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# Unveiling the potential of RFID-enabled intelligent patient management : results of a Delphi study

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**Abstract**

Information technology (IT) in general, and radio frequency identification (RFID) technology in particular, are considered as key enablers of healthcare sector transformation in terms of better quality of care, improved patient management, and increased healthcare efficiency and effectiveness. There is, however, a shortage of studies on the impact of RFID technology on patient management-related processes. This study intends to fill this knowledge gap in literature by unveiling the potential of RFID-enabled intelligent patient management. Twelve patient management-related processes are identified, followed by the assessment of the impact of RFID on the said processes by a panel of experts using a three-round Delphi study. The study identifies the top five processes that may benefit from RFID technology as follows: (1) accurate patient identification for medication safety; (2) patient identification to avoid wrong drug dosage; (3) accurate patient identification; (4) infant identification in hospitals to avoid mismatching; and (5) tracking of drug supplies and procedures performed on each patient. Furthermore, the evaluation of standard deviation variation shows a high convergence of consensus among the members of the panel with regard to nine of the twelve processes. Finally, the paper discusses future research directions.

**Keywords**

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# Unveiling the Potential of RFID-enabled Intelligent Patient Management: Results of a Delphi Study

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## Abstract

*Information technology (IT) in general, and radio frequency identification (RFID) technology in particular, are considered as key enablers of healthcare sector transformation in terms of better quality of care, improved patient management, and increased healthcare efficiency and effectiveness. There is, however, a shortage of studies on the impact of RFID technology on patient management-related processes. This study intends to fill this knowledge gap in literature by unveiling the potential of RFID-enabled intelligent patient management. Twelve patient management-related processes are identified, followed by the assessment of the impact of RFID on the said processes by a panel of experts using a three-round Delphi study. The study identifies the top five processes that may benefit from RFID technology as follows: (1) accurate patient identification for medication safety; (2) patient identification to avoid wrong drug dosage; (3) accurate patient identification; (4) infant identification in hospitals to avoid mismatching; and (5) tracking of drug supplies and procedures performed on each patient. Furthermore, the evaluation of standard deviation variation shows a high convergence of consensus among the members of the panel with regard to nine of the twelve processes. Finally, the paper discusses future research directions.*

## 1. Introduction

The healthcare sector is facing tremendous challenges across the globe, including high operating costs, poor management of patient-related information, ageing patient population, increased mobility of patients, and high requirements from citizens for better quality care. For example, U.S. healthcare expenses, estimated at 5% of the country's gross national product (GNP) in 1963 [1], will account for about 17% of the GNP in 2011 [2] and will increase to approximately 20% by 2017 [3]. Likewise, despite the consensus that the U.S. healthcare system, from the technological and scientific standpoint, is among the most advanced in the world, the system still relies on error-prone methods (e.g., manual data collection, paper-based healthcare) to provide essential healthcare services to its population [4, 5]. Paper-based healthcare does not integrate well with electronic healthcare, has limited decision support capabilities, and more importantly, has "lots of information but no data" [1]. For example, analysts estimated that almost 90% of the 30 billion annual healthcare transactions in the US are still realized through human-related activities, which involve error-prone tools such as fax, mail, or phone [1]. In such context, information technology (IT) has been acclaimed as a key enabler of healthcare transformation [6], especially through improvements in patient management, service quality, operational efficiency, patient satisfaction, and patient care (p. 446) [7]. Indeed, the adoption of healthcare information systems by key U.S. healthcare stakeholders could help save about $150 billion of healthcare expenses [1]. More recently, radio frequency identification (RFID) technology, a wireless automatic identification and data capture (AIDC) technology [8], has emerged as a new class of IT that will further the transformation of the healthcare sector in general [9] and patient management in particular. Despite such claims, very few empirical studies have provided support for the enabling role of RFID technology in improving patient management. This study intends to bridge this knowledge gap by unveiling the potential of RFID-enabled intelligent patient management. More specifically, this study draws on the current research agenda on RFID technology [10] to examine the following research questions:

1. What is the impact of RFID technology on patient management-related processes in the healthcare sector?
2. What are the top-ranked patient management-related processes associated with the adoption of RFID technology in the healthcare sector?

In order to address these research questions, this paper draws on a review of IT potential and key challenges related to patients management, as well as on a Web-based Delphi study. The rest of this paper is structured as follows: Section 2 presents IT potential and key challenges related to patients management. Section 3 describes our research methodology. Section 4 presents the results and discussion while Section 5 deals with our conclusion and future research directions.

