2011), John (2007), Ilie-Zudor et al. (2011), Reyes et al. (2011), Chang et al. (2011), Cresswell and Sheikh (2008), Alemdar and Ersoy (2010), Martí et al. (2009), Gibbs et al. (2007), Lippi and Plebani (2011), Ravera et al. (2004), Sau-Fun et al. (2011), Foster and Jaeger (2008), Gadzheva (2007), Niemeijer and Hertogh (2008), Smith (2009), Poston et al. (2006)

Table A1 (*Continued*)

Dimension	Number of papers	Percentage	References
Staff management	34	13.33	Murphy (2010), McGrady et al. (2010), Jeppsson (2011), Wicks et al. (2006), Roark and Miguel (2006a,b), Kumar et al. (2010), Coronato et al. (2009), Agarwal et al. (2007), Favela et al. (2007), Barlow (2005a, 2010), Perrin and McAndrew (2006), Francis et al. (2009), Booth et al. (2006), Ju-Young et al. (2010), Chen et al. (2008), Bendavid et al. (2010), Bouet and Pujolle (2010), Censi et al. (2010), Nagy et al. (2006), Al-Safadi and Al-Sulaiman (2011), Mehrjerdi (2010), Sheng et al. (2008), Panescu (2006), Corchado et al. (2008), Cangialosi et al. (2007), Chao et al. (2007), Fisher and Monahan (2008), Ohashi et al. (2010), Tzeng et al. (2008), Qu et al. (2011), Liu et al. (2011a,b), Zhou and Piramuthu (2010), Najera et al. (2011)
Total	255	100	

Table A2
RFID-enabled healthcare benefits.

Dimension	Number of papers	Percentage	References
	86	43.43	Wang et al. (2010), Forcinio (2007), Harrop (2007), Gupta (2010), Attaran (2006), Bissels and Chandler (2010), Pei Ran et al. (2008), Britton (2007), Roark and Miguel (2006a,b), Scheeres (2010), Smith (2006), Wicks et al. (2006), Thompson (2004), Roark and Miguel (2006a,b), Crooker et al. (2009), Lavine (2008), Revere et al. (2010), Kumar et al. (2010), Agarwal et al. (2007), Chen et al. (2011), Varshney (2007), Christianson (2008), Philippe and Beaulieu (2011), Janz et al. (2005), Endicott (2007), Kaufman (2007), Reiner and Sullivan (2005), Acharyulu (2007), Raviprakash et al. (2009), Perrin and McAndrew (2006), Barlow (2007b, 2009b, 2010), Gibson (2009), Chung-Chih et al. (2008), Francis et al. (2009), Booth et al. (2006), Degaspari (2011), Ting et al. (2011), Ngai et al. (2009a,b), Ju-Young et al. (2010), Biffi Gentili et al. (2010), Mehrjerdi (2011b), Bendavid et al. (2010), Bouet and Pujolle (2010), Ahlund (2005), Potyrailo et al. (2011), Al-Safadi and Al-Sulaiman (2011), Mehrjerdi (2010), Davis et al. (2009), Chien et al. (2011), Symonds and Parry (2008), Kwok et al. (2010), Mehrjerd (2010), Mehrjerdi (2011c), Attaran (2007), Hall et al. (2003), Panescu (2006), Corchado et al. (2008), Cangialosi et al. (2007), Rodriguez et al. (2004), Nath et al. (2006), Chung-Chih et al. (2006), Chao et al. (2007), Hohberger et al. (2011), Kranzfelder et al. (2011), Fisher and Monahan (2008), Van der Togt et al. (2011), Peris-Lopez et al. (2011), Ohashi et al. (2010), Tzeng et al. (2008), Çakıcı et al. (2011), Bunduchi et al. (2011), Oztekin et al. (2010a,b), Liu et al. (2011a,b), Bendavid and Boeck (2011), Meiller et al. (2011), Najera et al. (2011), Ilie-Zudor et al. (2011), Reyes et al. (2011), Alemdar and Ersoy (2010), Martí et al. (2009), Banavar et al. (2005), Enyinda and Tolliver (2009), Zhou and Shi (2009a,b), Singh et al. (2008)

Table A2 (*Continued*)

