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RFID AND HEALTH MANAGEMENT: IS IT A GOOD TOOL AGAINST SYSTEM INEFFICIENCIES?

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Abstract: Healthcare is considered to be the biggest service industry on the planet. It is a growing industry, facing many complex challenges in trying to deliver cost-effective, high-value, accessible healthcare and has traditionally been slow to embrace new business techniques and technologies (Wickramasinghe et al. (2005) Int. J. Electronic Healthcare, Vol. 1, pp.316–334). Technology has the potential to help meet many of these challenges, thus contributing to reducing healthcare expenditure as well as offering quality healthcare treatment (Wickramasinghe, N. and Goldberg, S. (2004a) Int. J. Mobile Communications, Vol. 2, pp.140–156; Wickramasinghe, N. and Misra, S. (2004b) Int. J. Electronic Healthcare, Vol. 1, pp.316–334). The main aim of this paper is to bring to the attention of the reader Radio Frequency Identification (RFID) technology and to illustrating how the application of RFID in healthcare can enable this industry to overcome existing technological and workflow limitations.

Keywords: counterfeiting; EPC; healthcare; inefficiencies; privacy-tracking; real-time

1. Introduction

The percentage of Gross Domestic Product spent on healthcare between 1960 and 1997 by Organisation for Economic Cooperation and Development (OECD) members nearly doubled from 3.9 to 7.6%. US, the highest spender: 13.6% in 1997, is expected to increase this percentage to more than a 16% by 2010 (PriceWaterhouseCoopers, 1999)[1].
These figures just give us a hint of the reasons contributing to consider healthcare the biggest service industry on the planet. This industry offers many appealing possibilities for serious and relevant organisational research, since it is facing many complex challenges in trying to deliver cost-effective, high-value, accessible healthcare (Wickramasinghe et al., 2005). Technology has the potential to help to meet many of these challenges, contributing to reduce healthcare expenditure as well as offering quality healthcare treatment (Wickramasinghe and Goldberg, 2004; Wickramasinghe and Misra, 2004).
The key customer group of the 21st century in healthcare will be consumerist and aging patients, resulting in an overall increase in cost between 2.5 and 3.5% per year (PriceWaterhouseCoopers, 1999). Moreover, individuals are educated better about everything, including healthcare.
Consumers will be the key customer group of the 21st century in healthcare. The post-war baby boomers who have been an egocentric and demanding group at each stage of their lives are now becoming the key healthcare consumers, purchasing care for their own aging bodies, as well as for their frail parents.
Individuals are better educated about everything, including healthcare. Searchable health information has become available quickly and easily through the internet (Pew Internet's American Life Project, 2005) and reduced restrictions on direct-to-consumer advertising have opened a floodgate of advertisements by pharmaceutical companies in some countries. Thus, more educated consumers (as a result of the informational aspects of e-health) would then communicate more effectively with their primary care provider which should, in turn, lead to better understanding and improved quality of care. In fact, physicians have been spending less and less time with patients, so that patients have started to believe that no one is on their side. Patients are actively choosing doctors, hospitals, medical treatment, and so on (Shortell and Hull, 1996; National Center for Health Statistics, 2002). As quoted in Treasure et al. (2002):

"The world has changed for surgeons. There was the time when the very sick, with no other hope would go 'under the knife' and be grateful for anything that could be done to save their lives or to relieve their symptoms. Surgery is no longer heroic and desperate. People expect a low risk, a high probability of success, and accountability if anything goes wrong. In some ways it is paradoxical that as surgery offers more reliable results it is more often criticised and is under closer scrutiny. That is the way it is".

Of course, there are some remarkable exceptions, including hospitals that have taken note of this trend towards online healthcare by adding websites to their marketing programmes[2].

At the same time that e-health is, in a way, helping to erode faith in 'the system', the subsequent dissatisfaction is creating a climate for change. By making the knowledge bases of medicine and personal electronic records accessible to consumers over the internet, e-health opens new avenues for patient-centred medicine, enables patient education, and thus increases the likelihood of informed and more satisfactory patient choice (Umhoff and Winn, 1999).

So far, information technology appears to be catching up with hospital needs, such as better patient safety, higher staff performance, increased quality of care, and a higher bottom line, at the same time that turnover in the medical field is bringing in a younger generation of practitioners who are more comfortable with modern medical practices in their daily work (Lumsdon, 1992; Gelijns and Dawkins, 1994). This change in attitude extends beyond mundane applications such as internet and e-mail to highly intricate and sophisticated systems that amalgamate such tools as Computerised Provider Order Entry (CPOE) systems with PDAs, Electronic Medical Records (EMRs), and wireless bar- coding systems for drugs. Figures 1 and 2 illustrate this trend.