## 2. IT potential and key challenges related to patients management

For [11], "one of the primary motivators for adopting many clinical health IT applications is the belief that they improve the quality of patient care" (p. 160). Indeed, IT is recognized as the key solution to patient management-related problems, including medication order errors, errors related to adverse drug effects, patient medication mismatches, medication dosage errors, high error rates related to the administration of medications and procedures, and low adherence to evidence-based protocols [9, 12-14] [7]. Menachemi and Brooks (2006) [15] even suggested that the adoption and use of IT in the healthcare sector is "a critical goal of a 21st-century healthcare system" (p. 79). Without a doubt, IT can be used not only to prevent or reduce the medical problems identified above, but also to track blood bags and monitor drug allergies [16], access patient records and transactions [17], and improve healthcare decision making and healthcare resources allocation [18]. Electronic health records (EHRs), for example, can be used to store and automate medical records, thus facilitating the design and storage of patient-related decision functions such as individualized patient reminders and prescribing alerts [11] (p. 159), and offering the opportunity to integrate patient information for better care quality and efficiency [18]. Bar coding, another AIDC technology, can be used to capture and manage patient-related medication information, track patient laboratory and radiology results, and track and trace blood bags [11]. Recently, however, RFID technology has emerged as a new wave of IT that may radically transform the healthcare sector [9, 19] by allowing better patient identification [20], providing a better way of tracking and tracing the identity of patients within healthcare facilities [21], and reducing errors in patient care [22], as well as enabling better management of the various steps in the blood transfusion process [23], innovative management of patients with chronic conditions [16, 24], a better way of checking, tracking, and tracing pharmaceutical products origin, and the management of incident audit trail between medical equipment and healthcare staff [25]. Indeed, RFID technology offers greater capabilities when compared to traditional AIDC (e.g., bar coding); this technology does not need line of sight and possesses unique item-level identification, multiple tag item reading, better data storage capability, and data read-and-write capabilities.

Nevertheless, despite the high potential of RFID technology, very few empirical studies have been conducted to assess the potential of this technology as an enabler of intelligent patient management. In a review of academic literature on RFID technology [26], Ngai et al. (2008) found that the vast majority of peer-reviewed papers on RFID technology were mostly concerned with the retail sector. Therefore, this paper is an initial attempt to bridge the existing knowledge gap in literature. More precisely, we follow the recommendations that the discussion on RFID technology adoption should be conducted within a specific business domain [27]. Since the business impact of the applicability of RFID technology is influenced by its environment, the impact of RFID technology on patient management-related processes in the healthcare sector can be assessed and the relative importance of this impact evaluated.

## 3. Methodology

The main objective of this study is to explore the impact of RFID technology on patient management-related processes and to assess the relative importance of such impact. Therefore, a Web-based Delphi methodology is selected because previous studies have shown its relevance in achieving similar objectives [28-32].

### 3.1. Research design

The Delphi technique was initially proposed, developed, and used at Rand Corporation [28] as an interactive methodology to gain consensus from a group of experts [29]. Since then, many variations of the technique have been used by authors from various fields of research, including IT [29-32], operational research [29, 33], and the healthcare sector [34, 35]. The Delphi technique is considered as "a method for structuring a group communication process so that the process is effective in allowing a group of individuals, as a whole, to deal with a complex problem" (p. 3) [36]. The technique allows a methodical analysis of the inputs of selected experts on a particular subject matter through multiple iterations; it is highly suitable for cases in which limited historical data are available. The Delphi technique also offers anonymity to all participants, controlled information flow through the project leader, multiple feedback loops, and an equilibrium distribution (p. 291) [28]. Finally, the

Delphi method is well suited to this study because it "lends itself especially well to exploratory theory building on complex, interdisciplinary issues (e.g., adoption of RFID technology in the healthcare sector)" (p. 446) [37].

For the purpose of this study, a list of processes was generated from a review of academic papers dealing with the topic, together with white papers, industry reports, as well as clear insight into numerous discussions with experienced academics and practitioners. To confirm the validity of the processes and their definitions, a pilot testing of the questionnaire was performed by a post-doctorate student from Canada, a professor from Germany, two professors from Australia, and one professor from Brazil, all working on RFID technology. In addition, 12 processes related to patient management were retained (Table 2). Finally, a five-level Likert item (1=strongly agree, 2=agree, 3=neutral, 4=disagree, and 5=strongly disagree) was used to assess the impact of RFID technology on the said processes.

