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TECHNICAL REPORT

Study on the requirements and options for RFID application in healthcare

Identifying areas for Radio Frequency Identification deployment in healthcare delivery: A review of relevant literature

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Preface

This document is the first deliverable of the RFID & Health project. It provides an overview of the state of the art in RFID (Radio Frequency Identification) applications in healthcare delivery.

Some 325 sources have been reviewed in order to draft three 'long-lists' of applications, enablers and barriers of RFID deployment. In the next phase of the project, these will be validated and prioritised through expert interviews and a Delphi survey. Case studies will be used to further assess the costs and benefits of the most promising applications.

The list of sources which have been reviewed for this report is believed to cover all important scientific publications, policy documents and relevant articles from the professional press, in Europe, North America and Asia, related to the topic of RFID applications in healthcare. In addition, more general literature on RFID – technology, market, enablers and barriers – has also been covered.

Primarily, the report provides a basis for the rest of the study. As a stand-alone document it gives the reader an overview of all relevant issues related to RFID deployment in healthcare delivery. The line is deliberately drawn not to include the pharmaceutical industry, counterfeiting of drugs and tracking of medical devices as they move through the supply chain. This study is primarily focused on the delivery of patient care, mostly within the context of the hospital, but also including telemedicine applications.

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Executive Summary

This Report presents the findings of the first phase of a study to identify the policy options that can assist the development and applications of RFID in the delivery of safe and high quality care. The objectives of this first phase - the foundation upon which the rest of the study will be built on - were:

- first, to identify and discuss the most relevant areas for deployment and use of RFID in healthcare
- second, to shed light on the most important enablers, obstacles and uncertainties that have the potential to influence RFID use in healthcare applications
- finally, to include a discussion of other alternatives to RFID technologies.

A thorough, systematic review of all relevant literature was conducted to generate a comprehensive overview of the existing information. Peer-review literature and 'grey' literature, including various organisations' reports, presentation material and commercial publications, were identified and searched. An electronic database was created to record the findings. Data were abstracted and recorded in a specially created summary template, then summarised and analysed. We categorised the findings according to RFID-enabling function (tracking, identification and authentication, automatic data collection and transfer, and sensing) and subject (staff, patients, assets and clinical trials). The database included 325 items.

Overall, findings indicate that tracking is the **key RFID enabling function** used when the technology is applied to staff and assets; when applied to patients, then the key objective is identification and authentication; when used in clinical trials, RFID's primary function is automatic data collection and transfer. Automatic data collection and transfer is an RFID function also frequently used in relation to assets, staff and patients. Finally, RFID is employed for sensing, most often in relation to patients, but also to assets.

The analysis identified five categories of **enablers for the further dissemination of RFID in healthcare.**

1. RFID's capacity to enable better healthcare delivery
2. The clear business case for certain RFID applications
3. The use of sound implementation approaches
4. The technological superiority of RFID applications
5. The existence of government incentives/support for healthcare RFID

Similarly, the identified **barriers and obstacles** to RFID's wider-scale implementation are also classified into five categories.

1. Direct RFID costs
2. Privacy, security, data integrity and legal issues
3. Technical issues
4. Operational/ managerial challenges
5. Cultural and ethical concerns

Our review of the literature indicates that there are four RFID functional domains in which RFID can be supplemented or complemented by **other technologies**:

i) object/person identification
ii) data transfer from RFID tags to other tags/ the environment/ back-office applications
iii) sensing/ telemetry/ diagnosis
iv) integrating health-information infrastructures.

With respect to the first two functions, the relationship between RFID and the individual technologies performing these functions can be both complementary and substitutive. The relationship between RFID and the technologies performing the latter two functions, however, is clearly complementary (both by the judgment of the reviewed sources and by the complimentary natures of the technologies).

Overall, our structured literature search and analysis revealed that not only does a large functional range of RFID applications in healthcare exist, but applications, trials and pilots evaluating these applications are already emerging.

Contents

List of Tables

List of Figures

CHAPTER 1 Scope and objectives

1.1 Objectives and scope of this report

The objective of this report is to provide a solid basis for the full study of the large-scale, effective, and secure implementation of RFID and similar technologies in healthcare delivery. To this effect, the report sets out to deliver three lists in which it identifies and discusses:

1. the most relevant areas for the deployment and use of specific types of RFID in healthcare
2. the most important enablers for the use of RFID in healthcare applications
3. the most important obstacles and critical uncertainties to the use of RFID in healthcare applications.

In addition, the report presents a selection of relevant trials, experiments and other ongoing RFID applications and discusses how RFID compares with alternative technologies.

The scope of the report is clearly defined by the Inception Report and the tender specifications, and can be summarised as follows:

- The main emphasis will be on the delivery of care and, within this, on patient safety and quality of care.
- This explicitly includes telemedicine and intelligent, forward-looking applications (e.g. intelligent pillbox) as well as applications serving the needs of an ageing society (e.g. homecare environment applications).
- The pharmaceutical or medical devices supply chain is explicitly excluded in this review, but instances will be noted where the delivery of care has an upward vertical effect on these supply chains.
- Priority should be given to RFID, but alternative solutions must also be taken into account.
- The open-ended character of the study implies that it should inform policy making, not make policy.

– It may, however, recommend policy actions and interventions such as research topics, as well as areas for regulation, stimulation, support and control.

1.2 Broader context of the study

This report, containing a thorough review of all relevant publications, will provide the basis for the next phases of this study. The overall aim is to establish what policy options the inter-service steering committee (COM) has to affect positively the current and future development and application of RFID and similar technologies in healthcare.

To establish these, the next phase of the project will be to prioritise the applications, and understand the key drivers and barriers, as well as critical uncertainties for RFID deployment. This will be achieved through a Delphi survey of a selected group of diverse stakeholders. The most promising applications will be assessed further in case studies, to determine their costs and benefits. This will be complemented by a more general assessment of the economic impacts of RFID deployment in healthcare.

A number of scenarios will be developed on the basis of the literature review, the case studies and complementary key informant interviews. These will allow qualified statements to be made on the policy interventions needed to achieve future results.

These will finally lead to recommendations to the COM.

CHAPTER 2 Methodology: A systematic literature review

This chapter presents our approach to identifying the most relevant literature on RFID applications in healthcare, including peer-reviewed, 'grey' and 'white' papers, as well as the review process we adopted for the identified materials. The chapter then explains the RFID application classification approach we chose to use throughout the report and how we arrived at it.

2.1 RFID literature search

This literature review provides the foundation upon which the rest of the analysis will be based. It involves a thorough, systematic review of the existing literature of RFID uses in healthcare delivery.

2.1.1 Literature flow

We conducted a systematic review of literature relating to RFID and healthcare, following several steps, in order to generate a comprehensive overview of the existing literature on the topic. Strict selection criteria were applied, as the literature regarding RFID is extensive across a wide range of applications.

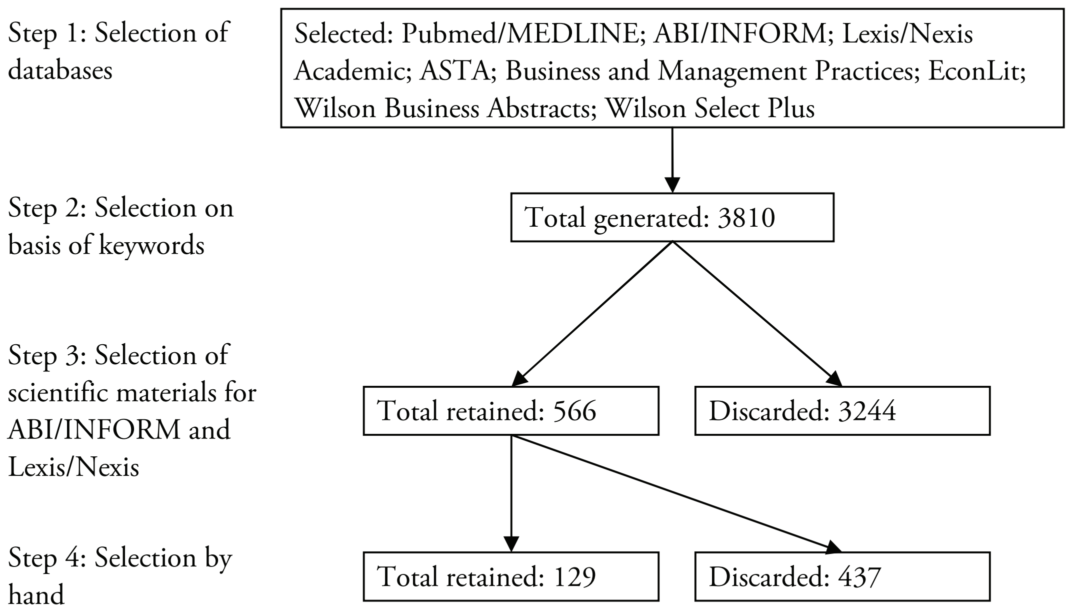
The first step of the review consisted of the selection of appropriate databases, which included the following:

- Pubmed/MEDLINE
- ABI/INFORM
- Lexis/Nexis Academic
- Applied Science and Technology Abstracts (ASTA)
- Business and Management Practices (from OCLC/Firstsearch)
- EconLit (from OCLC/Firstsearch)
- Wilson Business Abstracts (from OCLC/Firstsearch)
- Wilson Select Plus (from OCLC/Firstsearch)

To identify relevant articles, we pursued two approaches:

1. In the case of PubMed, due to its medical orientation, all articles filtered by 'RFID' or 'Radio Frequency Identification' were selected for hand review.
2. All other databases were searched according to the following search terms and keywords: (RFID OR 'Radio Frequency Identification') AND (healthcare OR medicine OR medical OR pharmaceutical OR surgery OR patient OR hospital).

The automatic results that were generated by these filters were then narrowed down by selecting only scientific materials or scholarly journals, in order to omit any irrelevant articles or information. For example, only the 'Scholarly Journals' from all ABI/INFORM articles[1] were retained, and only the category of 'Scientific Materials' in the case of Lexis/Nexis Academic[2]. Finally, all thus-generated automatic results underwent hand screening to identify the most relevant sources. The entire procedure resulted in a selection of 566 peer-reviewed articles to be examined. A schematic overview of the review is provided in Figure 1 below.



Source: RAND Europe

Figure 1: Assessment of literature sources

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[1] From among the following categories 'All sources'; Scholarly Journals; Magazines; Trade Publications; Newspapers; and Reference/ Reports.

[2] From the total list of categories provided, consisting of 'All Results'; Newspapers; Industry Trade Press; Magazines & Journals; Newsletters; Scientific Materials; Aggregate News Sources; Newswires & Press Releases; Web-based Publications; News Transcripts; Legal News and Unclassified Documents.

The majority (75) of the 129 retained peer-reviewed articles were retrieved through PubMed, followed by the two Wilson databases (23), ABI/INFORM (15), Lexis/Nexis (7), ASTA (5), and Business and Management Practices (4).

2.1.2 *RFID Journal* search

The *RFID Journal* is an online journal providing daily updates on RFID applications and uses from around the world. To systematically identify articles relevant to the study, the journal was searched for health applications since 2005 in the following countries: Germany, Italy, the Netherlands, the United Kingdom and Sweden. The choice of which countries to focus on was driven by two objectives:

i) to assess RFID applications in a wide variety of healthcare systems, ranging from full national health systems (UK and Sweden), to systems with a strong corporatist nature (Germany) and systems that have recently introduced more market-oriented elements (The Netherlands)

ii) ii) to focus on countries already experimenting with a variety of RFID applications.

Using the search feature of the website, all articles for Italy, the Netherlands and Sweden were generated, after which the articles relating to health were handpicked from the entire selection. Due to the substantive amount of articles generated for Germany and the UK, a more elaborate search strategy was employed to select health-related articles for these countries. Again, using the search feature of the website, seven lists of articles were generated for each country using the following search terms:

- "Country" AND Health
- "Country" AND Healthcare
- "Country" AND Hospital
- "Country" AND Pharmaceutical
- "Country" AND Medical
- "Country" AND Medicine
- "Country" AND Patient.

From the lists of articles generated, 144 relevant articles were handpicked to come to the final selection.

2.1.3 Other sources

In addition, we used key informants and searched the World Wide Web to obtain additional 'grey' literature, including industry and commercial reports, slide presentations and other documents. We drew on publications by The Institute for Prospective Technological Studies (IPTS), the National Committee on Vital and Health Statistics of the US Department of Health and Human Services, presentations and reports by Accenture, Cap Gemini, and BearingPoint, and presentations from the MIT RFID Special

Interest Group among others. A full list of reviewed resources is available in Appendix 1. The guiding principles applied in the selection of these additional materials were identical to the ones used for the identification of peer-reviewed articles.

2.2 Overview of article review

After obtaining all literature sources via the search strategies outlined above, we reviewed the materials and recorded a set of key characteristics for each article in a central electronic literature database[3]. These characteristics were based on an initial screening template (presented in Appendix 2), comprising the following domains:

- Basic information (including title, reference, date, summary, abstract, country)
- Relevance
- Focus
- Alternative technology
- Application areas (patients, staff, assets, trials, other)
- Policy areas
- Obstacle, risk or barrier
- Enabler
- Economic analysis
- Market and cost–benefit analysis
- Comments, references.

Within each domain (except for basic information, economic analysis, market and cost–benefit analysis, comments and references), we started out with an initial set of descriptors that the reviewer could, non-exclusively, choose from via a drop-down menu. For example, in the case of application areas, pre-identified descriptors included "patient identification @ hospital for surgery", "infant identification @ hospital to forego mismatching", and "dementia patients tracking and tracing @ elderly homes to forego missing".

In case the already-specified menu of descriptor options did not exhaust or cover the content of the article, reviewers were encouraged to add new descriptors. Since reviewers were encouraged to capture the information in the articles as comprehensively as possible, more than one descriptor per domain was frequently identified and added.

A total of 325 sources were thus summarised in the electronic database by the end of the review.

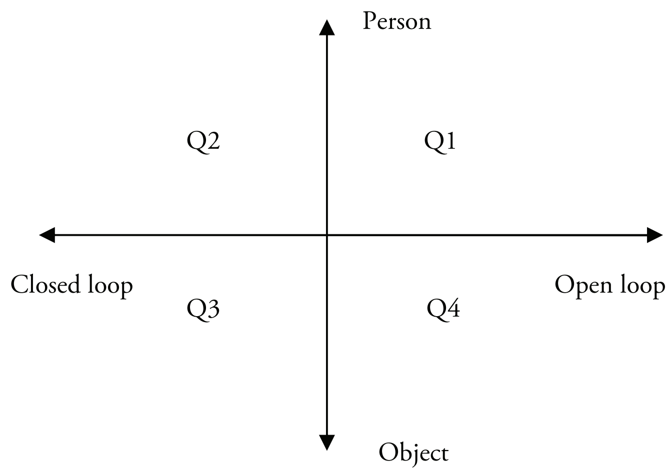
[3] The database was created as an Access 2003 application tool, which allowed for filtering of information according to pre-set queries.

2.3 Typology of applications

Simultaneously with our review process, we sought to find or derive an RFID application typology that classified applications without overlap between objectives and functions and directly addressed healthcare delivery improvement. This was necessary to understand better the kinds of RFID applications in healthcare, and to ensure that their true value added was identified.

Our review highlighted an impressive variation in approaches to classifying RFID applications in healthcare, a representative selection of which is shown in Appendix 3. While some typologies distinguished between the types of entity to which RFID tags are attached (human versus object), and discussed application classifications from a privacy operational point of view; other typologies used system-based classifications (e.g. network versus non-linked transponders) and focused on operational functionality. Still other classifications employed goal- or solution-oriented taxonomies (e.g. asset management versus localisation versus performance data monitoring versus task management). None, however, accentuated more than one critical factor related to healthcare delivery.

In response, based on available typologies, the original classification of RFID applications in healthcare we proposed in our Inception Report[4], and our objective to discern near-term, scalable, effective and secure solutions for better healthcare delivery and the merit for regulation associated with them - we identified a matrix which we believe best captures the information aspects most relevant to the goals of our work (see Figure 2 below).



Source: RAND Europe

Figure 2: Healthcare RFID application classification matrix

[4] The typology we proposed in our Inception Report classified RFID applications in healthcare according to four key RFID functions (identification-authentication, tracking, sensing and alerts-triggers) and four major application areas in healthcare (patient safety and quality of care, pharmaceutical applications, management of medical equipment/devices/material, and patient and health personnel tracking).

According to this matrix, each RFID healthcare application that answers to the criteria of near-term scalability, effectiveness and efficiency can be analysed with respect to its level of "sensitivity", whereby sensitivity is determined by:

i) how big would the damage be in case of mistakes or abuse in the use of RFID data for the specific application

ii) the likelihood of things going wrong through abuse or system failures for the specific application.

This classification of RFID applications is also a starting point for policy-action needs analysis, as illustrated below. From a policy point of view, the main distinguishing factors that determine the level of "sensitivity" are:

- Closed versus open (networked) systems: is RFID used within a confined environment or closed user group; does it stop at a locally un-networked PC or is it linked to a public network? Can and will an RFID tag be switched off after a certain step in the value chain?
- Identifying a person versus identifying a good or service: does the RFID signal the presence of an identifiable person? This can imply a tag fitted to a person or a person's belongings (carried outside the confinement of the person's home), but may also include the traceability of cars and other vehicles.

Hence, for example Quadrant 3 applications may raise few concerns, as generally speaking a closed system that does not use RFID tags linkable to a single person. On the other hand, a system in which item-level tagging reaches the patient or provider of care (Quadrant 1 and 2 applications), may require more attention from policy makers.