[INSERT FIGURES 1 AND 2 ABOUT HERE]

Wickramasinghe et al. (2005) define e-health as an emerging field at the intersection of medical informatics, technology, public health and business, which entails the delivery of health services and health information through the internet and other related e-commerce technologies. In a broader sense, the term e-health characterises not only technical development, but also a state of mind, a paradigm shift, and a commitment to networked global thinking to improve healthcare locally, regionally, and globally by using information and communication technologies. A similar definition is provided by The WHO (2003), a major world health body, which defines e-health as 'being the leveraging of the Information and Communication Technology (ICT) to connect provider and patients and governments; to educate and inform healthcare professionals, managers and consumers; to stimulate innovation in care delivery and health system management; and, to improve our healthcare system'.

About 90% of healthcare today has no real outcome measures, which is rather shocking since healthcare is such an important segment of the economy and such a key component of human welfare: Society and its institutions are willing and able to commit an almost unlimited amount of resources to explore and improve the system. As a matter of fact, substantial financial resources have been allocated to the healthcare industry in recent years. According to data provided by the Centres for Medicare and Medicaid Services, Office of the Actuary, healthcare spending in the US reached $1.67 trillion in 2003, or 15.3% of a GDP of $10.9 trillion. The soaring prices paid to treat the growing volumes of demanding, aging patients are prompting payers to search for more efficient ways of treatment and care.

On the other hand, healthcare has been slow to exploit the cost savings potential of information technology as yet. Cost containment in the hospital sector is a key issue in stabilising health costs at a sustainable level (Herzlinger, 1997; Bernstein et al., 2003; Reinhardt et al., 2004; Chernew et al., 2003; Newhouse, 1993; Pauly, 1993; Woolhandler et al., 2003; Davis and Cooper, 2003). Despite efforts to control hospital costs, empirical evidence shows that constant dollar per capita spending on hospital inpatient care rose by 53% between 1980 and 1993 (PriceWaterhouseCoopers, 2002). Furthermore, during the same period, real per capita spending rose by 65% for all types of hospital care and more than 87% for all health services (PriceWaterhouseCoopers, 2002). From a managerial perspective, understanding the cost structure of hospitals and their inefficiency in using resources is crucial in deciding healthcare policies and budget decisions. Higher operational efficiency in hospitals is likely to help control medical service costs, and consequently provide more affordable care and improved access for the public (Hollingsworth et al., 1999).

Could IT help hospitals to improve their cost structures? On the one hand, we have to remember that IT may slash the time it takes to make referrals, obtain test results, obtain payment, find patients for clinical trials, disseminate best practices, share cost information and so on. Furthermore, it helps to avoid inefficiencies due to duplicate or unnecessary diagnostic or therapeutic interventions (Healthcare Advisory Board, 2002). On the other, IT possibilities are being increasingly known by clinicians, physicians and empowered customers. Indeed, as it is stated in recent study by PriceWaterhouseCoopers (1999), an increasing number of hospitals appear to be moving towards the adoption of CPOE, since the main goal is to be able to enter orders on a computer and receive alerts and other support for patient treatment decisions. Patients are already demanding more information about treatments proposed for them, their effectiveness and the track record of the medical team offering the treatment. This trend will accelerate the demand for the standardisation of health processes. Governments, health purchasers and insurers will also support standardisation in their crusade to control inefficiency and costs with the aid of common platforms and benchmarks.

The latest developments in Radio Frequency Identification (RFID) offer a new approach to reducing inefficiencies and waste in the healthcare industry, which complements Lean Manufacturing principles. This technology has proven very useful when the main purpose is to simplify and improve the service delivery process. Among the cases where RFID has been successfully integrated in the healthcare environment, those most outstanding are the initiatives related to work flow improvements, asset tracking, patient identification, drug procurement and administration, and inventory management. The main benefits in using RFID have been the improvement of patients care together with a reduction in costs and assets utilisation. In this article, we have researched RFID techniques to examine their ability to provide patient care and be competitive in the market, the barriers that keep hospitals from adopting and using more RFID solutions, and the lessons that other hospitals can learn from the pioneers in their implementation.

Summarising, since modern healthcare delivery is increasingly recognised as an information business as well as people business, there is a growing awareness that healthcare should be more integrated to enable patients to receive the best possible care. Hospitals provide time sensitive and usually resource-intensive interventions, and this vital function is a highly information-rich and information-dependent undertaking. The problem is that many healthcare delivery organisations seem significantly underprovisioned in modern information management capabilities.

Figure 3 symbolises these pressures exerted over doctors, nurses, healthcare managers. Integrated IT solutions provided them with a powerful tool to achieve higher levels of quality care, reliability, flexibility and effectiveness.