### 3.2. Panel selection and data collection

All panel members involved in the Delphi study have outstanding experience in RFID technology projects and/or have published at least a scientific paper on RFID technology (Table 1). They were recruited through an aggregate list of authors who submitted papers for various special issues on RFID technology within the framework of different international conferences, academic journals, and so on. From this list, a random sample of 85 panelists was selected, and in January 2010, each panelist was invited via email to participate in the Delphi study. Explanations were also provided concerning the research objective, the estimated time to carry out the survey, the estimated number of rounds for the Delphi study, and the link to the Web-based questionnaire. The use of a Web-based questionnaire saves time in data collection and considerably reduces missing values while maintaining a response rate similar to traditional paper-based instruments [30, 38]. The collection of data encompasses a three-round process. For the first round, out of the 85 invitations emails sent, 61 panelists agreed to participate. After the analysis of the responses, 41 were identified as correctly filled out and suitable for analysis, yielding a response rate of 67.21%. In the second round, one participant who was absent in the first round expressed his willingness to participate, which increased the total number of respondents to 42. During the third round, 28 panelists participated in the study.

## 4. Results and discussion

A breakdown of panel members by level of education shows that 71.4% of the respondents hold a doctorate degree, followed by 14.3% with a master's degree, 7.1% with an M.B.A. degree, and 4.8% with a bachelor's degree (Table 1). By the level of business association, the review of data shows that 75.6% of respondents are from the academe, followed by 9.8% from the healthcare sector, and 2.4% from healthcare services provider, research, government, academia & consulting, consulting and media (Table 1).

Regarding the level of knowledge on RFID technology, 57.1% of the respondents claimed to have "good knowledge about RFID technology," while 28.6% claimed to be an "RFID technology expert," and 14.3% stated they had "some knowledge about RFID technology." Overall, more than 85% of the respondents had good knowledge of RFID technology (Table 1).

Table 2 provides a snapshot of the impact of RFID technology on the 12 patient management-related processes sorted in the order of importance by the mean. The first main observation is that for the two rounds of the Delphi study, all means of the 12 patient management-related processes are less than 1.800, suggesting that all our panel members either "strongly agree" or "agree" to our processes. Likewise, our panel of experts identifies the top five processes that may benefit from RFID technology as follows:

1) accurate patient identification for medication safety;
2) patient identification to avoid wrong drug dosage;
3) accurate patient identification;
4) infant identification in hospitals to avoid mismatching; and
5) tracking of drug supplies and procedures performed on each patient.

Meanwhile, the process that occupies the last position of the ranking is: "tracking of patient location".

To assess the level of consensus between the panel members, variations in their responses were measured using standard deviation variations [28]. Regarding the standard deviation, "the lower the standard deviation is, the higher is the consensus achieved. Thus perfect consensus on an issue has a standard-deviation value of zero" (p. 424) [28]. Moreover, the reduction of standard deviation across the Delphi process shows a high level of consensus among the panel members [28].

In Table 2, the 'rank' column presents the ranking of all twelve processes sorted in descending order, from the most important process to the least important process, based on the mean ranking of the second round of the Delphi study. The 'process ID' column indicates the identification of the process used to explore the standard variation, while the 'process name' column provides the process definitions. The 'mean' and 'SD' columns represent the means and standard deviations of the process, respectively, for each round. Finally, the column named 'SD variation' shows the differences in standard deviations between the two rounds. Figure 1 and the last column of Table 2 indicate a high convergence of consensus among the panel members with regard to nine of the twelve processes (negative standard deviation variation).

Even if "infant identification in hospitals to avoid mismatching" is ranked as the fourth process that may profit from RFID technology, the process fails to achieve a high consensus level in the second round. A small increase in its standard deviation was noticed in the second round, which is the same case for the processes "infant tracking and tracing hospitals for security to avoid theft" (ranked 10) and "intelligent medication monitoring for elderly at home" (ranked 11). Finally, the process "tracking of drug supplies and procedures performed on each patient" (ranked 5) had the same standard deviation for the two rounds.