Dimension	Number of papers	Percentage	References
Quality gains	67	33.83	Wang et al. (2010), Bose et al. (2009), Pei Ran et al. (2008), Catarinucci et al. (2008), Roark and Miguel (2006a,b), Scheeres (2010), McGrady et al. (2010), Jeppsson (2011), Smith (2006), Sensmeier (2005), Wicks et al. (2006), Roark and Miguel (2006a,b), Crooker et al. (2009), Lavine (2008), Revere et al. (2010), Kumar et al. (2010), Coronato et al. (2009), Agarwal et al. (2007), Siegemund et al. (2005), Christianson (2008), Janz et al. (2005), Endicott (2007), Kaufman (2007), Reiner and Sullivan (2005), Acharyulu (2007), Raviprakash et al. (2009), Perrin and McAndrew (2006), Shuenn-Yuh et al. (2010), Swartz et al. (2010), Francis et al. (2009), Shih et al. (2008), Yu et al. (2008), Petro et al. (2009), Ku et al. (2011), Booth et al. (2006), Degaspari (2011), Ju-Young et al. (2010), Biffi Gentili et al. (2010), Mehrjerdi (2010, 2011b), Bendavid et al. (2010), Schwaitzberg (2006), Panescu (2006), Philipose et al. (2004), Cangialosi et al. (2007), Rodriguez et al. (2004), Chao et al. (2007), Hohberger et al. (2011), Kranzfelder et al. (2011), Fisher and Monahan (2008), Van der Togt et al. (2011), Peris-Lopez et al. (2011), Ohashi et al. (2010), Tzeng et al. (2008), Çakıcı et al. (2011), Bunduchi et al. (2011), Yao et al. (2011), Liu et al. (2011a,b), Zhou and Piramuthu (2010), Najera et al. (2011), Reyes et al. (2011), Martí et al. (2009), Gibbs et al. (2007), Zhou and Shi (2009a,b), Smith (2009), Coustasse et al. (2010), Singh et al. (2008)
Management gains	45	22.72	Wyld (2008a,b), Enyinda and Szmerekovsky (2008), Bissels and Chandler (2010), Smith (2006), Crooker et al. (2009), Kumar et al. (2010), Perrin and McAndrew (2006), Barlow (2009b), Neuwirth (2005), Francis et al. (2009), Booth et al. (2006), Ting et al. (2011), Ngai et al. (2009a,b), Ju-Young et al. (2010), Mehrjerdi (2010, 2011b), Carrasco and Jackson (2010), Bendavid et al. (2010), Bouet and Pujolle (2010), Ahlund (2005), Kumar et al. (2009), Al-Safadi and Al-Sulaiman (2011), Davis et al. (2009), Symonds and Parry (2008), Kwok et al. (2010), Mehrjerd (2010), Panescu (2006), Corchado et al. (2008), Cangialosi et al. (2007), Stantchev et al. (2008), Hohberger et al. (2011), Peris-Lopez et al. (2011), Tzeng et al. (2008), Çakıcı et al. (2011), Bunduchi et al. (2011), Oztekin et al. (2010a,b), Bendavid and Boeck (2011), Zhou and Piramuthu (2010), John (2007), Ilie-Zudor et al. (2011), Reyes et al. (2011), Oztekin et al. (2010a,b), Enyinda and Tolliver (2009), Coustasse et al. (2010), Singh et al. (2008)
Total	198	100	

Table A3
RFID-enabled healthcare issues.

Dimension	Number of papers	Percentage	References
Technological issues	97	39.27	Wang et al. (2010), Kapoor et al. (2009), Parkinson (2008), Zhou and Shi (2009a,b), Attaran (2006), Pei Ran et al. (2008), Catarinucci et al. (2008), Britton (2007), Yu-Lee et al. (2009), Smith (2006), Wicks et al. (2006), Thompson (2004), Crooker et al. (2009), Kumar et al. (2010), Coronato et al. (2009), Agarwal et al. (2007), Cao et al. (2011), Falck et al. (2007), Schiefen (2007), Schiefen (2008), Barlow (2004, 2005a, 2006b, 2007a, 2008a,b,c, 2009a,b, 2010), Janz et al. (2005), Endicott (2007), Reiner and Sullivan (2005), Acharyulu (2007), Raviprakash et al. (2009), Chen et al. (2010), Liu et al. (2011a,b), Chung-Chih et al. (2008), Shuenn-Yuh et al. (2010), Swartz et al. (2010), Yu et al. (2008), Lee and Shim (2007), Sani et al. (2010), Fiocchi et al. (2011), Ngai et al. (2009a,b), Ju-Young et al. (2010), Biffi Gentili et al. (2010), Pantchenko et al. (2011), Van Der Togt et al. (2008), Ogirala et al. (2011), Kozma et al. (2011), Erdem et al. (2009), Bendavid et al. (2010), Bouet and Pujolle (2010), Censi et al. (2010), Nagy et al. (2006), Ahlund (2005), Potyrailo et al. (2011), Mehrjerdi (2009, 2010), Ropponen et al. (2011), Wyld (2008a,b), Symonds and Parry (2008), Kwok et al. (2010), Han-Pang and Chih-Peng (2006), Li et al. (2006), Attaran (2007), Phunchongharn et al. (2010), Bassen et al. (2007), Fei et al. (2009), Sheng et al. (2008), Hall et al. (2003), Panescu (2006), Corchado et al. (2008), Cangialosi et al. (2007), Rodriguez et al. (2004), Marrocco (2007), Opasjumruskit et al. (2006), Pei-Hsuan et al. (2011), Occhiuzzi and Marrocco (2010), Chung-Chih et al. (2006), Kranzfelder et al. (2011), Fisher and Monahan (2008), Peris-Lopez et al. (2011), Ohashi et al. (2010), Huang et al. (2008), Liu et al. (2011a,b), Bendavid and Boeck (2011), Najera et al. (2011), Ilie-Zudor et al. (2011), Kapa et al. (2011), Ihmig et al. (2006), Alemdar and Ersoy (2010), Martí et al. (2009), Smith (2007), Zhou and Shi (2009a,b), Singh et al. (2008), Masters and Michael (2007)