[INSERT FIGURE 3 ABOUT HERE]

2. Digital hospitals, lean manufacturing, inefficiencies in healthcare and RFID

For hospitals right now, enhancing patient care and reducing errors are top priorities so that facilities, technology, and operations should support the patient care process, and IT improvements are allowing them to support these goals. In 2005, 59% of respondents to a survey conducted by PriceWaterhouseCoopers (2005a) said that clinical improvement was the reason for the use of IT in healthcare compared with 36% in 2003 and 47% in 2004. Moreover, hospitals' IT priorities for the next two years further support these findings: moving toward an electronic health record, improving patient-care capabilities and improving decision support for clinicians rounded out the top three concerns of executives in the foreseeable future. Hospital executives have come to the realisation that the quality of care administered to patients as supported by EMR and CPOE is the most important goal of their IT investment. These hospitals rely on delivering higher quality care in increasingly efficient ways through the significant integration between process redesign, information technologies, and medical technologies – such as patient beds, surgical equipment, nurse call and communications systems, pagers and medical imaging technologies.

In spite of the fact that there is not as yet a consensual definition of a 'digital hospital', experts seem to agree that core technologies and automated processes should be common elements of the definition. Figure 4 depicts digital hospital applications and technologies.

[INSERT FIGURE 4 ABOUT HERE]

Since becoming digital is not a simple buy-and-install project few real-world examples of digital hospitals exist. Implementing the digital hospital concept requires the integration of many subsystems and hospital executives must assume significant process re-design responsibilities, in order to create a smoothly running system that fully exploits the technology and empowers clinicians and other hospital staff to more effectively fulfil their responsibilities. So far, organisational transformation is needed: the goal is eliminating process components to realise benefits – potentially completely rethinking the manner in which a process is undertaken.

Lean Manufacturing has been described as a philosophy, a perspective that abhors waste in any form, relentlessly strives to eliminate defects, and continually attacks both in a never-ending pursuit of perfection. Most descriptions of lean manufacturing quickly move beyond the philosophical approach to an interrelated set of practices that range from overall material flow in the factory to detailed work and equipment design to human resource practices (Ohno, 1988; Shingo, 1989; Womak et al., 1990; Adler, 1993; Monden, 1993; Toyota Motor Corporation, 1995). Ongoing research (Jimmerson et al., 2005) at Montana State University and Community Medical Centre in Missoula, Montana, has adapted several key tools and principles from Lean Manufacturing to healthcare, and demonstrated their effectiveness in improving hospital operations.

Table 1 summarises some examples of the adaptation of the well-known 'seven wastes of manufacturing' (Ohno, 1988) to the particular circumstances of healthcare, in an effort to spotlight where waste occurs.

[INSERT TABLE 1 ABOUT HERE]

According to Jimmerson et al. (2005)'s research, Toyota's notion of 'ideal' fits healthcare so well that we have adapted it as shown in Figure 5. Some of these principles are introduced in the following paragraphs (Jimmerson et al., 2005).

- Relentless pursuit of an ideal state of error-free work (Spear and Bowen, 1999). Every change must move the organisation closer to this ideal along one or more dimensions; otherwise, the change is not approved.
- Problem solving that happens as close to the event as possible. Specification of the work and clear definitions of 'defect-free' outcomes makes it readily apparent when defect-free outcomes do not occur (i.e. they do not conform to the ideal).
- Vigilant consideration of the current work systems and evaluation of the ability to produce defect-free outcomes, therefore driving a production system that changes as soon as a better way is known.
- Process redesign focuses on specifying work activities, making clear connections between those requesting and those receiving goods and services, and simplifying the production pathways of goods and services.

[INSERT FIGURE 5 ABOUT HERE]

Processes improve and problems become more transparent when activities are specified according to content, sequence, timing and outcome so that, regardless of who performs the work, it is completed in the best way known with defect-free results (Spear, 2004). Processes improve also when connections between workers which are making requests and providing services are direct, simple, and binary; doing so makes them prompt, efficient, and reliable. In addition, processes improve when goods and services follow the same simple pathway through the system every time without interruption.

Accordingly, hospital managers should look for IT investments that allow their healthcare delivery organisations to achieve a more flexible, responsive, and adaptive communication, so that hospitals can adjust quickly to changing patient needs, improve standards in clinical practice and gain agility in new market conditions.

RFID is evolving as a major technology enabler for tracking goods and assets around the world[3]. RFID tags store identifying information about the physical objects to which they are attached, enabling the monitoring of a device's location through remote sensors. It can, for example, help hospitals locate expensive equipment more quickly to improve patient care, pharmaceutical companies to reduce counterfeiting (Thompson, 2004) and logistics providers to improve the management of moveable assets. It also promises to provide new efficiencies in the supply chain by tracking goods from manufacturers through the retailers.

Inspired by Lean Manufacturing principles, anytime a hospital wishes to become 'digital', it should start the project's initial design phase by including the modelling of an ideal patient flow through the hospital. The model will have to detail what information is needed where, when, by whom, and in what format. Physicians and other clinicians, as well as stakeholders from the hospital, have to be included in the design process. It is also advisable to assign an active role in workflow design to clinical IT specialists from vendor candidates—in advance of the hospital final vendor selection for a technology provider. The time taken for process design to become fully woven into hospitals' operations may help to account for the lag typically seen between systems implementation and subsequent cost reduction.