In this report, we apply the RFID application typology, which is the building block for the classification matrix. Developing the proposed matrix in a manner that would allow mutually exclusive and fully comprehensive classification is too sophisticated at present, and will be an objective for the next phases of the project.

This RFID application typology is a modified version of the original classification approach we suggested in our Inception Report, informed by the findings of our literature review. It is a four-by-four matrix (see Table 1 below) classifying RFID applications in healthcare across two axes:

- *RFID enabling functions*
- *healthcare applications*.

The four key and mutually-exclusive *RFID enabling functions* we identified and used in the application discussions in Section 3.1. are:

i) tracking

ii) identification and authentication

iii) automatic data collection and transfer

iv) sensing.

The four key *healthcare applications* we used in Sections 3.2 (preliminary list of most promising areas for RFID applications in healthcare) and Chapter 5 (examples of promising RFID applications, pilots and trials) are:

i) patient safety/ quality of care

ii) pharmaceutical application (excluding supply chain and counterfeit drug issues)

iii) management of devices, supplies and biological material

iv) patient and healthcare provider support/management[5].

Table 1: Preliminary classification of healthcare RFID applications

		HEALTHCARE APPLICATIONS			
RFID ENABLING FUNCTIONS		Patient safety / Quality of care	Pharmaceutical application	Management of devices, supplies and biological material	Patient and healthcare personnel support/ management
	Tracking				
	Identification and Authentication				
	Automatic data collection and transfer				
	Sensing				

Source: RAND Europe

For the purpose of this analysis we base our conclusions about the potential individual RFID applications carry for improving the delivery of healthcare on the frequency with which each application is discussed in the literature and the perspective and each article's took on it. The final prioritization of the lists of applications we identify in Section 3.2, will hence be established via a Delphi panel exercise in the next stage of the project, which will take place where frequency based findings will be validated using expert assessment.

The final criterion we applied when distinguishing the most promising types of RFID applications in healthcare in Section 3.2 and Chapter 5 was near-term scalability.

[5] Compared to the original classification we proposed in our Inception Report, the key change is that the RFID enabling function 'alerts and triggers' was found not to be a substantially distinct category from 'sensing', consequently it was superseded by the latter. A new relevant category also emerged – 'automatic collection and transfer'. To avoid confusion, tracking was reserved as a function and deleted from the list of applications.

However, this is not explicitly incorporated in either the typology or the sensitivity classification of RFID applications, as it would have added unnecessary complication.

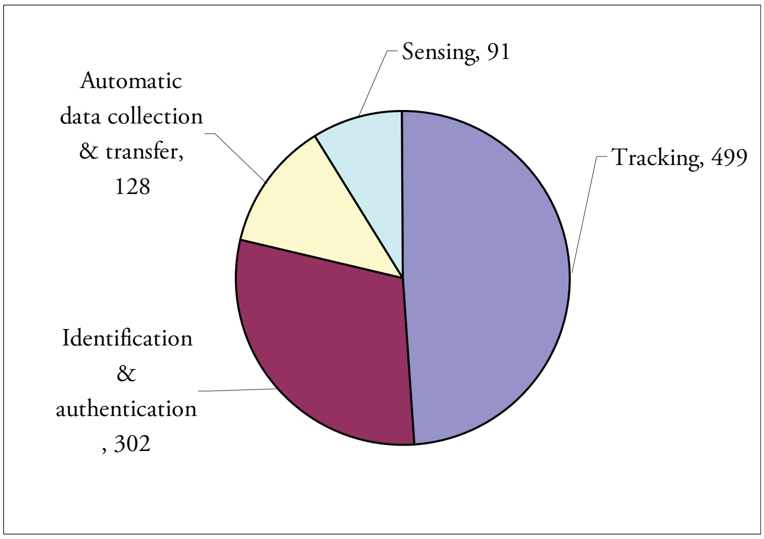
Although layered and incremental, we believe this classification approach can deliver a clear map for the Commission on the areas where interventions are most needed. It is, therefore, worthwhile.

CHAPTER 3 Areas for RFID deployment in healthcare

This chapter begins by taking stock of all areas for RFID deployment in healthcare delivery as identified in the reviewed sources. Four lists of applications per RFID enabling function (tracking, identification and authentication, automatic data collection and transfer, and sensing) and subject (staff, patients, assets and clinical trials) are presented. These are subsequently filtered to arrive at a preliminary list of most promising RFID applications using the typology described in Section 2.3 and in accordance with the selection criteria highlighted in the Inception Report. This list will be further vetted through the Delphi stage of the project. The chapter concludes by considering how RFID compares and co-exists with alternative technologies – to draw the broader context in which technology exists; and to inform the RFID dissemination barriers and enablers discussion in Chapter 4.

3.1 Lists of applications

Figure 3 below shows how frequently each main RFID enabling function (as defined in Section 2.3) was mentioned in the reviewed literature.



Source: RAND Europe

Figure 3: Main categories of RFID applications, and frequency of mention in sources

As can be seen, the most commonly reported application[6] of RFID in healthcare is to track objects, staff and patients. Identification and authentication is the second most prevalent use of RFID, with automatic data collection and sensing being the least frequent areas for RFID deployment. The specific RFID applications delivering these functions are examined in the next section.

3.1.1 The lists

Tables 2 to 5 below present the lists of specific RFID tasks/objectives for each of the RFID functional categories – staff, patients, assets, and clinical trials – and their frequency of mention in the reviewed literature.

As the tables suggest, tracking is the key RFID enabling function used when the technology is applied to staff and assets. When RFID is applied to patients, then the key objective is identification and authentication. When used in clinical trials, RFID's primary function is automatic data collection and transfer; this function is also frequently used in relation to assets, staff and patients. Finally, RFID is employed for sensing most often in relation to patients, but also to assets.

Table 2: List of application areas per category (Trials), and frequency of mention

Application areas – Trials	Frequency
1. Tracking	3
Tagging test tubes (automatic tracking) for transport control	1
Reducing trial process errors (test tubes lost, not returned, wrong ones)	1
Patient/volunteer management (e.g. loss to follow up/drop out)	1
2. Identification and authentication	0[7]
3. Automatic data collection & transfer	7
Data collection for analysis	7
4. Sensing	5
Patient compliance with treatment @ trial	3
Regulating the release of medications	2

Source: RAND Europe

[6] The frequency of mention displayed in this and following graphs and tables is based on the screening approach chosen for this analysis. Using the Screening template, all relevant RFID application areas, alternative technologies, obstacles and enablers were selected when a source was reviewed. Therefore, more than one of each was identified for each information source. By aggregating individual entries into larger analytic categories, the frequency of mention of a category simply represents how often each of the applications/technologies/ enablers/ barriers comprising it was referred to in all screened sources.

[7] The frequency count of zero reflects the fact that with respect to clinical trials, none of the screened articles listed an RFID application relating to identification or authentication.

Table 3: List of application areas per category (Assets), and frequency of mention

Application areas – Assets	Frequency
1. Tracking	233
Real-time inventory count and location tracking	53
Asset tracking	37
Asset tracking and tracing: to avoid procedure delays	23
Materials tracking to avoid “left-ins”	19
Medicine tracking	13
Inventory utlisation	11
Maintenance of medical equipment	10
Asset tracking and tracing: equipment tracking and tracing @ operating room (OR) to ensure hygiene compliance	9
Safety and traceability (e.g. blood transfusions)	9
Theft and misplacement of inventory	8
Logistics	7
Tissue Bank operations	10
Asset identification, tracking and monitoring: bed identification @ hospital to ensure hygiene compliance	6
Lot and batch tracking	5
Document tracking	4
Management of surgical instruments	3
Scrubs automatic dispensing	2
Vaccine asset transportation and distribution tracking	1
Tracking production of dental prosthetics	1
Spare parts for surgery	1
Locating open beds and medical equipment in wide-scale emergency	1
2. Identification and authentication	44
Asset tracking and tracing: for access control and inventory shrinkage decrease	23
Asset identification: blood bags identification @ hospitals/OR to ensure blood type matching	16
Product authentication	3
Auto ID/bar code enabled medication administration (ABMA) system	2
3. Automatic data collection & transfer	56
Inventory management	30
Asset tracking and tracing: for expiration date and restocking	13
Tracking pharmaceutical inventories	6
Expiration data management	3
Automatic supply and equipment billing	3
Cost capture	1

4. Sensing	**21**
Asset monitoring: blood bags equipped with temperature sensors @ hospital to ensure cold chain & efficacy	8
Real-time temperature tracking of pharmaceuticals in transport	7
Improving compliance with scheduled equipment inspection/maintenance	3
RFID-administered medication to monitor patient compliance	2
Disaster management – large goods shipments, ensuring cold chain for perishable goods	1

Source: RAND Europe

Table 4: List of application areas per category (Staff), and frequency of mention

Application areas – Staff	Frequency
1. Tracking	**111**
Staff monitoring @ hospitals for management purposes	44
Improving use of staff time	16
Improving workflow in hospitals	16
Staff tracking and tracing @ hospital (ED) to speed up service	16
Improving labour productivity	10
Eliminating in-hospital service bottlenecks	6
Protecting patients/staff in psychiatric wards from violence	1
Tracking movement of staff, patients, visitors to assess SARS spread	1
Drug procurement and administration	1
2. Identification and authentication	**38**
Staff identification @ hospitals to manage access	14
Error prevention (e.g. via SurgiChip)	10
Security and safety at hospitals	3
Improving Joint Commission and HIPAA compliance	3
Quality management in hospitals	3
Reducing liability-related problems	2
Diagnostic reliability at point of care	1
Prescribing and checking drug interactions at the point of care	1
Enhancing patient and staff working conditions	1
3. Automatic data collection & transfer	**34**
Reducing forms processing time	10
Using tablet PCs for care coordination	8
Process automation	8
Preventing data entry and collection errors	6
Administration in hospitals	2

4. Sensing	13
Implementing real-time safety reminders for staff	5
Alerting staff to patient needs	2
Ensuring accurate medicine dosage given to patients	5
Hand-washing compliance monitoring	1

Source: RAND Europe

Key: ED = Emergency Department; HIPAA=Health Insurance Portability and Accountability Act

Table 5: List of application areas per category (Patients), and frequency of mention

Application areas – Patients	Frequency
1. Tracking	152
Patient tracking and tracing @ hospitals for monitoring patient flow	55
Monitoring/tracking of patient location	38
Infant tracking and tracing @ hospitals for security/to forego theft	16
Patient tracking to ensure safety/access control (dementia, psych)	12
Dementia patients tracking and tracing (in-/out-patient)	11
Tracking of drugs, supplies and procedures performed on each patient	11
Real-time patient location systems	4
Accounting for patient time in ED	3
Managing the large numbers of seriously injured patients during catastrophic events	2
2. Identification and authentication	220
Patient identification to reduce incidents harmful to patients (wrong drug, dose, time, procedure)	112
Patient identification to avoid wrong drug, dose, time, procedure	*[51]*
Eliminate wrong patient/wrong procedure surgery	*[30]*
Accurate patient identification for medication safety	*[13]*
Patient identification for blood transfusion	*[10]*
Reduce errors due to misidentification	*[7]*
Reduce patient complications	*[1]*
Portable, current and comprehensive health records	25
Critical information to the patient	*[11]*
Real-time clinical information associated with patient	*[5]*
Keeping current and comprehensive patient charts	*[5]*
Portable health records	*[3]*
Validating patient charts and imaging	*[1]*
Accurate patient identification	35
Implanted RFID carrying medical record	20
Infant identification @ hospitals to forego mismatching	12
Patient identification @ disasters	8

Protecting patient privacy	3
Person identification for forensics	2
Contactless retail payment	2
Selectively jam RFID readers	1
3. Automatic data collection & transfer	**31**
Interventions: automated care, pathways, procedures audit, management	23
Improving patient/staff satisfaction	6
Incident audit trail	2
4. Sensing	**52**
RFID ingested or implanted to provide real-time information on health indicators and vital signs, to monitor and report on the results of surgeries, to regulate the release of medications, telemedicine	22
Intelligent medication monitoring (for elderly at home)	15
Assisting the visually impaired	4
Infection control (nosocomial infections)	2
Proper positioning of the endotracheal tube during intubation	2
Clinical improvements	2
Helping surgical recovery	2
Tracking healing around an implant	1
Functional-neuromuscular stimulation	1
Flexible surface wetness sensor for adult paralysed patients	1

Source: RAND Europe

3.1.2 Descriptions

This section presents succinct descriptions of the four RFID enabling functions identified in the typology of applications (Section 2.3), based on the results of the literature review.

A. Tracking

Tracking as an RFID enabling function is centred on the identification in motion of a person or object. This includes both real-time position tracking (for example for patient-flow monitoring and improving workflow in hospitals) and tracking of motion through choke points (e.g. entry/exit in/from designated areas). In relation to assets, tracking is most frequently applied to continuous inventory location tracking (for example for maintenance, availability when needed and monitoring of use), and materials tracking to prevent left-ins during surgery. Specimen, blood product and records tracking are also frequent RFID applications.

B. Identification & authentication

Identification and authentication is the key RFID enabling function deployed in relation to patients. It can take a variety of forms including accurate patient identification to reduce incidents harmful to patients (such as wrong drug/dose/time/procedure), RFID-enabled comprehensive and current electronic medical record maintenance (both in the in- and out-patient settings), and infant identification in hospitals to prevent mismatching. In relation to staff, identification and authentication is most frequently used to grant access (e.g. to areas and cabinets) and to improve employee morale by addressing patient safety issues. In relation to assets, identification and authentication is predominantly used to meet haemovigilance objectives (e.g. ensuring correct blood-to-patient transfusion).

C. Automatic data collection & transfer

Within the functional capabilities of RFID, automatic data collection and transfer is mostly aimed at reducing form processing time, and at process automation (including data entry and collection errors), as well as automated care and procedures audit, and medical inventory management. The function also relates to integrating RFID technology with other health information and clinical application technologies within a facility, as well as the potential expansion of such networks across providers and locations.

D. Sensing

As previously mentioned, sensing as an RFID enabling function centres on patients, and in particular on diagnosing patient conditions, providing real-time information on patient health indicators. Application domains include different telemedicine solutions, monitoring patient compliance with medication regiment prescriptions, and alerting for patient well-being. In this capacity, RFID can be applied both in in-patient and out-patient care. RFID sensing is also a key function for controlling staff hygiene compliance (hand-washing) and proper perishable medication and blood product handling and safekeeping.

3.2 The most relevant areas for deployment

This section presents our preliminary and exemplary list of the most relevant areas for RFID deployment based on the findings discussed above and the selection criteria outlined in Section 2.3. The list will be further vetted and expanded during the expert interview and Delphi stages of the project.

3.2.1 Applying typology

Based on the application domains we identified in Tables 2 to 5 above, and the expected wide-scale dissemination timeline of different RFID applications (presented in Figure 4 below[8]), we drew up a preliminary list of the most relevant areas for RFID deployment in healthcare delivery. It is based on the RFID typology developed in Section 2.3, and is presented in Table 6 below.

YEARS	UP TO 2004	2005 - 2010	2011 ONWARDS
Main uses	Error prevention of products (drug dose, correct blood and treatment, mother/ baby mismatch etc) Patient tagging for error prevention Locating staff/ staff alarms Locating assets	Error prevention of products now including auto rejection of wrong luer connections and parts Patient tagging for error prevention Locating staff/ staff alarms/ tags that record incidents Locating assets/ speedy, accurate stocktaking Theft prevention Cost control Recording procedures (eg for defence of lawsuits) Drug trials compliance monitoring/ prompting Behavioural studies to optimise operations Pharmaceutical anti-counterfeiting	Error prevention of products Patient tagging for error prevention Locating staff/ staff alarms Locating visitors/ visitor alarms/ virtual queuing Locating assets/ speedy, accurate stocktaking Theft prevention Cost control Recording procedures(eg for defence of lawsuits) Drug trials compliance monitoring/ prompting Patient compliance monitoring/ prompting (taking drugs) Behavioural studies to optimise operations Pharmaceutical ant-counterfeiting Track and trace of most medicines, consumables and assets

Source: Harrop et al, 2007

Figure 4: Wide-scale timeline for dissemination of leading RFID applications in healthcare

Table 6: Preliminary list of the most promising areas for RFID deployment in healthcare

		Healthcare Applications			
RFID enabling functions		Patient safety/ Quality of care	Pharmaceutical application	Management of devices, supplies and biological material	Patient and healthcare personnel support/ management
	Tracking	Tracking of vulnerable patients for safety and security without infringement of freedom (dementia, MR) Tracking of patient whereabouts to account for patient time during treatment	Easy recall of products	Prevention of left-ins during surgical procedures Equipment tracking to ensure hygiene compliance and regular maintenance, and for fast location when needed	Personnel tracking to improve workflow and reduce patient waiting times in ER

[8] This is the most recent RFID application dissemination timeline available in the literature. We also believe that it is the most realistic one as it is based on a comprehensive review of the current state of RFID dissemination in healthcare, as well as an RFID health application market analysis.