**Table 1 Breakdown of panel members by the level of education, business association and the level of knowledge of RFID technology based on round 2**

| Demographic categories | Frequency | Percentage |
|---|---|---|
| *Level of education* | | |
| Doctorate degree | 30 | 71.4 |
| Master's degree | 6 | 14.3 |
| M.B.A degree | 3 | 7.1 |
| Bachelor's degree | 2 | 4.8 |
| Others | 1 | 2.4 |
| Total | 42 | 100 |
| *Business association* | | |
| Academia | 31 | 75.6 |
| Consulting | 1 | 2.4 |
| Healthcare | 4 | 9.8 |
| Healthcare services provider | 1 | 2.4 |
| Research | 1 | 2.4 |
| Government | 1 | 2.4 |
| Academia & consulting | 1 | 2.4 |
| media | 1 | 2.4 |
| Total | 41 | 100 |
| *Level of knowledge of RFID technology* | | |
| I am an RFID technology expert | 12 | 28.6 |
| I have a good knowledge of RFID technology | 24 | 57.1 |
| I have some knowledge of RFID technology | 6 | 14.3 |
| Total | 42 | 100 |

**Table 2: Ranking of processes related to intelligent patient management by importance**

| | | | Round 1 (n=41) | | Round 2 (n=42) | | SD variation |
|---|---|---|---|---|---|---|---|
| Rank | Process ID | Process name | Mean | SD | Mean | SD | |
| 1 | Process 01 | Accurate patient identification for medication safety | 1.340 | 0.480 | 1.330 | 0.477 | -0.003 |
| 2 | Process 02 | Patient identification to avoid wrong drug dosage | 1.390 | 0.542 | 1.380 | 0.539 | -0.003 |
| 3 | Process 03 | Accurate patient identification | 1.540 | 0.596 | 1.500 | 0.595 | -0.001 |
| 4 | Process 04 | Infant identification hospitals to avoid mismatching | 1.490 | 0.597 | 1.520 | 0.707 | 0.110 |
| 5 | Process 05 | Tracking of drug supplies and procedures performed on each patient | 1.540 | 0.552 | 1.520 | 0.552 | 0.000 |
| 6 | Process 06 | Patient identification for blood transfusion | 1.590 | 0.741 | 1.570 | 0.737 | -0.004 |
| 7 | Process 07 | Eliminate wrong patient wrong procedure surgery | 1.590 | 0.774 | 1.600 | 0.767 | -0.007 |
| 8 | Process 08 | Patient tracking and tracing hospitals for monitoring patient flow | 1.630 | 0.829 | 1.620 | 0.825 | -0.004 |
| 9 | Process 09 | Critical information to the patient | 1.710 | 0.750 | 1.690 | 0.749 | -0.001 |
| 10 | Process 10 | Infant tracking and tracing hospitals for security to forgo theft | 1.710 | 0.901 | 1.740 | 0.964 | 0.063 |
| 11 | Process 11 | Intelligent medication monitoring for the elderly at home | 1.710 | 0.782 | 1.740 | 0.798 | 0.016 |
| 12 | Process 12 | Tracking of patient location | 1.800 | 0.954 | 1.790 | 0.951 | -0.003 |