3. Radio Frequency Identification (RFID)

RFID is not a new technology: the British used RFID to distinguish friendly aircraft from enemy aircraft during World War II. Although the use of RFID in healthcare lags the retail setting, RFID seems to hold much promise for healthcare and some pioneering implementations have begun. Today, the US Department of Defense uses RFID and GPS technologies to track major shipments of all its military supplies, including the tracking of medical supplies and hospital patients at its Pensacola Fleet Hospital in Iraq, according to RFID wristband supplier Precision Dynamics.

RFID is a generic term that is used to describe a system that transmits the identity (in the form of a unique serial number) of an object or person, using radio waves, and is grouped under the broad category of automatic identification technologies, (Auto-ID). The auto-ID technologies have been used to reduce the amount of time and labour needed to input or manage data manually and to improve operations and data accuracy (HealthCare Pilot, 2005). Auto-ID technologies also include bar codes, optical character readers and some biometric technologies, such as retinal scans.

RFID and bar codes have some very important and fundamental differences. First, traditional bar codes only identify a category of products. For example, all Gillette Mach 3 power razors have the same bar code. However, with RFID tags, each packet of these razors would have its own unique identifier that can be transmitted to suitably located readers for monitoring. Currently, the Electronic Product Code (EPC) is the dominant standard for the data contained in RFID tags for item-level tracking, and can hold more data than a bar code. Second, RFID allows data capture without the need for a line of sight, another significant advance over the bar code. This means that the need for physical manipulation or access to individual items, often stacked or piled, is virtually eliminated for purposes of identification and tracking. This is not the case with the bar

code, which must be ‘seen’ at close range by scanners in order to be identified. Third, RFID can identify a large number of tags at the same time, resulting in faster movement of goods at each step of the supply chain. It also minimises the need for human intervention, reducing labour requirements.
The main differences between these two auto-identification technologies are highlighted in Table 2.

[INSERT TABLE 2 ABOUT HERE]

The basic components of any RFID system include:

- Tags (or transponders) made up of a powered (active) or non-powered (passive) microchip with an antenna.
- Data stored on tags, which could be a simple ID number relating to an online catalogue or complex information such as manufacture date, lot number, serial number and so on.
- Readers (or interrogators) are used to identify all tags within the reception coverage area and aggregate the data collected.
- IT infrastructure (or Middleware) to support the collection, management and use of key RFID data, that can be used, among other things, to (Intel Corporation, 2005):
    - improve product availability
    - reduce theft and counterfeiting
    - increase inventory accuracy
    - streamline logistics efficiency
    - improve business forecasting and planning
    - measure supply chain efficiency and highlight problem areas
    - reduce inventory stuck in the supply chain
    - reduce service costs
    - identify location of specific items or persons
    - alow focussing on costly process exceptions.

3.1. RFID tags

As has been stated, there are two kinds of RFID tags, passive and active (Hodges and Harrison, 2003):

- Passive tags are assigned a unique serial number when manufactured and only have the ability to transmit data to associated readers. This type of tag requires no power source or battery within the tag. The tag uses the energy of the radio wave from the reader to power its operation. This is the least expensive tag. Passive tag RFID systems are the most prevalent.
- Active tags contain memory for state management and chip-based intelligence, and

can both transmit and receive data, including a unique serial number. Such tags have an electronic circuit (printed circuit board) with their own power supply.

Both passive and active RFID tags are capable of responding to a variety of low-, high- or ultra-high frequencies. Each has unique capabilities in terms of the amount of data it can transmit, as well as footprint and proximity constraints (see Table 3). Currently, basic RFID tags sell for between $0.25 and $0.50 each[4], with readers in the $300-$500 range, though prices vary depending on the functions included and are changing rapidly. In general, due to the greater need for security and visibility, the need for active tags is higher.

[INSERT TABLE 3 ABOUT HERE]

A number of complementary miniature or nano-technologies will enhance the use of RFID:

- Micro-sensors: devices that detect physical phenomena and report on specific conditions, such as temperature, humidity, toxicity, radioactivity, light, gravity, acceleration, pH, etc.
- Micro-actuators: devices that act based on computer instructions or information from other sensors to start motors, turn on or turn off switches.
- Dynamic Display Devices: electronic ink, holograms and other technologies that can be integrated into packaging and be activated with electronic charges or flexible display technology.

3.2. Data stored on tags

The RFID tag is essentially a memory device which can display and communicate its memory contents when prompted (scanned) to do so. The memory consists of a plurality of binary (two state) digits, also known as bits, and communication comprises RF reception and transmission. The binary data (bits) are formed into binary words typically comprising 8, 16 or 32 bits that can make up letters and numbers in the same manner as in computing.