	Identification and authentication	Mother–baby e-handshake to ensure accurate matching	Auto ID-enabled medication administration system.	Maintenance of real-time clinical information associated with patient within a hospital	Patient identification to reduce incidents harmful to patients (wrong drug, dose, time, procedure)
	Automatic data collection and transfer	Use of tablet PCs for care coordination.	Tracking pharmaceutical inventories	Inventory management for better use of staff time and faster care delivery	RFID-supported automated care, pathways, procedures audit, and management.
	Sensing	Patient vital signs to trigger alerts for medical personnel, and remote monitoring at patient's home	Patient compliance with prescribed medication treatment (in- and out-patient)	Blood bags equipped with temperature sensors in hospital to ensure cold chain and efficacy	Personnel and asset tracking to ensure infection control (nosocomial infections)

Source: RAND Europe

This preliminary list of the most promising areas for RFID application in healthcare presented above will be further vetted during the expert interviews and Delphi stage of the project. However, we believe that the application areas identified in Table 6 hold significant promise in terms of adding safety, efficiency and effectiveness to healthcare delivery. Where available, information on specific trials, pilots and applications within these domains is presented in Section 3.4 and Chapter 5.

3.3 Alternative technologies

Two frequent topics of discussion in the reviewed literature were:

i) how RFID compares to alternative technologies

ii) the case for combining RFID with other technologies.

To draw the broader context in RFID exists and to inform the discussion in Chapter 4 on the RFID dissemination barriers and enablers discussion in Chapter we review these issues in the current section.

We begin by taking stock of the alternative technologies that are compared to RFID. Table 7, below, shows how frequently RFID-alternative technologies (organised by function) are mentioned in the reviewed sources. It also shows their type of relationship – supplementary versus complementary – to RFID.

As the table indicates, the four main technology-related topics that were discussed included:

i) alternative identification solutions versus RFID

ii) alternative data transfer/infrastructure solutions versus designated RFID readers

iii) sensor/telemetry and diagnostic systems/applications and RFID

iv) health information technology (HIT) and electronic medical record (EMR) and RFID.

Within these, the key alternative technologies identified are bar codes (as identification solution) and WiFi (as data transfer/infrastructure solution).

A brief description of each technology follows, along with a review of their comparative functionality. How they are seen to complement or compete with RFID is reviewed last.

Table 7: Key alternative technologies, per frequency of mention and relationship to RFID

Technology	Frequency of mention
Alternative identification solutions	81
Barcode	70
Barcode vs. RFID	*[45]*
Barcode & RFID	*[25]*
Infrared (IR)	5
Infrared & RFID	*[3]*
IR location technology vs. RFID	*[2]*
Chip cards/Smart cards vs. RFID	2
Biometrics	1
Alphanumeric bracelets	1
Anthropometric data readers	1
Electronic security systems	1
Alternative data transfer/infrastructure solutions	51
WiFi vs. designated RFID readers	21
LAN	10
UWB vs. WiFi	7
GSM/GPRS	4
Bluetooth	3
Zigbee	2
VOIP & RFID	2
Video/radio & RFID	1
WLAN	1
Sensor/ Telemetry/ Diagnostics	7
Sensor telemetry & RFID	3
TTI temperature labels vs. RFID	1
Traditional imaging techniques vs. RFID	3
RFID & HIT/EMR	4

Source: RAND Europe

Key: WiFi=wireless network; LAN=local area network; UWB=ultra wide band; GSM=global positioning system; GPRS=general packet radio service; VOIP=voice over internet protocol; WLAN= wide local area network; TTI=time-temperature integrator; HIT=health information technology; EMR=electronic medical record.

3.3.1 Descriptions and comparative functionality

This section contains brief descriptions of the main types of technologies identified in Table 7 above. For clarity of comparison a brief description of RFID technology is presented first.

A. Types of RFID

RFID tags may be classified in a number of ways. A technology-driven typology can differentiate RFID by:

1. active, semi-active, passive tags
2. data storage/memory: read-only, read-write systems
3. frequency classes
4. reading ranges
5. design (capsules, buttons, labels)
6. robustness
7. level of security (encrypted, not-encrypted, cloning, easy to destroy, anti-collision procedure).

All RFID chips are connected to an antenna, generally of wound copper, that transmits the RFID signal, allowing for no-line-of-sight communication with a reader. This feature is particularly important because it allows transmission in a variety of environments.

However, the most frequently drawn distinction is between passive and active RFID tags. Passive tags have no power source; they are powered by the energy of the interrogation by an RFID reader. They have a long life, but a relatively short range of activity (up to 5 m). In contrast, active tags contain a battery. This increases their effective operating range, but shortens the life span of the tag because the battery will eventually fail. Although passive RFID tags are smaller and cheaper, active RFID systems are actually cheaper (e.g. as their readers are cheaper) and easier to install (especially as stand-alone systems) (Britton, 2007).

Tags may also be classified by operating frequency. Low-frequency tags (100–500 KHz) are used for inexpensive short-range applications in which the reading speed of the tag is not critical. High-frequency tags (10–15 and 850–950 MHz), which have a medium range and a faster reading speed, are used for gate cards and similar applications. Ultra-high-frequency/microwave (2.4–5.8 GHz) is used for the most expensive, the fastest, and the longest-range tags, but requires line-of-sight transmission. These tags are especially useful for identification applications involving movement. It is anticipated that medical application will fall in the 13-, 27-, 430-, 910-, and 2400-MHz ranges used for development of electronic article surveillance (EAS) and industrial, scientific and medical (ISM) applications. By the very nature of these applications, the response by the transponder to interrogation must be brief. There are, at present, two major RFID standards: the Electronic Product Code (EPC) developed by EPCglobal (embraced by retailers), and ISO (International Standards Organisation) 18000-6. The increased interest in creating ubiquitous open-loop healthcare information networks based on RFID technology has meant that data storage and protection, as well as robustness, are becoming particularly relevant technical parameters for RFID classification. However, these were not discussed extensively in the reviewed sources.

B. Alternative identification solutions

i) Bar codes

Bar codes, both 1D and 2D, are machine-readable representations of information (usually dark ink on a light background to create high and low reflectance which is converted to 1s and 0s). Bar codes can be read by optical scanners called bar code readers or scanned from an image by special software, but require a direct line of sight for successful reading.

Table 8 below gives an overview of the functional characteristics of bar codes, RFID technology and the WiFi information transportation solution, which will be discussed next.

Table 8: Comparing RFID, bar code and WiFi technologies – applications, pros and cons

Technology	Characteristics	Pros	Cons	General Use	Health Care Use
1-D bar code	Alpha and alpha-numeric data, 20-25 characters	Inexpensive, ubiquitous	Limited data capacity; reader requires line of sight	Ubiquitous; virtually all commodity items in everyday life have a 1-D bar code on the package	Patient identification bands (limited penetration); drugs (limited penetration)
2-D bar code	100-2000 characters	Can hold large amount of data	Requires special reader and line of sight		Patient identification bands (limited penetration)
WiFi	Uses WiFi for location; can locate personal computers, handhelds, and tags	Multitasking; global trend to ubiquitous deployment of networks	Tags need batteries; radio frequency can impact performance; security issues	Data transfer from portable computing devices	Hospital information system data to PDAs, laptops, and computers on wheels (limited penetration)
Passive RFID	Label is energized by a reader and transmits data to reader	Relatively small and inexpensive	Short read range; very limited data capacity; does not provide unique identification; location and time data only as good as last read	Electronic article security, clothing tags in stores	Staff identification; medium and large sized items, such as implantable prostheses, blood products, patients (all experimental)
Semiactive RFID	Battery-powered tag; passive reader activates tag	Longer range (~40 ft)	Same cost and battery issues as active tags, but no location data—portal application	E-Z Pass on highways	
Active RFID	Battery-powered tags that transmit radio signals	Provide identification and location; long range (30 ft); real-time data	Battery life; blocking of RF; tag cost and size; some require infrastructure		Location in time and space of assets moving through the covered area

Note: PDA = personal digital assistant; RFID = radio frequency identification; WiFi = wireless fidelity.

Source: Egan, 2007

ii) Infrared technology

Infrared (IR) technology relies on a passive infrared signal emitted from a tag to identify or track the person or object to which the tag is attached. However, a clear line of sight is needed for infrared signals to be read. The functional characteristics of infrared technology are presented in Table 9 below.

IR location is an active tag technology that uses an infrared signal from a tag to transmit location to a dedicated infrastructure of optical receivers. The optical nature of these tags limits them to line of sight applications generally applicable to infrared and bar code technologies.

iii) Chip cards/Smart cards

Chip cards, also know as Smart Cards, are a 'smart chip technology' with a PIN in which a variety of information can be stored. The cards can be used both as access cards – to the medical history of patients – by both healthcare providers and patients alike (e.g. on an internet portal); and as portable health records – the card can store the medical history of the patient. More detailed demographic and insurance information can also be stored on the Smart Card chip. This can potentially reduce the paperwork burden and improve the accuracy of patient identification at the point of care, especially in the out-patient setting. Smart Cards require direct contact for this information to be extracted (unlike bar codes, infrared or RFID tags).

iv) Other identification systems

The other main identification systems discussed in the literature as alternatives to RFID and barcode identification are bracelets with alphanumeric codes, devices able to read anthropometric data, biometric readers and high frequency tags. Alphanumeric bracelets contain both numbers and letters that open a mechanical barrier system when a code is recognised by a reader. They, along with devices able to read anthropometric data, comprise two of the three main item/patient identification options used in haemovigilance systems today, the third one being bar codes and RFID tags. The background philosophy on which these technologies are based is to force operators towards self-correction during the procedure. Hence they do not maintain process logs.

Other less frequently mentioned alternative identification systems are high frequency tags and biometric readers. However, both were mentioned only marginally.

Finally, electronic security systems were discussed in the context of interoperability issues that implantable medical devices face in the presence of strong magnetic fields in the frequency range between extremely low frequency (ELF) to radiofrequency (RF) as they are emitted by electronic security systems (ESS). The article containing this discussion presented a mathematical model that helps predict such interferences. The main conclusion put forward by the authors was that all electronic security systems can potentially interfere with the operability of implantable devices – a threat that should be taken into consideration when designing such systems.

C. Alternative infrastructure solutions

Seven technologies were identified in the review as having the potential to supplement RFID readers and serve as alternative infrastructure solutions:

- WiFi
- WLAN
- LAN
- Bluetooth
- ZigBee
- GSM/GPRS
- Voice over Internet protocol (VoIP).

In the context of RFID, VoIP also serves a technology-enabling function and is hence discussed in this section as well. Tables 9 to 11 below, and Table 8 above, provide information on the functional characteristics of active RFID, Bluetooth, GSM/GPRS and WiFi technologies.

Table 9: Active RFID vs. Bluetooth/WiFi, infrared and radio triangulation – parameter comparison

Comparing techniques

	Active RFID/ (Multilateration)	BlueTooth/WiFi (Radio fingerprinting)	Infrared	Radio triangulation
Precision	Scalable, zone to 1M	1 – 10M depending on number of access points	Room level	Room level
Accuracy	Virtually 100 percent based on peer-reviewed study	No peer-reviewed data; requires frequent "relearning" to maintain	High within enclosed space	High when precisely calibrated
Affordability				
Tag price (ea)	$7-$20	$40-$200	$70 - $100	$40-$120
Infrastructure for 200-bed hospital	$200,000	$200-300,000	$500,000	$1.5 million
Tag battery life	2-6 years	1 day to 6 months	6 months – 2 years	1- 7 years
Installation	CAD files	Site Survey	Site Survey	Site Survey
Frequency	433 MHz	2.4GHz	433 MHz	2.4GHz
Receiver Infrastructure	Ethernet	Existing WiFi	RS-485	Coaxial Cable

Source: Harrop et al, 2007

Table 10: Telemetry technologies and their drawbacks for patient monitoring

TELEMETRY TECHNOLOGY	COMMENTS/DRAWBACKS
GSM/GPRS, WiFi, Bluetooth	Too expensive, complex and power hungry
USB, RS232, IRDa, Ethernet, POTS/Modem	Too impractical or expensive
RFID	Best, but still not sufficient

Source: Harrop et al, 2007

Table 11: Comparison of real-time location systems – WiFi and Zonal (RFID)

TYPE	TYPICAL ACCURACY	COST OF OWNERSHIP	INSENSIVITIY TO OBSTRUCTIONS/ RELIABILITY OF SIGNAL	SOFTWARE UPGRADES	INFRA-STRUCTURE MAINTENANCE UPGRADES	BATTERY LIFE
Zonal (Cell ID)	Poor eg 10 meters	Medium	Good	Negligible	Considerable	5-10 years
WiFi parasitic (radio fingerprinting)	Fair eg 2 meters	Medium to Low	Less good	Regular remapping needed	Low (almost no infrastructure)	1 month to 5 years

Source: Harrop et al, 2007

An alternative to the above discussed technologies, and RFID-designated readers, is Ultra-wide band (UWB) technology. UWB is advertised as a “true hospital-grade wireless solution” designed for healthcare in its frequency (6.2GHz), power output (5.4 nanowatt average), and short cycle (2 nanoseconds). UWB meets four main requirements:

- reliability and accuracy (for HIPAA, HIT, patient safety)
- electromagnetic compatibility (HIT/EMR)
- low probability of intercept
- low probability of detection

This makes it more efficient than traditional wireless (low power need and consumption, less infrastructure), immune to interference from other equipment and unlikely to interfere with other equipment. UWB also has no costly spectrum license requirements, and reports more consistently accurate data. UWB is a more scalable system than WiFi or IR, with a self-assembling architecture (transmitters, receivers and transceivers) supporting thousands of tags via a pocket PC application. It is also more flexible and efficient as a common architecture can support multiple uses, including tag to tag and tag to environment relationships, wireless medical telemetry, access control, person/equipment tracking, VoIP and biometric identification. It is estimated that the hardware and software UWB cost for a 300-bed hospital with 500,000 feet^2 (requiring roughly 1,500 Tags) is \$490,000 (Cohen, 2007).

LAN, WLAN and Zigbee are the other three information-transfer technologies that can be used as an alternative to stand-alone RFID sensors. LAN operates on a number of frequencies. It is suitable for real-time location and tracking systems, and avoids the cost of installing a dedicated RFID reader system, but does not have as good granularity as WiFi. In addition, its bandwidth can be depleted very fast if several applications are running concurrently in real time. WLAN operates in 5GHz and licence-free 2.4 GHz, is largely free from interference, and offers authentication mechanisms and encryption. It is expensive, bigger and often not practical, yet offers long reading ranges, good for area-wide coverage, and robustness of signal. ZigBee, based on the IEEE 802.15.4 wireless communication standard, also operates in 868 MHz, 915 MHz or licence-free 2.4 GHz. ZigBee individual modules communicate to each other autonomously (peer-to-peer network). In its functionality, ZigBee technology is similar to Bluetooth technology, yet ZigBee standard also foresee sensor and actuating elements, semi-active technology with sleep-modus. Zigbee is an energy-efficient solution, priced similarly to active RFID tags.

Voice over Internet Protocol (VoIP) is a protocol using voice transmission through the Internet or other packet-switched networks. In the RFID context, it acts as a data transfer solution. One example of such application is the use of VoIP in tandem with RFID in the University Hospital of Ghent (Belgium) to facilitate the tracking of patient vital signs and to keep nurses informed of a patient’s condition. Wireless VoIP phones allow nurses to view a patient’s blood pressure, oxygen level, and electrocardiogram images; if a dramatic change in vital signs occurs, or if there is an emergency, the phones issue an alert.

D. Sensor/ telemetry / diagnostics

i) Sensor telemetry

Sensor telemetry uses sensor technologies and two-way wireless technologies to gather more fine-grained information from products, people and places. The articles which discussed sensor telemetry and RFID focused on the capacity of RFID to be integrated with more elaborate sensor telemetry solutions across a range of applications (e.g. patient monitoring, hazardous or radioactive material management and vaccine asset transportation) but did not elaborate on the technical aspects of such integration, or of the sensor telemetry solutions alone.

ii) Time–Temperature Integrator (TTI)

TTI labels have the capability to sense a combination of time and temperature as they affect product shelf life, quality and safety for human consumption, as well as the preservation of pharmaceutical products. Unfortunately, the article which identified TTI as an alternative to RFID (Edwards, 2007) did not provide a discussion on how its functionality compares to that of RFID tags, hence this remains unknown to us.

iii) Traditional imaging techniques

Three of the reviewed articles highlighted the potential for RFID application as an alternative to dangerous or invasive imaging. These included:

1. M2A patency capsule for diagnosis of critical intestinal patency (Banerjee et al., 2007)
2. passive RFID tags use to monitor the proper positioning of the endotracheal tube during intubation (Reicher et al., 2007)
3. passive RFID tag use for patient comfort and cold sore prevention (Yang et al., 2008).

E. Health information technology (HIT)/ Electronic medical records (EMR)

Health information technology (HIT) is a blanket term used to refer to clinical information systems/softwares geared to safer, more effective and efficient patient care. Within HIT, EMR is the integration architecture that aggregates all clinical information about a patient in an electronic record, and provides an interface for accessing and inputting such information.

3.3.2 **Complementary or competition?**

As highlighted above, our review of the literature indicates that there are four RFID functional domains in which RFID can be supplemented or complemented by other technologies. These are:

i) object/person identification

ii) data transfer from RFID tags to other tags/the environment/back-office applications

iii) sensing/ telemetry/ diagnostics

iv) integrating health information infrastructures.

In relation to the first two functions – object/person identification, and data transfer from RFID tags to other tags/the environment/back-office applications – the relationship between RFID and the individual technologies performing these functions can be either complementary or substitutive. The relationship between RFID and the technologies performing the latter two functions however – sensing/ telemetry/ diagnostics, and integrating health information infrastructures – is clearly complementary (both by the judgment of the reviewed sources and by the complimentary natures of the technologies).

Hence, the remaining paragraphs of this section will focus on the first two functional areas - object/person identification, and data transfer from RFID tags to other tags/the environment/back-office applications. In particular, we will look at the complementarities and competition documented between RFID and bar codes (as identification solution), and RFID and WiFi (as data transfer/infrastructure solution), since the two were identified as key RFID-alternative technologies by an overwhelming majority of sources.