Table A3 (*Continued*)

Dimension	Number of papers	Percentage	References
Data management, security and privacy issues	58	23.48	Yu-Lee et al. (2009), Smith (2006), Wicks et al. (2006), Crooker et al. (2009), Agarwal et al. (2007), Cao et al. (2011), Janz et al. (2005), Reiner and Sullivan (2005), Acharyulu (2007), Raviprakash et al. (2009), Chen et al. (2010), Chung-Chih et al. (2008), Shih et al. (2008), Yu et al. (2008), Ting et al. (2011), Kozma et al. (2011), Chen et al. (2008), Cannataci (2011), Bouet and Pujolle (2010), Nagy et al. (2006), Mehrjerdi (2010), Malasri and Lan (2009), Xiao et al. (2006), Chien et al. (2011), Kwok et al. (2010),Li et al. (2006), Fei et al. (2009), Sheng et al. (2008), Hall et al. (2003), Panescu (2006), Corchado et al. (2008), Yonglin et al. (2010), Chung-Chih et al. (2006), Katz and Rice (2009), Chao et al. (2007), Fisher and Monahan (2008), Van der Togt et al. (2011), Peris-Lopez et al. (2011), Ohashi et al. (2010), Çakıcı et al. (2011), Davis et al. (2011), Yao et al. (2011), Tu et al. (2009), Najera et al. (2011), John (2007), Reyes et al. (2011), Masters and Michael (2007), Halamka et al. (2006), Alemdar and Ersoy (2010), Chatterjee et al. (2009), Foster and Jaeger (2008), Smith (2007), Sharpe (2008), Gadzheva (2007), Niemeijer and Hertogh (2008), Smith (2009), Poston et al. (2006), Singh et al. (2008)

Table A3 (*Continued*)

Dimension	Number of papers	Percentage	References
Organizational and financing issues	92	37.24	Brading (2009), Wyld (2008a,b), Parkinson (2008), Kumar et al. (2008), Attaran (2006), Britton (2007), Smith (2006), Zalucki (2010), Wicks et al. (2006), Thompson (2004), Roark and Miguel (2006a,b), Crooker et al. (2009), Revere et al. (2010), Kumar et al. (2010), Schiefen (2007), Schiefen (2008), Barlow (2004, 2005a, 2006a,b,c,d, 2007a,b, 2008a,d,e, 2009a,b, 2010), Brooks (2010), Janz et al. (2005), Endicott (2007), Reiner and Sullivan (2005), Acharyulu (2007), Raviprakash et al. (2009), Carr et al. (2010), Liu et al. (2011a,b), Shuenn-Yuh et al. (2010), Francis et al. (2009), Yu et al. (2008), Ku et al. (2011), Degaspari (2011), Ting et al. (2011), Ju-Young et al. (2010), Chen et al. (2008), Carrasco and Jackson (2010), Bendavid et al. (2010), Nagy et al. (2006), Ahlund (2005), Kumar et al. (2009), Potyrailo et al. (2011), Mehrjerdi (2008, 2009, 2010, 2011a,c), Wyld (2008a,b), Schwaitzberg (2006), Davis et al. (2009), Kwok et al. (2010), Li et al. (2006), Attaran (2007), Spekman and Sweeney (2006), Panescu (2006), Chao et al. (2007), Hohberger et al. (2011), Kranzfelder et al. (2011), Fisher and Monahan (2008), Van der Togt et al. (2011), Peris-Lopez et al. (2011), Tzeng et al. (2008), Çakıcı et al. (2011), Ustundag et al. (2010), Bunduchi et al. (2011), Qu et al. (2011), Meiller et al. (2011), John (2007), Ilie-Zudor et al. (2011), Fiocchi et al. (2011), Reyes et al. (2011), Masters and Michael (2007), Temponi et al. (2009), Oztekin et al. (2010a,b), Smith (2007), Sharpe (2008), Gadzheva (2007), Niemeijer and Hertogh (2008), Enyinda and Tolliver (2009), Coustasse et al. (2010), Singh et al. (2008)
Total	247	100	

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