The data in the RFID tag memory may be pre-loaded (determined at the time of manufacture) as a Read Only Memory (ROM), or may be dynamically variable (Static Random Access Memory) and take up the status of the last write/read cycle. The data is always read out serially so that it can be correctly parsed. The information contained in the RFID tag memory is deliberately kept to a minimum, and, typically, is dependent upon the data format (its syntax, numerical format – decimal, hexadecimal, etc.) requiring translation into a human-readable form via a host system.

3.3. Readers

An RFID reader has an antenna that emits radio waves at a given frequency to 'activate' tags within its range – often referred to as inductive coupling. Upon receipt of the RFID reader's radio signal, a tag sends information stored in its memory back to the reader. The reader then converts the data into digital information and forwards it to the appropriate application.

The complexity and configuration of the interrogator/reader depends on the functions to be fulfilled, which can differ quite considerably between applications. In general, however, the reader's function is to provide the means of communicating with the tags, and to facilitate data transfer.

The speed with which the scanner/reader can interrogate the tag and write to it will depend upon the RFID technology used, especially the radio frequency. Most importantly, the proximity necessary between the scanner antenna and the RFID tag for successful operation is dependent upon the radio frequency and whether the tag is active or passive.

There are four main frequency bands (Table 4) used for RFID systems (Microlise, 2003; Psion Teklogic Inc., 2004).

[INSERT TABLE 4 ABOUT HERE]

3.4. IT infrastructure or middleware

RFID deployment requires middleware to program and read tags. RFID middleware consists of computer hardware and data processing software connected to the enterprise's inventory or identification management systems. A middleware platform provides the operating system, data repository, and processing algorithms that convert multiple tag inputs into visible tracking or identification data. Middleware can be managed by company personnel using RFID or be contracted out to an IT service provider.

The primary challenges in implementing the necessary IT infrastructure and organisation processes for RFID include integrating disparate systems across an organisation, establishing the corporate governance that ensures the system is used properly, and ensuring interoperability with other systems.

Industry analysts have predicted that RFID will produce 30 times more data than companies have today (Unisys, 2004). To ensure that data does not overwhelm current systems and is instead used for smarter, better, faster performance, it is recommended that companies should leverage several other critical IT components, including data stores, Online Analytic Processing (OLAP) applications, business rules engines and distributed services. These components are necessary to build an effective RFID architecture and, ultimately, to integrate with existing enterprise infrastructure.

4. RFID in healthcare

The adoption of RFID technology by the healthcare industry has been sluggish because payback is less immediately visible compared to what most companies prefer. Recently, the evolution of the RFID technology has attracted the attention of the healthcare industry, and more organisations have begun to seriously consider RFID as a means to improve patient safety and service (Bazzoli, 2004). A recent survey, entitled 'RFID in

Healthcare', was carried out online in September and October 2005 by BearingPoint and the National Alliance for Health Information Technology (NAHIT) with the goal of understanding what is driving and impeding the adoption of RFID within the healthcare sector. It was found that RFID technology is being used for a wide variety of applications within healthcare organisations, including patient flow management, access control and security, supply chain systems and smart shelving. On the other hand, it also determined that the most popular areas for RFID deployment during the next two years would be using real-time medical equipment-tracking systems and patient safety systems, e.g., for identification and medication administration (Collins, 2005a; Briggs, 2005).

In total, 313 commercial and government healthcare organisations were included in the survey, 95% of which were based in the US. About 85% of respondents were reported as being executives for commercial and government health-care providers, while pharmaceutical manufacturers, medication suppliers/distributors, manufacturers of RFID equipment and technology service providers accounted for the rest. The goal was to understand what is motivating and hindering the adoption of RFID within the health-care sector. Key findings from the survey include the following (BearingPoint, 2005):

- The benefits that provider organisations expect from RFID technology were divided into technological and business categories in the survey. In the technological category, respondents cited improved data accuracy most often (54%), while in the business category improved patient safety was cited as the top benefit for RFID by 67% of respondents, with improved patient flow and general productivity ranking second, each cited by 48% of respondents as 'very important'.
- 80% of C-level respondents described RFID technologies as important or very important to their business strategies.
- 15% of 313 respondents indicate they are piloting some type of RFID technology today, 31% of respondents expect to pilot RFID technology in the coming year and 54% will do so in the next 24 months.
- 30% of large organisations (those with annual IT budgets over $100 million) have already deployed some RFID technologies, compared with just 13% of smaller organisations.
- Less than 20% of respondents plan to spend more than $250,000 on RFID in 2006 and 53% plan no spending at all. However, nearly 74% anticipate investment in RFID by 2007 and nearly 39% anticipate spending $250,000 or more on the technology in 2007 and 2008. Large organisations plan to spend considerably more – between $1 to $5 million on RFID in 2007–2008.
- Cost is the top technological barrier to adopting RFID technology, with 46% of survey respondents citing tags, or data storage chips and reader devices as the chief expenses. Barriers to business were led by the lack of available funding, noted by 57%.
- 60% of respondents said they have delayed implementing RFID while they wait for industry or government guidance on standards.