A. RFID and bar codes

Both bar code and RFID auto ID systems seek to address the critical need for positive patient identification, and thus reduce preventable harmful incidents. However, the main trade-off occurring between these alternative technologies is that between bar codes (1D and 2D) and passive RFID, as active RFID and bar codes have too few functionality overlaps to be in direct competition. For example, while passive RFID is best used for positive identification of small, inexpensive items, and for controlling access to restricted areas, active RFID is most effective for positive identification of people and things that move frequently and over large distances indoors (Dempsey, 2005).

According to Schuerenberg (2006) the key advantages of passive RFID tags over bar codes are:

1. their superior functionality (in terms of better durability and reliability, user-friendliness, and no direct line-of-sight requirement)
2. their greater granularity and the ability to identify each unique product in a palette without the individual scanning of all products
3. their great application potential, which bar codes cannot match (e.g. equipping newborns & mothers with an RFID transmitter and reader which allows positive mother–baby identification and sounds an alarm if no such occurs).

Moreover, unlike bar-code wristbands, RFID provides an 'over-the-air' non-line-of-sight interface, which can be read through and around the human body, clothing, bed coverings, and non-metallic surfaces. RFID has read/write technology for data transfer to and from host systems and data storage. It also has larger memory capacity, wider reading ranges, and faster processing time than bar codes.

Yet, bar code technology still has a realm of dominance over RFID. According to Dzik (2007), bar code technology is ideally suited for tasks in which a human being is stationary and objects are moving (e.g. blood sample collection and labelling) as it is still cheaper than passive RFID technology. In addition, many of the domains for passive RFID tag deployment are already occupied by bar code solutions, even if less functional, reliable and single sub-process oriented (e.g. haemovigilance) (Gassner et al., 2006). This makes bar codes suitable as a back-up solution to passive RFID tags, and as complements for specific tasks, such as medication management (Hagland, 2005).

As noted above, however, bar codes are neither complementary to nor can they supplement active RFID tags. Active RFID tags bring real-time and universal information on identity and location, not at predefined portals or ‘choke points’ (unlike passive RFID or other security applications). Overall, however, different flavours of active RFID have different characteristics, suiting them to different needs – often in combination with other technologies, such as HIT or sensor/telemetry solutions. These include operational frequency (433, 925, 2.4 and UWB), methodology (beaconing versus chirping) and hardware, and have direct implications for the level of accuracy the system supports (room-level versus high-resolution) and associated considerations (e.g. power consumption, accuracy, cost to resolution curve). Such seconds-old data has great value (very close to the value of real-time information), but the cost increases exponentially with increased resolution (<10’) and speed. Hence, active RFID is particularly well suited to process monitoring in healthcare, based on the movement and interaction history of tagged items, as well as status monitoring.

B. RFID and WiFi

According to Leonidas (2007) and Gassner et al (2006) there is no clear case indicating that any one type of RFID-supporting infrastructure is universally better than another.

For example, while dedicated RFID readers imply a higher infrastructure cost, they do not tax existing systems, which makes them good for small focused deployments of RFID. Alternatively, the main benefit of using existing WiFi systems instead is reduced infrastructure cost, sometimes up to 50% (Gearon, 2005b). The main drawback, however, is the potential for bandwidth depletion. Moreover, as Harrop et al (2007) point out, WiFi systems do not readily permit secure access, and have lower location accuracy and error prevention.

The general conclusion which emerges from the preceding discussion is that RFID and bar code technology, and RFID and WiFi data transfer technology are complementary, rather than competing, solutions. There is a need to tailor application design and implementation to concrete application and process goals. This is further confirmed in Chapter 4, which highlights the finding that choosing the right mix of RFID and alternative technologies (e.g. 1D and 2D bar codes, WiFi networks) for the needs of the institution is one of the key success factors in healthcare RFID implementation.

CHAPTER 4 Most important enablers and barriers to the use of RFID in healthcare

As illustrated in the wide range of applications discussed in the previous chapter, RFID appears to hold significant potential for improving the delivery of healthcare. The dissemination of this technology, however, is only at its beginning. To understand what factors play a role in the speed and breadth of RFID implementation in healthcare, we discuss first the main enablers for the dissemination of this technology, and then review the obstacles to it, as cited in the literature. Finally, we discuss the key uncertainties that could have a profound impact on RFID development, and which need to be explored further in the context of the scenario exercise in the final phase of this study.

4.1 Most important enablers for the use of RFID in healthcare

This section presents a categorised list of enablers for RFID technology dissemination in healthcare, as identified in the literature. The key enabler categories are discussed first.

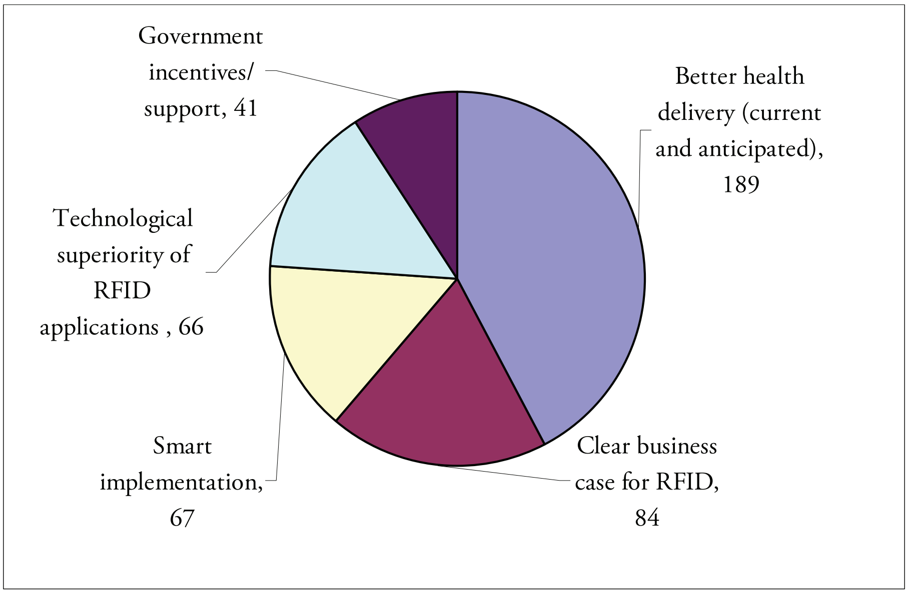
4.1.1 List of enablers

The most important categories of enablers to wider-scale RFID implementation in healthcare, as identified by our review, are:

1. Better healthcare delivery (current and anticipated): e.g. process control capacity; paperwork and manual activities unsupported by existing IT systems which RFID can address immediately; and telemetry intelligent out-patient care.
2. Clear business case for certain RFID applications: e.g. return on investment (ROI) on inventory and asset management applications; real-time location systems; haemovigilance systems; left-in avoidance; and reduction in incidents harmful to patients, by correct patient-procedure and patient-medication matching.
3. Smart implementation: e.g. staged implementation; staff training; and choosing the right mix of technologies to fit needs and processes.
4. Technological superiority of RFID applications: e.g. better durability and multi-functional applicability than bar codes.

5. Government incentives/support: e.g. financial stimuli; legislative mandates.

The ranking of the categories is based on the relative importance placed on them in the peer-reviewed and 'grey' literature, as well as their relative frequency of mention across all reviewed sources (see Figure 5 below).



Source: RAND Europe

Figure 5: Most important categories of enablers, per frequency of mention in the literature

The list of specific enablers per category, as quoted in the literature, is shown in Table 12, below, with their respective frequency of mention[9].

[9] For clarification of how the frequencies were obtained, see the footnote on p. 21.

Table 12: Detailed list of enablers per category and frequency of mention

Enabler	Frequency
1. Better health delivery (current and anticipated)[10]	189
Perceived benefits	133
Personal safety and security	9
Effectiveness	8
Paperwork and manual activities unsupported by existing IT systems	5
Improved resource utilisation	6
Need for safe, fast, unambiguous ID systems for patients and assets	6
Superior functionality	4
Reduce patient-related mistakes	3
Ageing population	3
Need for effective process controlling capability (e.g. poor information record and inter-departmental communication)	3
Modern medicine practices	2
Improved safety and security	2
Strong culture of performance-driven management	1
Patient satisfaction	1
Protects patient rights	1
Disparate IT systems	1
Tampered or adulterated products	1
2. Clear business case for RFID	84
Falling tag prices	23
Improved patient care, reduced costs	22
Vendor initiative for creating interoperable, cost-effective solutions	15
Optimised ROI	8
Treatment costs	8
Reduced logistic and technology costs	8
3. Smart implementation	67
Success of pilot ROI	11
Having a business plan for RFID in advance, suiting applications to needs, and understanding ROI for each investment	9
Avoid 'silver bullet' approach – seek use of different RFID in a system for greater benefit	8
Working with all stakeholders in preparatory phase	8
Coupling RFID with other clinical technology (e.g. EMR)	7
Bundling up applications	6

[10] This category groups the wide array of efficiency- and effectiveness-enhancing solutions RFID offers. It also gives examples of specific factors that add merit to the deployment of RFID in healthcare (given its strengths versus alternative technologies or the status quo).

Good project management is needed to integrate people from many different departments	4
Integration of RFID in existing IT systems	3
Having an RFID champion in the executive ranks	2
Invest in training	2
Code of conduct	2
Understanding RFID is an infrastructure	2
Clear and agreed goals at the start	2
User acceptance	1
4. Technological superiority of RFID applications	**66**
Broad functionality and numerous applications	20
User-friendliness of technology	13
Technological advantage versus alternatives	9
Wider readability field than bar codes	8
Ability to store more information than bar codes	5
More durable than bar codes	5
Technology must be fail-safe	3
Absolute read accuracy	2
Encryption capacity	1
5. Government incentives/support (financial, legislative)	**41**
Government legislation (national)	25
Government legislation (supranational)	6
Government endorsement of standards	5
Government incentive (national)	3
Government incentive (supranational)	2

Source: RAND Europe

4.1.2 Describing enablers

This section presents succinct descriptions of the five key enabler categories identified above.

A. Better healthcare delivery

According to our literature review, the primary enabler for the use of RFID in healthcare delivery is the improvement in the quality of care associated with its implementation and current and near-term capabilities. These include:

- process control capacity and capacity to support modern medicine practices
- reduction of harmful incidents
- improved resource use
- delivery of safe, fast and unambiguous identification

– the creation of an operationally-integrated hospital information system[11].

Some of the anticipated near-term RFID advantages have to do with:

– distant patient management (at home)
– biometric data collection
– telemetry and intelligent out-patient care.

These are seen as particularly promising giving the 'greying' of Europe's population. As presented in the literature, the benefits of employing RFID are also associated with the greater efficiency of this technology as compared to alternative solutions, and the patient satisfaction arising from improved quality of care.

B. Clear business case for certain RFID applications

The second strongest argument supporting the implementation of RFID applications is the clear business case healthcare providers, analysts and researchers identify for specific RFID solutions in healthcare. These include:

– the internationally widely documented ROI on RFID inventory and asset management applications
– the business case for installing real-time location systems for staff, patients and assets within healthcare facilities.

According to Murphy (2006), such asset and inventory RFID solutions can result in up to two days a week of saved time for nurses and clinical engineers alone – time which can be shifted to patient care. Other examples are:

– the RFID-supported haemovigilance systems
– the use of passive RFID for avoiding left-ins after surgery
– a range of RFID applications for positive, correct, patient-procedure and patient-medication matching.

These will all lead to improved patient safety, bringing direct (monetary) and indirect (e.g. reduced liability and additional treatment costs) benefits. In addition to the improvements in patient care and lower costs, two other key factors in the business case for healthcare RFID are:

[11] To be understood as an IT system that effectively interconnects separate clinical IT systems to allow better communication between them, or supplements previous manual processes, and results in improved workflow for care providers, and improved quality of care.

- falling RFID tag prices
- vendor initiative for creating interoperable, cost-effective solutions.

The final two arguments presented in the reviewed sources are:

- lowered treatment costs
- reduced logistic and technology costs.

C. Smart implementation

The way RFID technologies are implemented can also be addressed as operational conditions or success factors beyond the scope of the technology itself. However, the frequency with which this topic was discussed in the literature suggests that how RFID is deployed in a complex system such as healthcare can be critical for its success, regardless of other enablers and obstacles. This can also be attributed to the fact that healthcare RFID is a relatively new technology, still rapidly developing and gaining popularity, lacking established best practices. Moreover, as RFID encompasses a multitude of technological solutions differing significantly in their functionality and purpose, the process of their implementation can be particularly important.

Smart implementation was frequently associated with:

- staged implementation (including conducting a well-planned and successful pilot)
- prior understanding on implementation costs
- the type of tags to be used and how the system will run on the network
- bundling the right mix of technologies
- stakeholder involvement in RFID application planning
- having a business plan for RFID in advance
- getting support from top-management
- admitting, billing, lab and patient care, vendor selection
- having an aggressive training program, staff training and consultation in the preparatory phase (Murphy, 2006).

An argument also frequently made was that simple implementation does not automatically result in problem resolution – first, hospitals need to fully understand their business process.

D. Technological superiority of RFID applications

The technological superiority of RFID over alternative technologies is another enabler for the adoption and dissemination of RFID healthcare applications. As discussed in Section 3.3, there are a number of technologies which can be viewed as alternatives to RFID tags and RFID infrastructure. This enabler category focuses predominantly on the former – the advantages of RFID tags. Identified benefits included:

- greater power, versatility and range of active RFID tags
- hospital-scale benefits associated with wireless networks required for RFID
- real-time data availability
- ability to store more and encrypted information
- user-friendliness.

E. Government incentives/support

The last category of enablers for RFID dissemination in healthcare, according to reviewed sources, has to do with the existence of government incentives and support for RFID application in the delivery of care at the national and supranational level. Examples of such incentives and support can include:

- the promulgation of standards for patient safety or medication safety calling explicitly for RFID application
- the adoption of quality standards in national healthcare systems
- the provision of financial incentives for RFID adoption (e.g. in response to satisfying practice requirements)
- supranational agreements on RFID operational standards, and on information privacy and security practices.

4.2 Most important obstacles to the use of RFID in healthcare

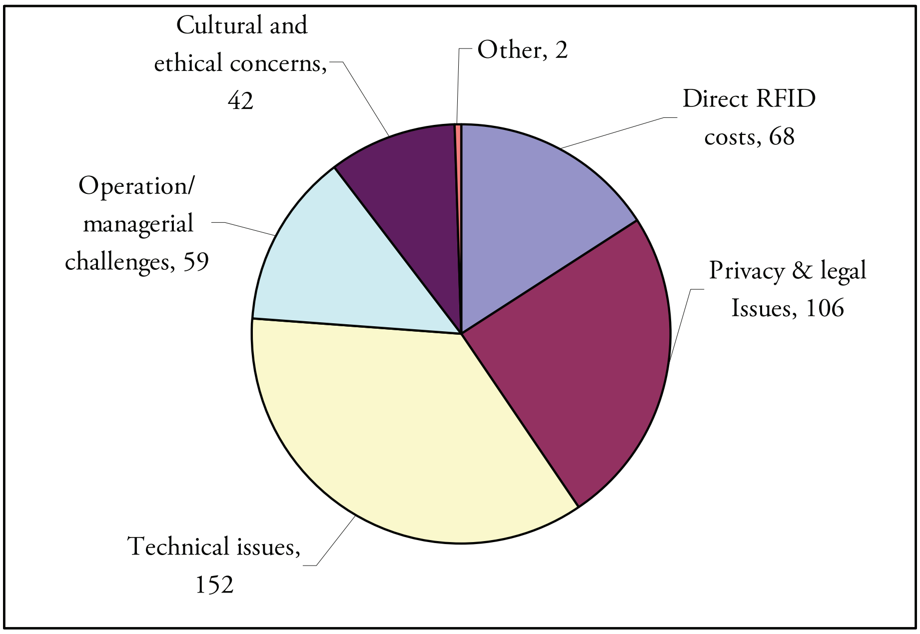
This section presents a ranked list of the key categories of obstacles to RFID technology dissemination in healthcare, along with a list of specific obstacles for each category as quoted in the literature. A brief description of the key obstacle categories is also given, with examples from reviewed sources.

4.2.1 List of obstacles

The most important categories of obstacles to wider-scale RFID implementation in healthcare, as identified by our screening, are:

1. direct RFID costs (RFID tags, infrastructure, middleware)
2. privacy, security, data integrity and legal issues
3. technical issues (interference, reliability, interoperability and standards)
4. operational/ managerial challenges (ROI, risk/uncertainty calculations, choice of technologies, best practice/successful cases, implementation costs/uncertainties, integration into IT application portfolio, maintenance costs, no integrated solutions on the market)
5. cultural and ethical concerns (ethical, cultural, social/societal, patient acceptance).

The ranking of the categories is based on the gravity of concern placed on them in the peer-reviewed and 'grey' literature, as well as their relative frequency of mention across all reviewed sources (see Figure 6 below). The latter, however, if taken as a sole criterion can be misleading as the categories vary in scope. For example, Category 1 includes only two distinct obstacles frequently discussed in different contexts, while Category 2 includes three distinct but intertwined issues that were often discussed together. We will seek to validate this classification and ranking of challenges in our interviews and case studies.



Source: RAND Europe

Figure 6: Most important categories of obstacles, per frequency of mention in reviewed literature

Table 13, below, contains the list of specific obstacles per category as quoted in the literature, with their respective frequency of mention. It includes a sixth, unidentified category of RFID dissemination challenges – Other – consisting of two entries which did not squarely fall within the scope of any of the other categories, yet did not merit the revision of the obstacle typology suggested above.