1 = Strongly Agree; 5 = Strongly Disagree

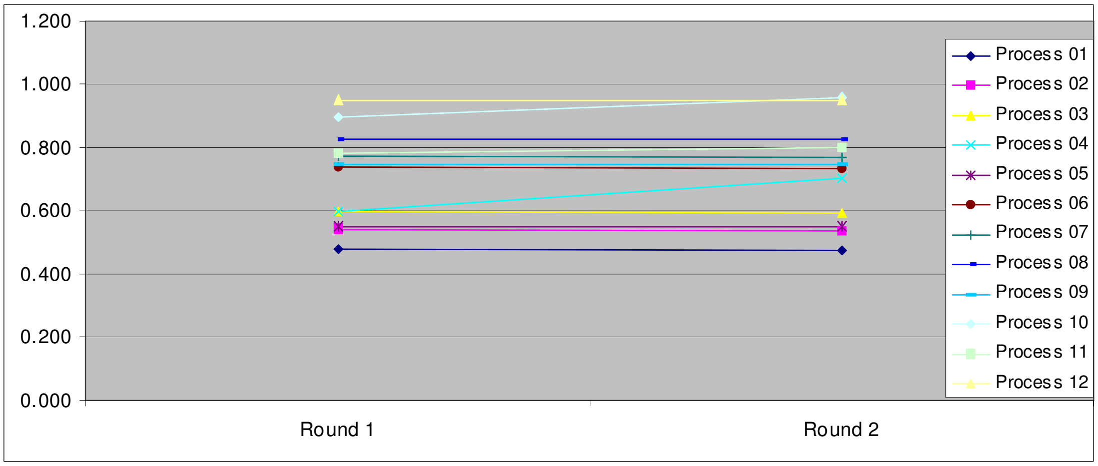


**Figure 1: Assessing the consensus on key processes using standard deviation**

## 5. Conclusion and future research directions

In this paper, we presented the impact of RFID technology on 12 patient management-related processes in the healthcare sector, as well as the rankings of RFID-enabled patient management-related processes. First, the mean of 12 identified patient management-related processes are less than 1.800, suggesting that all our panel members either "strongly agree" or "agree" to our processes. Furthermore, the panel of experts identified the top five processes that may benefit from RFID technology as follows:

a) accurate patient identification for medication safety;
b) patient identification to avoid wrong drug dosage;
c) accurate patient identification;
d) infant identification in hospitals to avoid mismatching; and
e) tracking of drug supplies and procedures performed on each patient.

Meanwhile, the process that occupies the last position of the ranking is: "tracking of patient location".

The variation of standard deviation was also used to assess the consensus among the panel members, therefore identifying a high convergence of consensus among the said members concerning nine of the twelve processes (negative standard deviation variation). For the remaining three processes, we noticed a small increase for two of them and a stable value for one in the second round. In terms of contributions, not only does this study offer a starting point for researchers when assessing the impact of RFID technology on patient management, but the list of processes used in this study can likewise serve as a comprehensive checklist for healthcare managers during the decision process of adopting RFID technology as an enabler of patient management. In addition, future research directions following three main dimensions, namely the technological, individual, organizational and inter-organizational levels, are proposed in the following sections.

### 5.1. Technological level

Regarding research opportunities at the technological level of RFID-enabled patient management in particular, and RFID-enabled healthcare in general, exploring the best RFID-enabled healthcare architecture should be included in future research. For example, the data on the network architecture based on the use of the Electronic Product Code (EPC) and related components of the EPC network architecture proposed by the EPCglobal (e.g., EPC information service, object name service) may allow the access and retrieval of all information of RFID-enabled patient management applications through a centralized database, while the data on tag architecture can allow each patient to carry a RFID-enabled mobile database (e.g., e-RFID-card) where all healthcare information is stored [39]. Each of these architectures has a set of strengths and weaknesses (e.g., cost, security); therefore, it would be interesting to explore (i) how these two architectures can support healthcare applications, and (ii) how a more robust, secure and cost-effective hybrid RFID-enabled healthcare architecture can be developed using concepts from these two dominant architectures.

What is the best strategy for the evaluation and selection of the optimal RFID architecture that will support RFID-enabled healthcare applications within one healthcare facility? Should be also included in future research. Moreover, future studies should explore strategies to ensure the reliability of all components of RFID-enabled healthcare applications at any time and anywhere. For example, Najera et al. (2010) [23] found that for RFID tags that are accidentally covered by a nurse's hand, the reading distance can drop from 5-8 m to less than 1m with unreliable reading accuracy, even if we are using high performance RFID tags and RFID readers (p. 6). Therefore, it becomes very important to look at the best strategy to integrate contextual factors when selecting the optimal RFID-enabled healthcare applications. Finally, the exploration of key technological enablers and inhibitors of RFID-enabled patient management in particular, and of RFID-enabled healthcare in general, should also be included in future research.

## 5.2. Individual level (e.g., patients, nurses, doctors)

Many future research opportunities on RFID-enabled patient management in particular and RFID-enabled healthcare in general at the individual level (e.g., patients, nurses, doctors) are identified. For example, privacy and security issues are considered being among key inhibitors of RFID-enabled patient management applications in particular and RFID-enabled healthcare applications in general [24]. Therefore, future research needs to address these issues. Another interesting question for future research is: what will be the cost and benefit of RFID-enabled patient management applications for each key individual stakeholder (e.g., patients, nurses, doctors)?