According to the figures that indicate that 31% of respondents expect to pilot RFID technology in 2006 and 54% will do so in the next 24 months, it's expected that, apart from allowing a bigger development of the technology, it will increase the possibilities of application of RFID in healthcare organisations.
Among the healthcare-specific RFID uses we highlight the following ones:

- patient identification and tracking
- asset management and tracking
- drug counterfeiting
- inventory management
- spare parts for surgery
- blood and specimen bags
- tracking patient files

Figure 6 illustrates the intricate relationships between these seven applications and the seven wastes in healthcare (see Table 1)

[INSERT FIGURE 6 ABOUT HERE]

4.1. Patient identification and tracking

The wireless, automated, and secure process of using RFID ensures positive patient identification and fully streamlined operations. With both patients and staff on the move, hospitals face significant challenges in managing the fluid process of patient care. As patients are often scheduled for multiple and consecutive procedures, knowledge of their location helps optimise the patient-care process and enables managing schedules in real-time. For instance, when a patient arrives in a lab for a radiology exam, the medical staff is instantly alerted via the RFID tag, and the transfer of records can be completed immediately. The development of RFID technology for tracking patients received a boost in October 2004, when the US' Food and Drug Administration (FDA) approved subcutaneous RFID implants for patients.
RFID is often used on patient wristbands to provide accurate identification[5] and to track their location. The use of the wristbands is particularly important in cases of long- term care, mentally challenged patients, and the newborn.
RFID readers would then be placed in specific areas of the facility so that a tagged patient can be located within a reasonable distance. The definition of reasonable distance is one that would be defined by the system integrator working with the client to define an area large enough to be cost-effective in terms of the number of readers required. It should also be small enough so that the patient can be located with some degree of confidence. Even for outdoor coverage, readers can be deployed so that patients can be tracked as they exit a facility and move around the facilities. Special alerts can be programmed based on the unique needs of a facility, an area or a patient. Similar systems are in place at a number of theme parks today where families are able to obtain tags which provide them

with visibility regarding the location of children and other family members throughout the park.

It should be noted that if an adequate RFID reader infrastructure is put in place to track patients and staff, that same infrastructure can also be utilised to track assets. However, there are cases in that it is not necessary to install an infrastructure of RFID readers. In the Acute Care Pavilion of the Jacobi Medical Centre, the IT staff instead of installing a separate array of RFID readers, incorporated the RFID technology into the pavilion's 802.11 wireless network. The pavilion's RFID network will be used as an active RFID system to track patients through the facility's separate adult and pediatric emergency departments (Schuerenberg, 2005).

There are different real examples of RFID patient identification and tracking. In some of them the procedure is carried out by means of wristbands and in other cases by means of labels attached to the patients' paper charts, to the IV bag or even placed on the patient near the surgical site (Collins, 2005b; Schuerenberg, 2005):

- An example of this is the Smart Band that the US-located Jacobi Medical Centre has already started to use together with embedded RFID readers in Tablet PCs used by clinicians. Thus, wristbands fitted with RFID tags are encoded with patient demographic information when a patient is admitted to the medical centre. Clinicians use the Tablet PCs to scan the wristbands before administering medications. Once the RFID tags are scanned, nurses are wirelessly connected to a medication administration page; physicians automatically see a screen where they can place orders. Before administering a medication, nurses must check the information collected from the tag with drug information in a drug order database. According to Dan Morreale, Jacobi Medical Centre CIO, the system has helped clinicians shave 70 minutes a day off the time they spend on medication administration. Jacobi has reduced its overtime payroll expenses by $1.5 million since the RFID system went live in five nursing units.

- The US-located Lucile Packard Children's Hospital uses RFID wristbands to track the location of its newest patients and ensure they won't be removed without permission. The same system is being used to track assets.

- Chang-Gung Memorial Hospital, in Keelung, Taiwan, has begun issuing RFID wristbands to its surgical patients. The RFID-based system allows the hospital to access and record patient data in the surgical room.

  Surgical patients entering the Taiwan hospital are given a SmartBand at the time of registration. On the front of the band is printed the patient's name and other information. An RFID 13.56 MHz chip embedded in the wristband contains encrypted medical data, such as the patient's blood type. Nurses and doctors in the surgical unit can read the wristbands with a RFID reader that attaches to an IPAQ HP pocketPC unit. The readers have a range of about 10 cm. The wristbands allow hospital administrators to encrypt a portion of the data, so that if the wristband is lost, it cannot be deciphered by another party. In addition, some data, such as blood type, is read-only and cannot be changed, while other data can be updated by surgeons, nurses and other hospital staff.

- St. Vincent's Hospital (Birmingham, Alabama) uses an active RFID system to track patients and monitor when they arrive and leave different departments, attaching RFID tags to patients' paper charts, which are clipped onto beds. The RFID system is integrated with a patient management system that collects data from various information systems and provides an on-screen, virtual floor plan of the facility. The floor plan has icons representing individual patients. The icons can be clicked to access the patients' clinical and demographic data, as well as their status- for example, if they are scheduled for discharge.