Table 13: Detailed list of obstacles per category and frequency of mention

Obstacle	Frequency
1. Direct RFID costs	68
Tag costs	65
Costs of infrastructure	3
2. Privacy & legal issues	106
Information security risk: privacy	49
Information security risk: security	25
Information security risk: data integrity	14
Legal	10
Data ownership issues	2
Cryptographic issues related to wireless transmission	2
Over-the-air spoofing attack susceptibility of VeriChip	2
Information security risk: confidentiality	1
Lack of clear laws & recommendations about tracking of goods and people	1
3. Technical issues	152
Interoperability	35
Standards	34
Reliability	26
Interference	20
Technology not yet fully mature	11
Existence and adaptability of international standards	6
Success of existing technologies	6
Healthcare industry factors (market structure, needs and requirements differ from other RFID-applying sectors)	3
Side-effects/consequences of exposure to electromagnetic energy on human health and/or product quality	3
Active RFID tag size	3
Bar codes already affixed by manufacturers/suppliers	2
Passive RFID fully reliant on electricity, bar code readers can use batteries	1
Proximity scanning need for RFID (anti-collision)	1
The relatively easy detachment of transmitters	1
4. Operation/ managerial challenges	59
Estimation of ROI without pilots	10
Choosing the right technology	9
Need for on-site engineering of specific applications	4
Modifying existing business processes	4
Integration of common RFID platform with existing IT application portfolio	3
Increased demands on nursing staff to keep RFID system operational	3
Building back-office infrastructure to support the system	3
Additional layer of complexity to infrastructure/processes	2
Staff training	2
Limited resources for research opportunities	2
Putting LAN infrastructure in place (workflow disruption)	2
No single vendor offers integrated broad solutions	2

Old building infrastructure	2
No best practice guidelines for RFID (vs. bar codes)	2
Lack of funding for RFID implementation	1
Not RFID-appropriate conventional financial analysis	1
Financial stability of vendor (to ensure continued support)	1
Vendors don't verify compliance of RFID system with current medical regulations (HIPAA)	1
No single hospital can test integrated broad applications	1
Older radio frequency networks	1
Only rudimentary applications are tested at pilots	1
Vendors don't tailor systems to specific hospital needs	1
Space for human error in scanning, despite 100% detection accuracy	1
5. Cultural and ethical concerns	**42**
Social /societal (perceptions etc.)	18
Cultural	13
Ethical	5
Patient acceptance and knowledge of benefits	4
Comfort level of hospital staff/preserving freedom of individuals	2
6. Other	**2**
Developing a comprehensive application standard model for regional diffusion	1
Funding and incentives and political awareness	1

Source: RAND Europe.

4.2.2 Describing obstacles

This section presents succinct descriptions of the five key barrier categories identified above.

A. Direct RFID costs (RFID tags, infrastructure, middleware)

Obstacle Category 1: Direct RFID costs include the continuingly high costs of RFID tags, RFID infrastructure and RFID middleware. According to Page (2007), the cost of RFID infrastructure can run from $200,000 to $600,000 or more for a facility-wide RFID tracking system in a medium-sized hospital. This almost prohibitive cost can be reduced by substituting RFID-designated reader networks with an existing WiFi network (at the cost of worse granularity and network overload), or by using handheld devices at all times (leading to loss of user-friendliness). Davis (2004) reports that the costs for an RFID system can run from $20,000 to over $1 million depending on the size of the area where the technology is deployed and the application. $20,000 can monitor and control patient movement in a small in-patient area. A $1 million system can track thousands of pieces of equipment throughout a hospital facility.

B. Privacy, security, data integrity and legal issues

The second set of key barriers to wide-scale healthcare RFID implementation includes the issues pertaining to the protection of the privacy, security, integrity and ownership of the data collected through RFID applications in healthcare; as well as the related set of legal issues pertaining to the use of this RFID data. These issues are still not fully or consistently addressed both within and across healthcare markets.

According to Sotto (2008), benefits of using RFID in medical settings are achievable only if patients are confident that the data being transmitted will not be misused. In addition, patients need to have confidence both in the security of the technology and in the related policy environment. Sotto distinguishes between four categories of privacy concerns, which however are not unique to the RFID context:

i) the inappropriate collection of health information through RFID technology (resolvable by allowing patients to opt out of RFID systems, and by not storing any medical data on the chip itself)

ii) the intentional misuse or unauthorised disclosure of the data by an authorised data holder

iii) the intentional interception of the transmitted/stored in RFID applications information and its subsequent misuse by unauthorised parties (generally addressed through encryption and authentication technologies)

iv) the unauthorised alteration of the data kept by an RFID application.

To mitigate the privacy concerns associated with healthcare RFID technology Hagland (2005) suggests that when engineering RFID systems health entities should ensure that neither personal, nor confidential information is transmitted via RFID. Such data shouldinstead be stored in a secure server in compliance with the Health Insurance Portability and Accountability Act (HIPAA).

Similarly, Halamka et al. (2006) point to the fact that VeriChip (an implantable RFID tag meant to provide key medical information in emerncies) is vulnerable to simple, over-the-air spoofing attacks. Scanning a VeriChip, eavesdropping on its signal, or simply learning its serial number can create a spoof device whose radio appearance is indistinguishable from the original. They regard this as the key obstacle to VeriChip's large-scale implementation. However, the authors suggest that, paradoxically, for bearer safety a VeriChip should be easy to spoof; an attacker then has less incentive to coerce victims or extract VeriChips from victims' bodies. They also suggest that VeriChip should serve exclusively for identification, and not authentication or access control.

C. Technical issues (interference, reliability, interoperability and standards)

Another set of issues serving as obstacles for wide-scale RFID dissemination are:

i) the lack of unequivocal clarity on the absence of technical issues with the reliability and interoperability of RFID technologies

ii) its non-interference with other clinical systems or bio-medical implants

iii) the lack of RFID industry standards and tested best practices.

For example, the lack of standardisation of the protocols for RFID at the hardware and software levels causes lack of interoperability across providers Fisher and Monahan (2008) also identify as specific obstacles to RFID use the practice of vendors to not verify compliance of RFID system with current medical regulations (HIPAA), and the fact that vendors also don't routinely tailor systems to specific hospital needs, leading to maladaptation of technology. They also highlight the limited interoperability between RFID and existing systems in hospital (due to few standards).

One prospect for overcoming some of these obstacles is the European Commission decision in 2007 to adopt formally an ultra-wideband (UWB) frequency range from 3.4 to 4.8 GHz and 6 to 8.5 GHz, for RFID healthcare application use in EC member countries. This will establish several frequency limitations requiring UWB vendors to alter their technology to meet those limits.

D. Operational/ managerial challenges

While the smart implementation of RFID solutions was highlighted as one of the main enablers for RFID dissemination, a large number of operational/managerial challenges have been cited in the literature as a key barrier to RFID implementation. These include:

- lack of return on investment (ROI) guarantees, mainly due to wide variability of RFID technologies and of settings within which they are deployed
- lack of standardisation in the risk/uncertainty calculations performed for identical RFID applications
- difficulties in choosing the optima mix o RFID technologies to match the needs of the adopting institution
- lack of RFID Best Practices due to the relative "youth" of the technology
- implementation costs/uncertainties, also due to the relatively little experience thus far acquired with RFID
- challenges related to integrating the RFID solutions into the existing IT application portfolio
- maintenance costs (which may not be clear upfront)
- the limited availability of integrated RFID solutions on the market.

According to Hagland (2005), other specific RFID adoption challenges include:

- building a hospital-wide infrastructure
- overcoming attendant back-office hurdles, and
- the successful bundling of applications within a hospital.

Dempsey (2005) also identifies as main RFID challenges the need to recognise that there are different types of RFID, each with a rightful place in health care; and that RFID implementation can lead to organisational challenges and a change in processes.

E. Cultural and ethical concerns

According to the reviewed sources, a final set of obstacles to wider RFID implementation in healthcare are the cultural and ethical concerns associated with RFID. These include:

- concerns about the surveillance potential of RFID
- lack of understanding of the true privacy and security threats associated with RFID in healthcare, and in general
- ethical, cultural, and social/societal perceptions about RFID and its functions
- lack of potential patient acceptance due to the factors listed above.

According to Fisher and Monahan (2008) there is also a need to examine more closely the social and organisational factors that contribute to the success or failure of RFID systems, and their consideration should be woven in the preparatory work for RFID deployment.

4.3 Critical uncertainties for the use of RFID in healthcare

In this section we list and describe the critical uncertainties about the use of RFID in healthcare as highlighted in our review.

4.3.1 List of critical uncertainties

The critical uncertainties about the use of RFID in healthcare applications were significantly less frequently discussed in the literature than the types of RFID applications, or the key enablers or barriers to their wide-scale dissemination. However, based on the reviewed materials, we can highlight the following list of key critical uncertainties about RFID dissemination:

- cost of RFID, in particular for interoperable solutions
- acceptance of national or supranational RFID standards on private information protection, security and data integrity (especially with respect to open-loop applications)
- promulgation of sub-national, supranational or national mandates/regulations on RFID implementation in healthcare (e.g. in connection to patient safety, such as e-handshake for positive identification at point of care)
- public opinion on RFID.

We will seek to verify and expand this list during the next stages of the project.

4.3.2 **Describing uncertainties**

A. Cost of RFID

As highlighted in the list of obstacles discussed above, the direct cost of RFID solutions is one of the key barriers to the large-scale application of this technology in healthcare. While it is widely believed that the prices of RFID tags, both passive and active, will fall substantially in the near future (Harrop et al., 2007), and similar assumptions are made about complete RFID applications, including tags, infrastructure and middleware/hardware, the size of the cost decrease and its timeline are somewhat ambiguous. Even more so are the costs for the more recent generations of RFID-based interoperable solutions that support integrated hospitalwide, or hospital systemwide approaches, and the telemedicine and intelligent, forward-looking RFID applications in out-patient care.

Better understanding of integrated/intelligent-solution RFID price horizons and drivers, as well as concrete impacts, will be goals of our interviews and case studies.

B. Acceptance of national or supranational RFID standards on private information protection, security and data integrity

The personal data privacy, security and integrity issues associated with RFID technology applications in healthcare appear to be another set of key barriers currently inhibiting their scaling up and dissemination.

While the threats current healthcare RFID applications entail are not as looming as occasionally publicly portrayed (as discussed in section D below), they are real and potentially particularly pernicious for open-loop RFID applications. There has been continuous debate on what rights, for whom, and how they should be guaranteed, in the healthcare and policymaker communities (Fisher and Monahan 2008) with no prospects for upcoming resolution. There is also increasing fear of potential privacy threats as the capacity of interoperable RFID technologies expands and so do the hopes placed on them.

C. Promulgation of subnational, supranational or national mandates/regulations on RFID implementation in healthcare

Currently, there are few general national mandates worldwide on RFID implementation in healthcare. There are even fewer such for concrete RFID applications (a notable exception is the US FDA mandate on medication pedigrees, which mentions RFID). As mentioned above, the lack of such mandates is largely seen as a hindrance. Moreover, the existence of similar mandates for technologies viewed as alternatives to RFID (e.g. bar coding and Bluetooth) is regarded as particularly problematic, as these create strong incentives to hospitals to invest in systems other than RFID and support them until fully obsolete. In this context, the potential promulgation of subnational, supranational or national mandates/regulations on RFID implementation in healthcare can have an important impact on RFID's scaling-up capacity.

D. Public opinion on RFID

As with the other key uncertainties we have identified, public opinion on RFID is an uncertainty factor rooted in the key obstacles our literature reviews emphasised, namely – Category 5: Cultural and ethical concerns.

While RFID applications in healthcare have largely been received with much anticipation and attention to privacy issues in the healthcare community, the true threats the technology carries for personal data security and privacy have largely been misunderstood in the popular media (Boulard, 2005; O'Connor, 2005c). The distinction between these threats and those posed by RFID applications in other fields is also not widely understood. Based on these fears, a number of anti healthcare-RFID initiatives have already emerged in the US – including a Christian-based consumer union referring to RFID as the "sign of the Beast" (Albrecht, 2007) – and secular lobbying initiatives aimed at preventing RFID deployment through fear of ubiquitous surveillance (Boulard, 2005).

Although such strong negative reactions to RFID healthcare applications are not frequent or overpowering, the lack of public understanding about the feasible risks and challenges facing the still-developing healthcare RFID industry could have very damaging effects on its potential to improve the safety and quality of healthcare provided. This is especially the case if there is no widespread awareness of RFID among consumers (a rather dated 2004 study by CapGemini reported that only 18% of European respondents to its survey had heard of RFID). These issues can be particularly hard to overcome among older Europeans whose acceptance of RFID is a prerequisite for the success of any RFID-based in- and out-patient quality-of-care improvements. Drafting national and supranational legislation which addresses the privacy and legal issues discussed in the obstacles section above, supported by public information campaigns, is likely to help avert such outcomes.

CHAPTER 5

Examples of promising completed or on-going RFID trials, pilots and applications by country

This chapter presents a first selection of promising RFID applications, pilots and trials descriptions to be used for the selection of in-depth case studies in the following stage of the project. The examples presented are meant to be illustrative, not exhaustive, and other applications and pilots identified during the expert interview and Delphi stages of the research will also be considered.

The chapter, therefore serves as a taking-stock step – allowing us to asses the landscape of plausible applications – and a bridge to the next stage of the project in which we will select up to six case studies for more in-depth analysis of the benefits, enablers and barriers to RFID implementation in healthcare. The current chapter also illustrates how the conceptual classification scheme we proposed in Tables 2 and 6 can be correlated with real-life RFID applications.

The criteria for selecting the application and trial examples presented in the first section, and for the short application descriptions in the second section (for which more information was available), included:

- capacity for near-term scalability
- impact on quality and continuity of care and patient safety
- impact on the effectiveness and efficiency of care delivery.

In addition to these criteria, to arrive at a candidate list of case studies for in-depth exploration in the next step of our work, we considered:

- data availability on the impacts and costs of the application
- presence of interoperability across RFID functions.

Although our emphasis is on applications in Europe, in this chapter we also present trials and experiments that took place internationally as we believe they meet the criteria for forward-looking, integrative and ambient intelligent solutions and thus complement the activities and experience gained in Europe. Our expanded search identified applications in countries other than the ones we initially included in our selection criteria; certain of these applications are included and presented in this chapter. Case studies are presented from the following countries (alphabetically): the Czech Republic, Finland, Germany, Italy, the Netherlands, Norway, Switzerland, United Kingdom, Canada, India, Japan, Taiwan, and the US. We believe that the great variability in the healthcare systems in which these applications took place can provide valuable insights into the relevant factors affecting RFID dissemination and cost-to-benefits potential.

5.1 Relevant trials, experiments and other completed or ongoing RFID applications

In this section we present a list of relevant trials and experiments within the most promising domains for RFID application in the sphere of healthcare delivery and, in particular, quality of care and patient safety, as discussed in Section 3.2 above.

Table 14, below, is a list of examples of promising healthcare RFID trials and experiments by:

- healthcare application (according to the typology developed in Section 2.3 and the list of most promising areas for RFID deployment in healthcare in Section 3.2: quality of care, patient safety, treatment, diagnostics or hospital management)
- description/function (again using the typology in Section 2.3 and application areas highlighted in Section 3.2: tracking, identification and authentication, automatic data collection, and sensing)
- case description/manufacturer
- case-study location (where available).

The list is only illustrative of the types of RFID applications that meet the selection criteria laid down in the Inception Report, namely those that can lead to:

- better adherence to recommended care
- better patient satisfaction
- reduced medical error rates
- improved final outcomes and costs

and those that are perceived as scalable in the near future. It also attempts to fill out the list of most promising application areas for RFID presented in Section 3.2.

Table 14: Examples of promising RFID trials by focus, application and country

Healthcare application	Description/ function	Case/ manufacturer	Trial location[12]	Country
Patient safety	Implantable chips/ EPR (out-patient) *Identification*	VeriMed Patient Identification System Network(VeriChip) – chips containing key medical information	x	US
Patient safety	Portable medical record (out-patient) *Identification*	MedicAlert – tags containing key medical information and an ID number allowing emergency medical personnel or law enforcement to retrieve detailed medical information on the patient	In operation in the US since 1956, in transition to RFID	US
Patient safety/ personnel support	Portable updatable medical records (in-patient) *Identification; automatic data collection; tracking*	Portable updatable medical record available on a smart, wireless RFID flexible skin patch (Frank Sammeroff Ltd. & Gentag, Inc.)	x	US
Patient safety/ personnel support	Patient tagging (in-patient) *Identification; automatic data collection; tracking*	Wristbands with EPR (Siemens)	Klinikum Saarbruecken	Germany

[12] Trial locations are not presented for all examples as they were not readily available in the reviewed sources. However, they can be obtained by the authors of the articles if selected for in-depth case studies.