Regarding the acceptance of RFID-enabled patient management applications and healthcare applications, it would be useful to investigate to what extend we can use the current dominant theoretical models (e.g., diffusion of innovation, technology acceptance model) to study the user acceptance of these applications. Exploring how RFID-enabled patient management applications and healthcare applications will change the relationship between key players within the healthcare (e.g., between patients-nurses, nurses-doctors, patients-doctors) on the one hand, and contribute to reduce patient-related transaction costs on the other hand, should also be included in future research, as well as the impact on work practices.

## 5.3. Organizational and inter-organizational levels

In line with the observations made by LeRouge et al. (2007)[40] that "the healthcare context provides high levels of complexity and nuance that can support information systems (IS) theory extension and innovation" (p. 670), we believe that future research needs to explore the organizational factors that may have an impact on the adoption and use of RFID-enabled patient management applications, as well as the full benefit realization of RFID-enabled patient management applications. Also, more studies need to look at the best way to link RFID-enabled patient management processes with other intra- and inter-organizational healthcare processes in order to provide enhanced healthcare services and increase the network externalities of RFID technology within the healthcare sector. Also, further research needs to investigate to what extend current IS theories are useful to explore these factors.

In addition to investigating issues related to the integration of RFID-enabled patient management applications with existing intra- and inter-organizational healthcare information systems, future research needs to be carried out on the level of business process change needed to achieve the high level of business value from RFID-enabled patient management applications, as well as to explore the best methodology to measure the business value of RFID-enabled patient management applications. Indeed, prior studies on interorganizational systems (IOS) such as electronic data interchange (EDI) adoption and use [41] and, more recently, RFID adoption and use [42] show a positive link between the level of business process transformation and the use of IOS and the level of business value realized from IOS [42]. Also, future research should look at the impact of factors such as RFID adoption incentives, RFID adoption mandate and organizational readiness on the level of business value realized from RFID-enabled healthcare applications. For example, Riggins and Mukhopadhyay (1994)[41], in their study on EDI adoption in the electronic and automotive industries, concluded among others things that if "the incentives for a suppliers to make these changes to their internal systems and processes seem quite low, suppliers will be hesitant to invest in these changes, thereby limiting the benefit buyers may receive from these interorganizational systems", while "by mandating how their trading partners use the technology internally, these buyers stand to reap the full benefits of the technology while continuing to develop strong long-term relationships with those suppliers who are willing to proceed with the internal upgrading of their systems" (p. 53). More recently, Fosso Wamba and Chatfield (2009) [42], when exploring contingency factors influencing value creation from RFID technology in logistics and manufacturing environments, found that environmental upheaval, leadership, second-order organizational learning, resources commitment, and organizational transformation were the key five factors that may explicate the full business benefits realized from RFID technology (p. 615). Therefore, it will be interesting to explore to what extend the observations made by Riggins and Mukhopadhyay (1994)[41], and Fosso Wamba and Chatfield (2009) [42], are valid in the healthcare context.

One of the premises of RFID-enabled intra- and inter-organizational transformation is the capacity of the technology to allow improved decision making. Consequently, exploring the impact of RFID-enabled patient management applications on the intra- and inter-organizational decision making in the healthcare context should also be included in future research.

Additionally, in many developing countries, healthcare environment is characterized by an increased mobility of patients and the dispersion of "patient care among an array of medical subspecialists, physical and occupational therapists, and social workers -all of whom work at different sites" (p. 64) [43], which increases the complexity of the management of patient healthcare records; as a result, it would be useful to develop methods, tools or strategies to ensure the interoperability of RFID-enabled patient management in particular, and RFID-enabled healthcare in general (e.g., between different departments of one hospital, between many hospitals of a state and between hospitals of countries).

In her study of RFID applications for integrating and informationalizing the supply chain of foodservice operators, Sigala (2007) [44] found that the development and staff training and acceptance of new management practices were among the key factors that may inhibit RFID adoption and use (p. 23); therefore, we support her findings and believe that future research on RFID-enabled patient management in particular, and on RFID-enabled healthcare in general, needs to explore mechanisms to better train staff and to better manage the transition toward the RFID-enabled practices.

Finally, future research should look at how RFID-enabled healthcare can contribute to the realization of the observation made by Lee (2010) [45], that is, "individual clinicians and hospitals have limited control over the fate of their patients. At any organization that provides health care, superior coordination, information sharing, and teamwork across disciplines are required if value and outcomes are to improve" (p. 52).

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