  RFID tags attached to the beds track them and patients, throughout the facility. When a patient leaves a floor, an icon comes up in the system to let a care-giver know they are in transit. The RFID system also enables the hospital to check or change the status of each room. For example, if a patient is being discharged, or is being moved to another department, that room can be earmarked for cleaning after the system shows the patient has been moved.

  Integrating RFID technology with the patient management system has provided a clearer snapshot of how patients are moving through the facility. Since the RFID technology was deployed, the time it takes to discharge patients has decreased by 30%.

- In Hannibal (Mo.) Regional Hospital the day before a surgery, clinicians assign patients a badge fitted with an RFID tag. The badge's serial code is entered into the patient tracking application. The patient receives the badge during registration. Clinicians attach the badge to the patient's IV bag during a procedure. The RFID system tracks the patient badge as it moves throughout the facility. Nurses use PCs to check the patient's name, location and time they arrived in each area via the tracking application.

  Nurses also provide visitors with the patient’s badge number so they can track them using kiosks in waiting rooms. The kiosks only list badge numbers and their corresponding location, although clinicians can enter notes into the tracking application that can be read at the kiosks. The hospital also configured the system to track when surgery preparation work began and finished, and when the first incision was made.

  Clinicians also can enter information about why a procedure has been delayed, such as if the right equipment wasn't in the room or a clinician was late.

  Hannibal Regional also used the technology to analyse its surgical scheduling process. Administrators found that many procedures were being done after hours, which increased costs because support staff had to be paid overtime. It is for that reason for which the hospital has decided to implement a block scheduling system to ensure surgeries are being scheduled for specific time frames when appropriate support staff is available. The system has helped Hannibal to increase its surgical department utilisation rate from 70 to 57%.

- The Palm Beach (Fla.) Orthopaedic Institute is one of the first provider organisations to implement RFID technology to mark the sites where patients will have surgery with the SurgiChip. This system was designed to help reduce medical errors by ensuring the right procedure is being done on the right patient in the right location.

Clinicians print a patient's name and surgical site on a label on a SurgiChip RFID tag. They encode the tag with the date of the surgery, type of procedure and name of surgeon. The tag then is placed in the patient's file. The tag is scanned again prior to surgery to verify the information. It’s then placed on the patient near the surgical site. In the operating room, the tag is again scanned to verify the data with the information in the patient’s chart.

In sum, the use of RFID to track and identify patients and staff offers many advantages for healthcare organisations, since it enables them to record their location, the patient flow, the time that each step in the process takes, the distance travelled, inventory levels and so on, all in real time, thus detecting and eliminating waste related to transportation, motion, waiting, defects and inventory much faster.

4.2. Asset management and tracking

Large hospitals lose hundreds of thousands of dollars worth of equipment each year and spend countless hours searching for patient-care assets. This includes medical devices (such as infusion pumps, portable X-ray machines and patient monitoring devices), as well as other mobile assets such as wheelchairs, stretchers and gurneys. Nurses sacrifice time with patients to seek equipment they need, and maintenance staff lose productive hours searching for specific items that need maintenance. Examples of how this can create operational and economic challenges for a healthcare facility include (Young, 2005):

- Increased labour costs associated with assigning individuals to search for equipment when needed.
- Decrease in number of revenue-generating procedures that can be performed due to time lost because of equipment not being available as needed.
- Increased inventory costs as more equipment is acquired via purchase or rental in order to offset the perceived lack of available equipment.
- Disgruntled staff, as the already overworked employees become increasingly frustrated with the operational inefficiencies.

The use of RFID in this context offers many advantages similar to those outlined in the previous section. The following are some real application cases (Goedert, 2004; Rogoski, 2006):

- Bon Secours Richmond (Va.) Health System is an example of asset management and tracking with RFID. The three-hospital delivery system uses 10,000 pieces of movable equipment, ranging from medical devices, stretchers and wheelchairs, to IV poles and thermometers. But equipment that employees needed for patient care often was either stuck in a closet, lying unused in another department, or in some cases had been stolen.

  The situation became more complicated when a fourth hospital opened its doors in

September of 2005, making that Bon Secours Richmond opted for RFID to track movable medical equipment.

The software runs on a Wi-Fi wireless network and tracks equipment assets and measures utilisation, and includes embedded business processes that help manage workflow. This enables users to track the location and status of a piece of equipment, and know if it is available, in use, or out of service for cleaning or repair. Nurses, orderlies or technicians in the biomedical department which is responsible for maintaining much of the equipment click on an icon on the desktop to check the status and location of equipment. Staff also can connect to the inventory management system via PDAs operating on the Windows mobile operating platform.