Healthcare application	*Description/ function*	*Case/ manufacturer*	*Trial location*	*Country*
Patient safety/ personnel support	Patient tagging (in-patient) *Identification; automatic data collection; tracking*	Smart wristbands (Precision Dynamics) carrying medical record number and key patient data, interlinked with existing hospital applications for patient record updating	North Bronx Health Centre (NBHN); Jacobi Medical Centre (NY)	US
Patient management	Patient tagging (in-patient) *Identification; tracking*	Prospective Patient Flow manager (Radianse)	Providence Health Centre (Waco Texas)	US
Patient safety	Patient item tagging for stray-prevention (out-patient) *Tracking*	Patient item tagging for stray-prevention (dementia)	X	Taiwan
Patient safety/ quality of care	Remote monitoring of in-patients in real time *Sensing;, automatic data collection; identification*	eICU – Remote monitoring of ICU patients in multiple hospitals via cameras and telemetry, allowing communication with the hospital staff in real time	Advocate Health Care, Chicago; Sentara Health Systems, VA	US
Patient safety/ quality of care/ pharmaceutical application	Patient non-compliance; track medication use (out-patient) *Sensing; identification; automatic data collection*	MedAmigo (Aardex) – a Measurement Guided Medication Management program showing and recording real-time dosing histories	x	Switzerland

Healthcare application	*Description/ function*	*Case/ manufacturer*	*Trial location*	*Country*
Patient safety/ quality of care/ pharmaceutical application	Patient non-compliance (out-patient) *Sensing; identification; automatic data collection*	Electronic Compliance Monitor (Med-ic) retrieving and displaying patient compliance information for any standard blister packaging format	On-going trial in Europe with 250,000 patients	Canada
Patient safety/ quality of care/ pharmaceutical application	Alert patient non-compliance; track medication use; symptom monitoring in ambulatory setting *Sensing; identification; automatic data collection*	RFID-enabled eMedoline (Leap of Faith Technologies)	x	US
Patient safety/pharmaceutical application pharmaceutical application	Preparation and processing of drugs and therapies (in-patient) *Sensing; automatic data collection*	To be further expanded to patient IDs, personnel IDs & asset inventory	Masaryk Memorial Cancer Institute	Czech Republic
Patient safety/ personnel support	Real-time safety reminders (in -patient) *Identification; automatic data collection*	Real-time safety reminders to physicians, including laboratory and radiology reports	Pilot with 10,000 patients at non-psychiatric hospitals in Taipei	Taiwan

Healthcare application	*Description/ function*	*Case/ manufacturer*	*Trial location*	*Country*
Quality of care	Ingestible, diagnostic tags *Sensing*	M2A Patency Capsule – ingestible, dissolving tags to replace invasive and dangerous small bowel diagnostic	Asian Institute of Gastroenterology, Hyderabad	India
Quality of care	Ingestible diagnostic tags *Sensing*	Eastman Kodak	x	US
Patient safety	Wrong site surgeries (surgical error) *Tracking*	SurgiChip	Trial at The Palm Beach Orthopaedic Institution	US
Patient safety	Leaving sponges and tools behind *Tracking*	Siemens	Klinikum Rechts der Isar, Munich	Germany
Patient safety	Leaving sponges and tools behind *Tracking*	SmartSponge from ClearCount	Stanford University School of Medicine	US
Patient safety	Leaving sponges and tools behind *Tracking*	RF-Detect, RF Surgical Systems	x	US
Patient safety	Management of blood transfusions *Identification; sensing*	Ecross-match	San Rafaele Blood Bank (Milan)	Italy

Healthcare application	*Description/ function*	*Case/ manufacturer*	*Trial location*	*Country*
Patient safety/ management of supplies	Person and patient logistics in the operating rooms; tracking and tracing of operating room materials; tracking and tracing of blood products. *Identification; tracking; automatic data collection*	AMC, Intel, Geodan, Oracle, CapGemini	Amsterdam Academic Medical Centre (AMC)	Netherlands
Management of supplies/ patient safety	Tracking and tracing of surgical sets *Tracking; automatic data collection*	Embedded RFID tags to trace small equipment through decontamination cycle	Leeds Teaching Hospitals NHS Trust (General Infirmary)	UK
Management of assets	Tracking and tracing of medical devices *Identification; tracking*	Bed management (Siemens)	Bielefeld Hospital	Germany
Management of assets	Tracking and tracing of medical devices for inventory management *Identification; tracking*	IRISupply Cabinet (Mobile Aspects)	Preoperative services department at NY Presbyterian Hospital	US

Source: RAND Europe

5.2 Examples of promising completed or on-going RFID trials, pilots or applications by country

Below is a selection of short application descriptions we identified in the process of our review as particularly relevant to the objectives of the study, organised by country of implementation. The application and trial examples were selected for their capacity for near-term scalability, impact on quality of care and patient safety, and the effectiveness and efficiency of care delivery. Attention was also paid to telemedicine and telemetry solutions that can provide continuity of care in the out-patient setting. While we sought to present applications, pilots and trials mostly taking place in Europe, we are also reporting the international experience either as a benchmark for comparison or due to lack of pilot replication in the European context.

5.2.1 Germany

<u>Haemovigilance – Saarbrücken Clinic Winterberg</u> (Wessel, 2006b; pilot)

Both patients and blood products at the Saarbrücken Clinic Winterberg Hospital are provided with RFID tags to ensure that minimal mistakes are made in the provision of blood.

In the test phase, about 1,000 bags of blood are being labelled, and all steps – from assigning each bag to a patient to the start of a blood transfusion onwards – are being tracked and recorded. All patients admitted to the hospital are given a wristband with a round case; inside the case is an ISO-compliant 13.56 MHz passive RFID chip which contains patient information. A match must be made between the data from the patient and the bag before the blood can be used. Data is read using a handheld computer.

Before the system was implemented, bags of blood were tracked with bar codes and human-readable text. With the new blood-tracking system, hospital workers attach a self-adhesive 1.5 by 1 inch RFID label to each bag of blood arriving at the hospital. The labels passive 13.56 MHz RFID chip has 2 kilobytes of memory for storing a unique identification number, the hospital tracking number (used by the blood bank system) and information on blood type.

<u>Medication error reduction: Jena University Hospital</u> (Wessel, 2006c, 2007a; pilot)

Germany's Jena University Hospital is testing a system using RFID to track medication from the point of dispensing in the hospital's pharmacy to the drug's administration to up to 24 patients in intensive care, in order to avoid drug errors.

The pilot is initially focusing on antibiotics. Before the prescribed antibiotic leaves the pharmacy on an automatic transport belt, the pharmacist will apply an RFID tag to the sealed packet of an individual dose of medication. In addition, the box transporting the bottles – as well as containers holding multiple items – will be tagged. Portal readers provided by Intel will read the tags as the medication leaves the pharmacy. At this step in the process, the exact pill count, its destination patient and other details will be transferred to a computer server. As the antibiotics arrive at the intensive-care unit, they will again be scanned with portal readers before nurses unload containers. The server will then be updated about the medication's arrival, after which the nurses will unload the containers and bring the appropriate medication to the patients' beds.

Preventing left-ins: Isar River University Hospital (Bacheldor, 2007o; trial)

To avoid the risk of leaving behind materials in a patient's body during surgery, Siemens and Isar River University Hospital, Munich are running a test with RFID tagging of materials. Siemens IT Solutions and Services, a division of Siemens, has teamed up with the hospital to test the use of active and passive RFID tags to:

- track sponges, swabs and other items used during surgery
- track the surgical process itself.

Klinikum Rechts der Isar (Isar River University Hospital) wants to test how well RFID technology can be used to ensure that sponges and swabs used during surgery are not inadvertently left behind inside a patient's body. According to Siemens, the project will use passive 13.56 MHz RFID tags, which will be manually woven into the sponges for the purpose of the test

5.2.2 Italy

Haemovigilance: National Cancer Institute (Sini et al, 2008; pilot)

In a pilot project to increase efficiency and safety in the management of the transfusion process in Italy's National Cancer Institute in Milan, RFID tags are placed on blood bags and patient wristbands. Staff are provided with RFID ID cards and personal digital assistants (PDAs or handheld computers) to:

- register patients upon arrival
- verify patient-blood group
- recognise patients and transfusion units at any time.

Previously, the Institute had no information system for the detailed monitoring and control of the process. The aim of the trial was to control and monitor the transfusion system in order to enhance transfusion safety, transparency and quality of care. According to the author, the pilot was successful and RFID resulted in safe transfusions and total blood traceability in the ward.

An expansion of the current project to the tracking of surgical instruments in the operating theatre and active monitoring of the Tissue Bank are currently planned.

Haemovigilance: Ospedale Maggiore (Wessel, 2006h; application)

To avoid errors with blood transfusion, the Italian hospital Ospedale Maggiore in Bologna has been using an RFID-based system to match patients and blood bags. It is moving from the currently used iButton, which consists of a computer chip enclosed in a 16-millimeter stainless steel circular case that requires a cable to be read. The hospital is moving toward an RFID system for several reasons:

- it is more user-friendly
- it has faster reading and writing capabilities
- it has larger data-storage capacities
- it can perform some steps of the positive-identification process automatically.

The newly introduced Tiomed system features MediLock, an RFID-based electronic seal attached to bags of blood. MediLock can be unlocked only when a multifunctional, wireless handheld device, the Palmed, communicates the correct identity of a patient receiving the blood. About the size of a mobile phone, the Palmed includes an RFID interrogator that conforms to the ISO 15693 standard and operates at 13.56 MHz. Finally, the MediLock contains a temperature sensor allowing it to monitor the temperature of the air outside the blood bag and its carrier. Once the MediLock is sealed, it begins to keep a log of the external temperature and the time, since blood can spoil at certain temperatures.

<u>Patient tracking: Ospedale Treviglio-Caravaggio</u> (Swedberg, 2008a; application)

In 2006, Ospedale Treviglio-Caravaggio, located in Treviglio, Italy, deployed an RFID system to track its patients as they are admitted to the hospital's emergency wing and then as they move through the facility, receiving medical services.

With an RFID system provided by Softwork, hospital personnel can immediately locate a patient. When new patients are admitted to the hospital, they receive an Identec Solutions active 915 MHz RFID tag to wear around their neck. Each tag contains a unique RFID number linked into the hospital’s database with that patient's name and pertinent health information. Portals are in place in the building with RFID readers to monitor where patients are.

The reported cost of the system was about €100,000 ($71,400).

5.2.3 **Netherlands**

<u>Medication compliance: Novartis</u> (Collins, 2006d; trial)

Novartis used battery-powered RFID tags embedded within medication blister packs in a European trial to evaluate the benefits of medication compliance monitoring.

From mid-October 2005 to mid-May 2006, 20 pharmacies in the Netherlands dispensed Novartis’ hypertension medication Diovan in RFID-enabled packages developed by Swedish RFID packaging specialist Cypak. The trial used Cypak’s active RFID Intelligent Pharmaceutical Packaging (IPP) design, with each package storing the date and time a patient removed a pill. When the patient returned the empty package to the pharmacy, the pharmacist placed it on a network-connected Cypak RFID interrogator, which displayed details of when the medication had been taken. The data was also uploaded to a central database, making the information available to authorised personnel, including physicians and the patients themselves.

The trial has showed that monitoring patients' compliance with medication prescriptions can help them comply with their medication schedule, thereby improving the benefits of taking the drug.

<u>Haemovigilance, asset, staff and patient tracing: Amsterdam Medical Centre</u> (Wessel, 2007c; pilot)

An RFID pilot at the Amsterdam Medical Centre consisted of:

- tracking and tracing medical equipment in the operating room
- monitoring the movements of patients and staff in and around the operating room (OR)
- tracking and tracing blood products.

The goal of tracking patients and staff in the operating room was to determine whether the hospital could use RFID data to optimise schedules so more patients could be treated. Each week, the pilot tracked about 20 patients having open-heart or vascular surgery.

The goal of the combined medical equipment- and patient-tracking pilot was to provide AMC with a clearer picture of which disposable products were used in which operations, and on which patients. That information could help AMC save money by controlling inventory and stock levels, and by accurately billing patients and insurers for the specific materials used.

The goal of the blood-tracking pilot was also to see if RFID could be a viable alternative to bar codes for meeting European Union blood-safety guidelines. These guidelines mandate that hospitals must always know where various blood products are, and under what conditions they are being stored.

Several benefits in the design of the pilot were observed:

- The hospital found that it was able to save upfront costs by employing the same interrogator infrastructure for the blood- and patient-tracking pilots.
- It was successful in confirming that the correct patients were receiving the proper blood products.
- It was also possible to identify which patients were treated with which medical devices.

<u>Asset management: Ter Gooi Hospital</u> (Bacheldor, 2007s; application)

To improve efficiency, Ter Gooi Hospital employs Wi-Fi-based active tags to track the location of infusion pumps and, later, EKG machines, in its surgery recovery and orthopaedics wards.

The system was installed by Ship2Save and uses AeroScout Wi-Fi-based 2.4 GHz battery-powered RFID asset tags, along with exciters to activate the tags, causing them to transmit their identification numbers. It also includes the AeroScout Engine, which calculates tag locations by processing data from the tags and various Wi-Fi access points.

Ter Gooi's Real Time Location System (RTLS) employs nine Wi-Fi access points, which the hospital had already installed as part of its Wi-Fi-based network, and eight exciters situated within the two wards and storage room.

Benefits from the application include better use of staff time, and more timely care.

5.2.4 **Norway**

Scrubs distribution: Trondheim Hospital (O'Connor, 2007d; application)

Trondheim Hospital has deployed an RFID-based uniform-tracking system offering real-time inventory visibility of its uniforms to save space and labour costs while improving inventory accuracy.

Texi, a Norwegian textile management solution provider, designed and deployed the system for the hospital using passive 13.56 MHz RFID tags from Texas Instruments (TI) and readers made by Feig Electronic. The tags, which are sewn into the garments, comply with the ISO 15693 and ISO 18000-3 standards.

Inventory closets and bins for soiled garments have readers which update the back-end software inventory list. Further, personnel RFID tags are linked to special uniforms when taken from special inventory closets. Since the new system required 90% less space than the old system (which was housed in an older, now defunct facility), it has already saved an estimated 40 million kroner ($6 million) in space savings.

5.2.5 **Finland**

Medication compliance: Medixine (Collins, 2005b; trial)

Medixine, a Finnish company specialising in disease management, tested a new communications system using RFID and mobile phones to help make sure Alzheimer's patients take their medication.

The system uses what the company calls an RFID communication board. Measuring approximately 8 by 12 inches, the board can be fitted with up to six near-field communications (NFC) RFID tags. During the trial, each patient is issued with an NFC-enabled cell phone and an RFID communication board with a template customised to his or her medical requirements. The template slides in a slot over the board and is printed with symbols positioned over its RFID tags. In the trial, three symbols and three tags are being used. One symbol confirms that medication has been taken, another asks for someone to call for a chat (e.g. 'I feel lonely'), and the third requests an immediate call in response to an emergency. When the patient touches the NFC-enabled phone to a symbol, the phone reads the unique ID number of the tag beneath the symbol and transmits that number over the cellular network to Medixine's medication management server application. If a patient does not touch the symbol on the board, then no message is sent, and the system assumes the patient failed to take the prescribed dosage and sends a reminder in the form of a pre-recorded voice or text alert, either to the patient or to a relative or caregiver.

NFC technology aims to provide a standard, low-cost way for a range of NFC-enabled objects and electronic devices to communicate with other devices over short distances, hence much hope is placed on the product.

5.2.6 United Kingdom

Patient identification and tracking: Birmingham Heartlands Hospital (Bacheldor, 2007r; application)

Birmingham Heartlands Hospital is using a system of passive HF RFID-enabled wristbands to:

- track patients and procedures in two surgical wards
- identify patients
- decrease incidents harmful to patients.

It is using plastic wristbands from Brenmoor, embedded with 13.56 MHz, ISO 15693-compliant RFID inlays, on all patients in its thoracic (chest) and ear, nose and throat (ENT) surgical wards.

The RFID wristbands are being issued to surgical patients, printed and encoded using an RFID wristband printer when the patients are admitted to the hospital. The RFID inlay embedded in each wristband is encoded with a patient's ID number, name, date of birth and gender. The patient inlay data is then associated with patient records held within back-end hospital systems, including the patient administration and surgical booking systems. A digital photograph is also taken of each patient, which is uploaded into the hospital's systems to further verify that person's identity.

Surgeons, anaesthesiologists and pre-operative nurses have wireless PDAs allowing them to view operating schedules and patient records. The wristband can be scanned through the hospital clothing, but the interrogator must be within about 10 inches to read it. Once the wristband is read, the system can pull up the patient's record.

Medication authentication (Collins, 2004b; trial)

In 2004, Merck, Novartis and three other pharmaceutical companies ran a trial that tagged individual items to detect dispensing errors and counterfeit drugs before they reached patients.

However, the items were not tracked through the supply chain. The 'authentication at the point of dispensing' pilot used read-only 13.56 MHz tags from Rafsec that conformed to the ISO15693. RFID tags were used along with a range of bar code technologies, including a unique ID number, EAN 128, Datamatrix 2D and RSS 14 bar codes.

Items were scanned before dispensing and the unique serial number on the tag or printed bar code was linked to the item's product data. The item was then scanned again prior to sale to ensure the product was authentic and correct.

Infant/elderly security: Xtag (Maselli, 2003; trial)

Xtag has developed a new RFID security system for tracking babies in hospital infant wards or wandering patients in elder care facilities. Xtag says its readers are designed to work with existing access control systems.

The Xtag system consists of a bracelet with an embedded battery-powered tag that operates at 433.92 MHz, readers placed at doorways and in hospital hallways, and software that manages the system. The transponder in a baby's or patient's bracelet or a staff member's ID badge emits a signal every two seconds. Readers placed throughout the facility pick up the signal and transmit location data to the software. If a baby or patient were to pass through an exit without authorisation, the reader would automatically send an alert to nurses or security staff via email, SMS message, pager or other predefined method. The message relays the exact location where the alarm was triggered, along with the time and date.

The product, which uses an FM transmission signal, also monitors the tags' battery status. If a badge is removed without authorisation, an anti-tampering signal is emitted from the chip and is picked up by the readers, which have a read range of 1.5 to 50 feet (0.5 to 15 meters). The system also alerts staff when the battery in a bracelet is running low.

Hospital equipment library: Royal Alexandra Hospital (Britton, 2007; application)

The Royal Alexandra Hospital uses a hospital-wide RFID asset tracking virtual asset library to:

– improve the use of its assets
– ensure the availability of medical devices at the point of need
– streamline routine scheduled maintenance
– reduce health and safety risks resulting from failure to meet scheduled inspection plans
– overall, improve equipment tracking, training and use across departments. .

Overall, the equipment costs for installing the system across the whole of the Royal Alexandra Hospital, together with the software, were estimated to be between £80,000 and £100,000. This is a basic system incorporating 40 active readers with an RJ45 communications interface, 900 tags, appropriately developed software and a server. Maintenance costs are estimated to be approximately £12,000 per annum – including software maintenance at £6,000 (representing 20% of total software capital cost), and another £6,000 to update and change the active readers and tags (representing 8% of the total equipment cost). Assuming that a one-year warranty applies, this gives a total cost for the system over 10 years of £208,000. When compared to setting up a fixed equipment library as a new build solution, which over 10 years relates to a total investment of £250,000, RFID would appear to be the more cost-effective solution.

The benefits from the virtual asset library are reported to be numerous, including roughly £10,000 annually saved on asset maintenance, and more timely availability of assets when needed.

5.2.7 **Canada**

Infant/elderly security: ProSolutions (Bacheldor, 2008a; trial)

ProSolutions, a Canadian start-up company, is now reselling an RFID-enabled system designed to protect newborn babies, Alzheimer's patients and other individuals staying in healthcare facilities. The BlueTag system, from Paris-based BlueLinea, uses active ultra high frequency (UHF) RFID tags embedded in bracelets.

The BlueTag system incorporates interrogators with integrated antennas, a computer and Blue Tag software, which contains a repository of each tag's unique ID number and associated patient information. The RFID-enabled bracelet is hypoallergenic and waterproof, and can be worn on the wrist or ankle. Removing the device without authorisation – if, for instance, someone were to cut the bracelet off – triggers an audible alarm. An alarm also sounds if anyone wearing the bracelet passes through a doorway equipped with the readers.

5.2.8 **USA**

Patient care documentation: Huntsville Hospital (Bacheldor, 2007k; application)

To improve efficiency and communication that would directly improve surgical start times, Huntsville Hospital is using passive HF tags to verify a patient's identity and document the surgical process, from admission to discharge. It is employing Aionex,s RFID-enabled Advanced Patient Response Platform (APRP), an integrated communication and transaction software product that can monitor caregivers as well as help keep track of patients. The system uses SkyeTek passive 13.56 MHz RFID tags and interrogators that comply with ISO 15693, ISO 14443A and ISO 18000-3 air-interface protocols. The tags are embedded in stickers and key fobs.

As the patient moves to each stage of surgical process, nurses or other caregivers scan the tag, and the tag ID number is automatically entered into a patient kiosk. –This consists of an embedded CPU, a touch-screen monitor, a Wi-Fi card and an RFID scanner. The kiosk compares the patient's name with the information associated with the tag ID; it will generate an error if the RFID tag and the patient identified do not match.

Today, the hospital issues about 2,400 RFID tags per month in the form of adhesive stickers worn by patients, and 25 RFID-enabled key fobs given to anaesthesiologists.

Patient-centred care: Willowbrook Emergency Health Centre (Bacheldor, 2007e; pilot)

The Emergency Health Centre (EHC) at Willowbrook, a freestanding provider of 'concierge' (personalised) emergency, diagnostic and imaging services in Houston, is using a real-time location system (RTLS) to improve its patient care.

The EHC tags its patients with RFID-enabled wristbands upon arrival and uses the RTLS system to track:

- how long patients wait before receiving care
- which caregivers are treating patients
- how much time caregivers spend with patients.

The system also alerts hospital employees when beds and rooms have been cleaned and are ready for incoming patients.

The RTLS combines Sonitor's ultrasound-based indoor positioning system (IPS) with Amelior EDTracker software from Patient Care Technology Systems (PCTS). Amelior EDTracker is designed to enable emergency departments to monitor and analyse patients' physical locations, as well as the status of their care. It then displays that information in charts and graphs via LCD screens and computers located throughout the hospital. Sonitor's IPS uses battery-powered tags that transmit 20 kHz to 40 kHz acoustic signals to receivers. Through frequency modulation, each tag communicates a unique signal to the receivers, which employ Sonitor's patented Digital Signal Processing (DSP) algorithms to calculate the signals' locations and convert them to data. The receivers then transmit the location and tag data via an existing LAN to a central computer.

Quality of care improvement: St Vincent's Hospital (Gambon, 2006; application)

St Vincent's Hospital, Alabama, deployed a patient-tracking and real-time clinical information system that:

- improved the quality of care
- increased revenues
- delivered on ROI.

Previously, St. Vincent's lacked up-to-the-minute information about the availability of the beds. As a result, patients had to be diverted and the hospital lost an estimated $20 million in net revenue. To address this problem, the hospital developed a strategy to:

- improve patient visibility
- eliminate backups in admissions and discharges
- reduce the time spent waiting for care.

A first step in reaching those goals was getting better insight into where patients were at all times, as well as making available real-time information about the status of doctors' orders and test results.

It launched a pilot project with an RFID system in the 34-bed cardiac-care unit. The tags were attached to the patients' charts, which accompany them wherever they go in the hospital. The system operates at 433.9 MHZ and reads the tags every 10 seconds. The RFID interrogators, wired into the hospital's Ethernet network, send information about the patient's location to an SQL Server database. Any location changes the interrogators detect are written to the database, then displayed in real-time on screens installed throughout the hospital. To protect privacy, no names are displayed on the screens – only room numbers identify the patients.

In addition to the patient-location information, the system integrates clinical data and relevant information, such as notification of lab results, prescription orders and other medical instructions. The system conveys this information on screens through a series of colour-coded graphics and icons, allowing nurses to tell at a glance what care a patient requires.

The entire project cost an estimated $1.7 million, including the PCs, software, RFID tags, interrogators, installation and integration, and it quickly reaped results. The number of patients discharged by noon – a key measure of operational efficiency for the hospital – climbed by 20% to about 40%. Moreover, fewer patients are being turned away for lack of beds: patient diversions dropped by 25% in the critical-care unit, and by 60% among medical-surgical beds.

The hospital estimates that in was able to serve more patients using the RFID system, for a net revenue increase of $2.58 million during the initial phase. The revenue gains have continued, with the hospital taking in an additional $5.5 million between March and July 2005. The 12-month ROI for the project was 151%, according to the hospital.

<u>Tracking and tracing assets and equipment: Southern Ohio Medical Center</u> (Swedberg, 2008b; application)

Southern Ohio Medical Center has deployed the Radianse Reveal Asset Tracking platform, made by Radianse to increase its efficiency of asset and equipment tracking.

Thus far, the hospital has purchased 2,500 Radiance 433 MHz active RFID tags and tagged 1,600 assets. To associate a tag with the asset to which it is attached, employees use a handheld bar-code scanner to read the bar code printed on the tag, which holds the same unique ID number stored on the RFID chip. The staff then input details about the item and store that data in the medical centre's database.

A network of 364 receivers, connected to SOMC's server via Ethernet cables, has been installed throughout the hospital, spaced about 30 feet apart. The receivers can read a tag from up to 50 or 60 feet away, and can pinpoint its location with an accuracy of up to 3 feet. Software on PCs allows staff to search for and locate the assets.

When SOMC first started exploring RFID a decade ago, as a means of automatically tracking its high-value assets, the hospital found that a system large enough to meet its needs would have cost about $750,000 – an expense it could not justify. However, after re-examining the technology in late 2006, it found the cost had dropped 40%, to roughly $400,000. That convinced the hospital to take another look.

Integrated solutions (Hardin, 2007; pilots)

In 2006, BearingPoint surveyed 13 US health system executives on their interest for RFID technology within their health systems. It outlined the following major areas for RFID to be applied within 12 months: asset tracking, medical equipment tracking, real-time location systems. Plans within 24 months included: medical equipment tracking, patient safety (identification and medication administration), asset tracking, and patient flow management.

On the basis of the survey results, BearingPoint developed "The Visible Enterprise", or enterprise visibility solutions, which included:

- RFID wristband identity tracking of patients (for non-intrusive patient location though their hospital stay)
- tracking of pharmaceutical inventories (for expiration date and restocking)
- access to pharmaceutical cabinets monitoring (to control access and decrease inventory shrinkage)
- real-time location systems (to track patient location in the hospital for faster care and quicker movement of patients)
- clinicians can use tablet PCs (to locate patients and coordinate care)
- accurate patient identification (via the wristbands, to improve medical safety of drug, dose, treatment, patient, time challenges)
- high-value equipment tracking (so doctors don't delay procedures due to missing equipment, and equipment location)
- lab work records location (all specimens of a single patient are easily tracked, no time lost looking)
- access to parking areas (safer, and better organised).

Areas in the operating room (OR) where improvements could be expected from the product included:

- OR supply costs: 50% of total supply expenses occur in the OR. Inventory turns average 2 to 3 times per year. Excessive average levels and obsolete or expired inventory is common.
- OR utilisation management: OR utilisation as a percentage of its capacity is lowered by lengthy turnover times caused by the search for supplies. Staff overtimes are predominantly driven by variances in actual versus expected surgery end times. Growing case volumes require better suite utilisation or building additional procedure rooms.
- supply and time charge capture: manual processes are typically employed to record speciality supplies and patient times in the OR. Lost charges result in up to 20% of supply charges and 40% of time charges.

- clinician productivity: OR nursing productivity is hampered because of supply management and time-recording responsibilities.

When deployed within the ORs of three hospitals, the following unprecedented avenues for cost-capture were reported.

Provider A:

- Gross charges identified as lost $1,000,000
- Charges not posted
- Incorrect quantity (bilateral)
- Incorrect CDM number
- Duplicate PO's totalling $80,000

Provider B:

- 74% of products documented on OR charge sheets
- 65% of implant logs included vendor sticker
- 58% of charges posted on patient bill
- Soon-to-expire products (less than 3 months) sent by distributor

Provider C:

- Charges posted to incorrect patient account in 15% of cases
- Vendor replenishment order submitted to distributor incorrect (n=2)

For all providers, the systems were able to deliver detailed product usage by physicians and by procedure, and to report on compliance with contract terms (capitated pricing, volume assumptions, new product introduction) – functions not previously available.

<u>Asset and workflow management: Bon Secours Richmond Health System</u> (Harrop et al, 2007; application)

Since 2004, Bon Secours Richmond Health System has deployed one of the largest RFID-enabled mobile asset management programs in US healthcare industry. The system is delivered by Agility Healthcare Solutions. Agility is providing tracking and management services for critical mobile medical equipment for three Bon Secours Richmond hospitals under a five-year service fee arrangement, featuring AgileTracTM, Agility's comprehensive mobile medical equipment management solution.

In less than a year, Bon Secours has documented benefits that include:

- capital avoidance, by being able to locate and use otherwise idle equipment
- utilisation efficiencies, by better distribution of equipment at its facilities
- nursing staff gaining approximately 30 minutes per nurse per shift in time saved as a result of not having to hunt down equipment

Bon Secours estimated $200,000 benefit per year over implementation costs, in productivity gains.

Patient flow: Providence Health Center (Bacheldor, 2007j; application)

Providence Health Center in Waco, Texas, has implemented a real-time locating system (RTLS) that uses active RFID to track patients, staff and equipment. The hospital wants to improve its patient and operational processes and tracking of medical devices.

Providence Health Center is using active RFID tags from Radianse, which operate at 433 MHz and communicate via a proprietary air-interface protocol to Radianse receivers. The receivers – small box-shaped devices typically mounted on the walls –plug into the hospital's local area network and relay the RFID data collected to a Radianse server.

The Prospective Patient Flow Manager, as the system is called, displays the location data via two 42-inch plasma displays in each of the general nursing units – one for patient flow management and one for asset tracking – so that staff can easily view patient status throughout the hospital, locate assets and track staff.

Out-patient paperless HMR: California State University-Stanislaus (Swedberg 2007c; trial)

The system MedicAlert Foundation and California State University-Stanislaus (CSU) are testing whether RFID-enabled medical cards can provide a more efficient method of collecting and forwarding patients' health-related data at the point of medical service.

The card is intended to eliminate the need for a patient to fill out a form upon each visit to a doctor's office, and reduce the time spent by office workers searching for files each time that patient visits.

About 200 students at the university's health centre will each receive a plastic MedicAlert card embedded with an RFID chip containing a unique ID number that maps to that cardholder's medical information, which is stored in a server managed by MedicAlert. The ID cards are equipped with 13.56 MHz RFID tags compliant with the ISO 15693 air-interface standard. During the 12-week CSU pilot, participating students will visit the health centre once a week to have their ID numbers captured by an interrogator mounted at an RFID kiosk. That data is then directed, via MedicAlert's server, to the medical centre's computer, where a record is printed for the staff. The centre and MedicAlert will test how well the system collects data about each participating student and forwards that data to the medical centre personnel.

Medication dispensing errors: St. Clair Hospital (Swedberg, 2005; application)

To eliminate medication-dispensing errors, St. Clair Hospital, Pittsburgh, implemented Sculptor Developmental Technologies' VeriScan bar code software system, which works in conjunction with Socket's CF Scan Card Series 5 CompactFlash bar code scanner. It added the 13.56 MHz RFID option, giving it dual RFID and bar code capacity. The CF

RFID Reader-Scan Card uses SocketScan keyboard wedge software that reads RFID or bar-coded data directly into any active Windows program.

The dual program is used to ensure patients are administered the correct drugs and medications. The drugs have bar codes to be scanned, while the nurses are identified via RFID. A link between nurse, patient and medication is the check to ensure everything is correct.

The hospital intends to expand the program to check blood transfusions and lab specimens by the end of the year. This would operate similarly to the current pilot, with bar codes used to identify containers of blood and lab specimens, and RFID tags to identify personnel and patients.

<u>ED workflow improvement: Memorial Medical Center</u> (Cross, 2006: application)

To improve the operation of its Emergency Department (ED), including cutting down patient waiting time, Memorial Medical Center in Long Beach (CA) relied on a people/asset tracking software. This was supplemented by AmeliorEDTracker from Patient Care Technology Systems, which uses both infrared and RFID technology to track patients, staff and physicians throughout the department and to keep records on which rooms are being used.

The new system provided unprecedented data on ED use and patient trajectories, and became the key tool in the quality improvement policies the hospital implemented (e.g. new triage procedures, staffing). These led to a decrease in the waiting time for the first triage nurse from 1hr 20 min to 9 min for incoming patients.

Patient tracking is done via badges, distributed to incoming patients, emitting signals on 3-second intervals. Similar badges are worn by nurses and physicians. These are run on infrared technology, with RFID used as backup when needed. The badges originate 75% of all information accessible through the system. The remaining 25% is from interfaces with other computer systems. Thus the system enables the transmission of information to and from the registration systems, the laboratory system, the picture archive and the bed-tracking system for the entire hospital. This leads to:

- increased patient safety
- better use of staff time
- increased facility capacity.

<u>ED workflow improvement: Shelby County Regional Medical Center</u> (Gearon, 2005b; application)

Shelby County Regional Medical Center in Memphis, Tennessee (with the help of a $250,000 grant from the RobertWoodJohnson Foundation) implemented an RFID patient-tracking system to reduce overcrowding in the ED. As a result, where previously the centre could only account for 25% of the typical patient's stay in the trauma unit; it now accounts for 80% of patient time.

Left-in prevention: Medline (Sullivan, 2006; trial)

Medline Industries, a US distributor of medical supplies, has begun marketing a medical system that uses RFID to detect any surgical gauze, towels and sponges left behind in patients after an operation. The platform now consists of passive RFID 145 kHz tags embedded in surgical gauze, sponges and instruments, a proprietary RFID interrogator, and a handheld wand containing an antenna connected to the interrogator. Hospital personnel pass the wand over the patient and the RFID interrogator would then pick up the RF signals of any tagged items left in the patient's body.

Diagnostic implant (Swedberg, 2008c; trial)

Lee Berger, a New Jersey orthopaedic surgeon, recently reported that he has developed an RFID-enabled device that can measure and transmit data regarding the condition of the tissue around an implant, as well as whether the implant is functioning properly.

Berger envisions employing sensors to measure pressure on the implant, as well as chemical balance, temperature and the presence of micro-organisms around the device after it has been surgically attached to a patient. Sensors would measure pressure to determine if the implant has shifted, and would gauge the other factors to track the presence of an infection. The sensors would be wired to an RFID chip, which would transmit the sensor data to an RFID interrogator used by a physician. Furthermore, the implant features an electric stimulator wired to the RFID chip. In response to instructions from the reader, the stimulator can generate 20 to 40 microamps of electricity. The electric current passes through the bone in which the implant is attached, to promote healing.

Patient well-being (Koblasz, 2007; trial)

Arthur Koblasz filed a US patent application for a body-worn RFID tag that includes an upper-body RFID tag located in a wristband and a lower-body RFID tag located in a sock worn by the monitored person.

The purpose is to prevent or detect specific types of movements of the person, such as falls from which the person has not recovered, wandering, bed egress, attempted room egress and medication errors. The RFID instrumentation located in the premises may include one or more antennae located in the floor, door, bed frame and mattress.

The system may also activate response actions upon detecting specified movements, such as sending an alert message to a patient monitoring system, activating an alarm, activating a camera, and/or playing a recorded message to the person.

5.2.9 **Japan**

International Medical Centre of Japan - POAS (Akyama, 2007; application)

In 2002, a Point of Act System (POAS) became operational at the International Medical Centre of Japan. POAS is a real-time consumption data capturing system that collects, manages and uses consumption data at the point of care (e.g. hospital bedside) and answers the questions When, Where, Who, to Whom, Why, What and How.

Although currently PDA/bar-code based, POAS is expected to gain greater flexibility with advances in RFID technology.

How does POAS work?

By collecting real-time data from wireless PDAs, examination-room terminals and laboratory equipment, POAS can:

- record medical actions in detail, everywhere
- assist practising medical treatment to patients
- monitor patient symptoms continuously
- comprehend logistical data by the 'minimum unit'.

What critical quality of care/patient safety functions does POAS support?

i) Risk management: by preventing medication errors

ii) Hospital management for improved medical safety and management efficiency:
   - by preventing medical accidents
   - thorough inventory management
   - by accurate acquisition of real-time bedside action entry
   - serialisation for single-item management
   - by accurate data cancellation/change

iii) Data management:
   - it accumulates accurate data for clinical research and clinical trials
   - allows for more accurate cost and financial analysis (e.g. by patient group and staff characteristics)

iv) Distribution management: it can optimise supply chain management in the medical industry, including improved security for donor privacy and organ traceability, and proven RFID tag durability for blood transfusion process.

How does it differ from conventional systems?

Conventional systems are characterised by schedule–entry, based on invoice-slip granularity, by one day, at the nurse station/out-patient department (hence is different from the actual state); whereas POAS is characterised by action-entry, based on single-item granularity, in real time, and at the patient bedside.

For example, in its risk management function, POAS's action-entry logic allows almost instantaneous updating of patient medication based on incoming test results (within 2 seconds). This improves inter-divisional safety as physicians and nurses can share the same data simultaneously (averting the 40% probability of misadministration if a change of order is not communicated in time). Also, as POAS' data units are peoples' actual actions, single-item-based (not invoice/payment-unit-based), POAS records both drug codes and serial codes (not drug codes only) and it supports individual care management (versus. management of items). In its hospital management function, POAS has led to inventory decrease by a tenth, a 225.5 million yen cost reduction for pharmaceuticals, and a 241.62 million yen cost reduction for medical supplies.

5.3 Key insights and next steps

This chapter presented a first selection of promising RFID applications, pilots and trials descriptions to be used for the selection of in-depth case studies in the following stage of the project. Although illustrative, not exhaustive, the examples of RFID use suggest two main conclusions:

1. RFID applications in healthcare have a large functional range, spanning the functions of identification, tracking, sensing and automatic data collection; and addressing patient safety, quality of care, operational efficiencies, and the effectiveness of care, among others
2. there is a high density of applications, trials and pilots documented in the literature (as previously examined in this chapter).

These conclusions suggest that the forthcoming analysis in the next stages of this project should be conducted at the case level. Moreover, the key process case selection criteria should be data availability on the impacts and costs of the application, along with the following content selection criteria:

i) impact on quality and continuity of care, patient safety, and on the effectiveness and efficiency of care delivery

ii) multi-function and multi-purpose RFID applications

iii) ambient intelligence solutions

iv) 5-year horizon scalability.

We believe that, given the richness of the literature, such cases are identifiable. The objective behind these selection criteria is to gather in-depth information on the different benefits and costs associated with implementing promising and forward-looking RFID technologies, including their impacts for key stakeholders, and proactive policy action implications.

APPENDICES

Appendix 1: Relevant Bibliography

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Appendix 2: Screening Template: RFID in Healthcare

1. Article specs

1.1 Article ID: (Link to cell in final list)

1.2 First Author: Last name of first author

1.3 Reviewer: Name

1.4 Review date: dd-mm-yyyy

2. Source

(check one)

Peer-reviewed journal

Industry journal

Report

Other: text

3 Summary

Guiding principles: What is the problem RFID is solving? How is RFID solving the problem? Please follow structure of the screening template.

For example:

input: quality of products

process: improved inventory management, BPR

output: economic gains (economic outcomes), improved patient safety, increased quality of care…

TEXT BOX (without limit)

4 Overall relevance, regarding applications

(check one)

High

Medium

Low

Not relevant (STOP)

5 Overall focus of the article

(check all that apply)

Application areas

Trials & pilots

Potential benefits and obstacles

Economic analysis & cost-benefit analysis

Market analysis

Alternative technologies

Critical uncertainty

Privacy and security

Implementation strategies

Basic knowledge and general information

Other (text)

6 Locations

(provide country names)

Europe:

America:

Asia:

Australia & New Zealand:

Africa:

7 Application areas

Guiding principles: List is not exhaustive, please develop further by adding application areas to the corresponding categories (i.e. other@Patient, other@Staff, other@Asset, other@Randomized Clinial trials, other@Other).

Naming should be as clear as possible.

Guiding questions: setting, where, who & by whom

(check all that apply)

Patient:

patient identification @hospitals for surgery

patient identification @disasters

infant identification @hospitals to forego mismatching

patient tracking and tracing @hospitals for monitoring patient flow

infant tracking and tracing @hospitals for security/to forego theft

dementia patients tracking and tracing @elderly homes to forego missing

other (text)

Staff:

staff identification @hospitals to manage access

staff tracking and tracing @hospital ER to speed up service

staff monitoring @hospitals for management purposes

other (text)

Asset: (by type of asset)

asset identification:

- sponge identification @hospital to ensure hygiene compliance
- blood bags identification @hospitals/OR to ensure blood type matching
- other (text)

asset tracking and tracing:

- equipment tracking and tracing @OR to ensure hygiene compliance
- sponge tracking & tracing @OR to prevent 'left-ins'

other (text)

asset monitoring:

blood bags equipped with temperature sensors @hospital to ensure cold chain & efficacy

other (text)

Randomised clinical trials:

patient identification @trial

patient compliance with treatment @trial

other (text)

Other:

telemedicine:

intelligent pillbox to monitor/prompt patient compliance

remote monitoring of vital signs @home (extended healthcare)

other (text)

assisting the visually impaired

chip implant (VeriSign)

supervising in vitro fertilisation

other (text)

8 Policy areas

(check all that apply)

patient safety/quality of care

e-health

e-inclusion

waste management (WEEE)

REACH

Lisbon strategy

improved utilisation of resources

reduce liability-related problems

other (text)

9 Obstacles/barriers/risks

(check all that apply)

information security risk:

privacy

security

data integrity

other (text)

interference

reliability

ethical

legal

cultural

social/societal (perceptions etc.)

interoperability

standards

costs

other (text)

10 Enablers

List not exhaustive – please develop further.

For legislation and incentive, please provide name and form (e.g. tax).

(check all that apply)

government legislation (national)

government legislation (supranational)

government incentive (national)

government incentive (supranational)

falling tag prices

perceived benefits

clear business case

other (text)

11 Alternative technologies

List is not exhaustive – please develop further.

(check all that apply)

bar code, substituting RFID

bar code, complementing RFID

WIFI, substituting RFID

WIFI, complementing RFID

other (text)

12 Economic analysis & cost-benefit analysis

Short summary.

Copy/paste graphics, tables, etc. (mentioning page numbers).

13 Market analysis

Copy/paste graphics, tables, etc. (mentioning page numbers).

14 Comments/Notes

TEXT BOX (without limit)

Appendix 3: Alternative Typologies of Healthcare RFID Applications

- **UK Department of Health. 2007. Coding for success – Simple technology for safer patient care.**

This document suggests the following classification of RFID:

- RFID and the patient (in-patient, out-patient)
- RFID and medication
- RFID in diagnostics
- RFID for devices and surgical procedures

- **Stroetmann, V.N., J-P Thierry, K.A. Stroetmann and A. Dobrev. 2007. eHealth for Safety – Impact of ICT on Patient Safety and Risk Management. European Commission**

In the framework of eHealth and patient safety, the authors distinguish RFID applications as:

1. For in-patient settings:
   - Security (access control, anti-theft devices)
   - Medication administration, authentication and stocking (tracking of drug origin and expiration data)
   - Hospital equipment, medical waste and supply tracking
   - Patient tracking, blood banking (tagging blood transfusions), medical alerts implants

2. For out-patient settings:
   - Self-medication (e.g. for use with elderly persons)
   - Patient tracking, medical alerts implants

- **Houliston, Bryan. "Integrating RFID Technology into a Drug Administration System"**

Houliston identifies 3 types of RFID functionality:

1. Identification applications involve a single action at a single location (e.g. identifying a staff member for access to a secure area)

2. Location-based applications perform continuous actions at a single location (e.g. an RFID-enabled "smart" medicine cabinet can provide a real-time inventory of drugs it contains, recording removals and additions)

3. Tracking applications use continuous actions at multiple locations (e.g. individual pieces of equipment may be tracked to prevent them being lost or stolen, or staff and patients may be tracked to analyse workflow

- **CE RFID. RFID Reference Model – Version 2007-2-1 as of 01-10-2007**

The RFID Reference Model is designed to give a quick overview of RFID applications, and associated properties and challenges, and as such can serve as framework for discussions on application-level RFID. It defines 40 RFID applications (called 'subcategories') summed up to 8 'Application Fields', namely:

1. Assistance for the disabled

   RFID can be used to provide extra assistance for disabled people – playing a major role in using RFID to make our societies more inclusive and overcome obstacles in accessibility for the disabled, in all areas from information to buildings to public transport

2. Hospital management

– Use of RFID to improve patient management efficiency and patient safety by avoiding mix-up of patient data (e.g. by using RFID wristbands), or ensure hospital hygiene
– Standards helpful to ensure sector-wide adoption and improve interoperability among different doctors and healthcare providers
– Special attention to privacy

3. Implants

– Use of RFID to track and trace donor organs to ensure correct handling during transportation (cold chain)
– Improve patient safety and help reduce costs by lowering the risk of organ rejection or fatalities after transplantation surgery

4. Medical monitoring

- Uses of RFID include the monitoring of basic body functions (blood pressure, respiratory functions, etc.), and the contactless transmission of patient data to hospital administration systems or handheld computers used by doctors
- Special attention to data security is necessary since critical medical data is involved

5. Smart implants

- Use of RFID to monitor functions of artificial implants, such as hearts, heart valves or cardiac pacemakers
- Future application could include implants to dispense medication (e.g. insulin)

- **Jervis, C. 2005. Chips is Everything. Is RFID ready for healthcare? *British Journal of Healthcare Computing and Information Management* 22(2).**

This article proposes a typology of RFID applications and potentials, distinguishing between:

- tagging people
- tagging objects
- monitoring interactions

Main RFID functions, however include:

- Identification and verification: patient and staff ID, access and security, samples, pharmaceuticals
- Tracking: vulnerable patients, assets and equipments, patient flow, supplies and stock
- Sensing: temperature, pressure, failure or fatigue
- Interventions: automated care, pathways, procedures, audit, management
- Alerts and triggers: blood transfusions, drug administration, tubes, syringes

- **Gassner, K., O. Koch, L. Weigelin, W. Deiters, A. Ritz and R. Kaltenborn. (2006). Einsatzbereiche und Potenziale der RFID-Technology im Deutschen Gesundheitswesen. Fraunhofer ISST.**

Classification of RFID projects – proposing goal/solution-oriented taxonomy for mature RFID applications (in 2006):

1. access management and documentation processes:
   - endoscopy cleaning procedures
   - patient identification and advice
   - documentation processes at infant intensive care
   - documentation processes for blood products:
     - identification of blood products

    - RFID services assisting blood transfusion processes
    - logistics for blood products

2. localisation:
    – baby security systems (Bonn, Castrop-Rauxel, Luebeck)
    – locating/tracking and tracing medical devices and patients
    – safeguard system for disoriented persons

3. performance data monitoring:
    – for blood products:
        - clinical application
        - monitoring temperature of blood bags
    – monitoring temperature of bottled breast milk

4. task management/process control via back-end systems:
    – controlling elevator drives
    – laundry sorting
    – monitoring temperature of blood bags
    – monitoring temperature of bottled breast milk

A technology-driven typology can also differentiate by:

- powering source - active, semi-active, passive tags
- data storage/memory: read-only, read–write systems
- frequency classes
- reading ranges
- design (capsules, buttons, labels)
- robustness
- level of security (encrypted, not-encrypted, cloning, easy to destroy, anti-collision procedure).

o **Zeller, S. 2007. Active RFID in Healthcare. Presentation at the MIT RFID Special Interest Group.**

The scope of applications for active RFID include asset tags, staff badges, patient bracelets, PDAs, laptops, tablets, WiFi VoIP handsets and WiFi telemetry. These allow for the following:

– Inventory and asset management: best use of equipment, and inventory; theft reduction
– Patient, personnel, visitor ID location: patient safety and location (ED boards);

wandering; security
- Bed management: maximise use and throughput
- Improved workflows: automation of processes; billing and audits; process observation and re-engineering

- **Malkary, G. 2006. Active RFID popular pick. ROI for the passive form is weak, but overall prospects look better, says study. *Healthc Inform*. 23(2):108.**

Identified application areas for passive RFID included:

- positive patient identification
- infant protection
- surgical tray tracking.

Identified application areas for active RFID included:

- tracking mobile assets
- tracking patients
- tracking medical staff.

- **Akiyama, M. 2007. Efficacy of serialization in hospital information systems with POAs – Point of Act Systems. Presentation at the MIT RFID Special Interest Group.**

What can POAS improve (main outputs)?

1. Risk management: it can prevent medication errors and thus improve patient safety.

2. Hospital management for improved medical safety and management efficiency via:

   i) prevent medical accidents

   ii) thorough inventory management

   iii) accurate acquisition of real-time bedside action entry and serialisation for single-item management

   iv) accurate data cancellation/change.

3. Data management:

   i) accumulate accurate data for clinical research and clinical trials

   ii) allow for more accurate cost and financial analysis (e.g. by patient group and staff characteristics).

4. Distribution management: optimise supply chain management (SCM) in the medical/ pharmaceutical industry (including improved security for donor privacy and organ traceability, and proven RFID tag durability for blood-transfusion process).

- o Leonidas, T.R. 2007. Finders keepers. Planning for a hospital wide RFID system. *Health Facilities Management* 20(11):21-5.

According to Leonidas, the main areas for RFID application are:

- asset tagging
- patient tagging
- portable health records
- surgical suite applications
- process automation.

- o Hardin, E.D. 2007. Low Frequency RFID: An Investment with a Return. BearingPoint Presentation.

The presentation outlines as major areas for RFID application within the following 12 months (i.e. 2006–2007):

- asset tracking
- medical equipment tracking
- real-time location systems.

Major areas for RFID application within the following 24 months (i.e. 2006-2008) included:

- patient safety (identification and medication administration)
- asset tracking
- patient flow management.

- o Hagland, M. 2005. Nine tech trends: Bar coding and RFID. *Healthcare Informatics*

Application areas in which active RFID is expected to push aside passive RFID and bar coding include:

- tracking physical assets
- tracking flow of patients and personnel
- asset and personnel management.

- **Gearon, C. 2005. Technology. Behind the hype.** ***Hospital and Health Network*****. 79(6): 22-4.**

Main identified RFID functions include:

– to monitor equipment
– to track patients (account for patient time spent in units)
– to track clinicians
– to prevent baby thefts in the maternity ward
– to prevent ED patients from inflicting (self) harm (locks doors and elevators when the patient RFID tag passes certain points).

- **Fisher J.A. and T. Monahan. 2008. Tracking the social dimensions of RFID systems in hospitals.** ***International Journal of Medical Informatics*****. 77(3):176-83.**

According to Fisher and Monahan the main RFID functions are:
– to track inventory
– to identify patients
– to manage personnel.

- **Cohen, S. 2007. Transforming the delivery of healthcare using UWB RFID based real-time location systems. MIT presentation.**

Currently, healthcare RFID industry applications are limited primarily to:

– identification
– location

both conducted by WiFi – IR.

However, UWB (Ultra-wide band) RFID is capable of supporting the following key functions as well:

– tracking (in motion)
– communication (tag-to-tag relationships: equipment to patient/staff to patient/mother to infant; and tag-to-environment relationships: equipment status/availability/security; staff presence; patient wandering/safety)
– workflow management
– analysis for which sub-foot granularity is required

- **RFID and Privacy: Guidance for Health-Care Professionals, by IPC (Information and Privacy Commissioner of Ontario) and HP (Hewlett-Packard), January 2008.**

From the point of view of privacy considerations, RFID applications are characterised broadly as 'tagging things', 'tagging things linked to people', and 'tagging people'. More specifically these include:

1. Tagging things:
   - bulk pharmaceuticals
   - inventory and assets (e.g. trolleys, wheelchairs, medical supplies)
   - medical equipment and instruments (e.g. infusion pumps, wheelchairs)
   - electronic IT devices (e.g. computers, printers, PDAs)
   - surgical parts (e.g. prosthetics, sponges)
   - books, documents, dossiers and files
   - waste and bio-hazards management

2. Tagging things linked to people:
   - medical equipment being used by patients, visitors or staff
   - readers, tablets, mobile and other IT devices assigned to staff
   - access cards assigned to staff or visitors
   - smart cabinets
   - devices, garments, or spaces (rooms) assigned to patients
   - blood samples and other patient specimens
   - patient files and dossiers
   - individual prescriptions vials

3. Tagging people:
   - healthcare employee identification cards
   - patient healthcare identification cards
   - ankle and wrist identification bracelets (e.g. for patients, babies, wandering or elderly patients)
   - implantable RFID chips