Jerry Maki, the chief administrative officer, 'conservatively' estimates annual savings of $200,000 for the initial three hospitals. The bulk of the projected savings comes from not having to replace equipment hiding in a corner somewhere. In addition, and according to Maki, 'Nurses on average spent 15 to 20 minutes a shift trying to find equipment'.

- At Yale-New Haven Hospital in New Haven, Conn., for example, RFID technology is being used to track down equipment, because the equipment was being moved in and out of units and it was not returned to the unit to which belonged. The end result was wasted labour hours searching out needed equipment.

  The hospital, licensed for 944 beds and with three patient towers with access shared among the three, reviewed RFID's applicability and decided to test its effectiveness and installed the necessary wireless infrastructure on the third floor of each tower to accommodate the ORs and the cardiothoracic ICU. The basement also was wired to track equipment in central supply, as well as in basement areas where tagged items could end up if inadvertently discarded. Approximately 1,000 pieces of equipment, including supply carts, were 'tagged' using reusable, programmable active tags, which can send hospital-defined alerts such as 'equipment tag removal' or 'equipment leaving defined usage perimeter'.

  Joe Lederer, director of perioperative support systems, says the system is getting about 25 hits a day from staffers looking for equipment.

  Yale-New Haven also decided to pilot the technology in the operating rooms that are extremely equipment-intensive.

4.3. Drug counterfeiting

The World Health Organisation estimates that between 5 to 8% of global pharmaceuticals are counterfeit. In some countries, the percentage of counterfeit drugs is significantly higher at 25 to 40%. Thus, the pharmaceutical industry reports that it loses $2 billion per year due to counterfeit drugs (HDMA, 2004).

Fortunately, RFID tags can help detect products that are: counterfeit or fake, tampered with, adulterated or substituted, and unacceptable (i.e. expired, discarded, returned, recalled, etc.) (Koh et al., 2003). They also create an electronic pedigree, or record of the chain of custody, from the point of manufacture to the point of dispensing. Electronic pedigrees will improve patient safety and protect public health by allowing wholesalers and retailers to rapidly identify, quarantine, and report suspected counterfeit drugs and conduct efficient, targeted recalls.

In early 2004, the USA's Food and Drug Administration issued a report recommending that pharmaceutical companies use RFID[6] on bottles of the most commonly counterfeited drugs starting in 2006 and on bottles of most drugs by 2007.

In July 2004, a group of manufacturers, including Abbott Laboratories, Johnson & Johnson, Pfizer[7], and Procter & Gamble, began shipping bottles of pills with RFID labels. McKesson Corp. and Cardinal Health are the participating distributors.

In addition to tracking fake drugs, tagged bottles can serve to prevent theft, as well as to manage recalled and outdated medication. As pharmacies receive medication through specific distribution centres, bottles would be tagged reflecting their point of origin. Alarms could thus be raised when an incomplete or inaccurate set of locations were found on a tag.

4.4. Inventory management

Large amounts of inventory can be typically found in hospital operating rooms. Lack of visibility in the supply chain often results in the proliferation of inventory that could be reduced by properly managing the material ordering process. RFID technology can provide an accurate account of inventory levels.

Following the example of leading retailers, hospitals could move to the next generation of supply chain management by having their suppliers manage product ordering and inventory levels. Hospital suppliers would then be responsible for providing product on a timely basis through RFID technology. A dramatic shift in how hospital supplies are ordered could drive down hospital inventory levels assuming the proper processes and metrics are in place.

There are RFID-enabled cabinets on the market for tracking supplies together with the software necessary to manage the dates collection and to automate the tracking, billing and ordering of these surgical items and link the system with to hospital's information system.

The normal procedure consists on applying a tag in the items' packaging. Items are then placed in a cabinet, which records each item's entry presence and notes which shelf that item is on. When an authorised member of the hospital staff needs items in the cabinet, he or she enters a personal pass code on a built-in keypad to gain access to the cabinet. The system then records each item that is removed, along with the time of removal, and the identity of that staff member. Access can also be authorised for supply companies to restock supplies as required.

One of the hospitals that use this system of inventory management is the Massachusetts General Hospital, than tracks more than $500,000 worth of supplies, most of which is used orthopaedic implants (Collins, 2004).

4.5. Spare parts for surgery

Hip surgery involves a number of different parts, all of which are specifically tailored and designed for a particular operation. The parts are supplied in the form of a kit, and must only be used together. Because the parts have to go through a number of manufacturing and sterilising processes, a label is not suitable. By employing a tag embedded in the part, it can be tracked through various processes, and then all the parts for the kit can be reconciled before being delivered to the hospital. The tag can remain in the part after it is fitted to the patient, so that if it fails at a later date, it can easily be identified (Raza et al., 1999).

4.6. Blood and specimen bags

Identifying and tracking different medical bags is the objective of this RFID solution. A RFID tag with a unique serial number or other stored information is placed on the medical bag. The application of an e-label will reduce handling, human errors and lead to the prevention of any resulting administrative problems.

The Massachusetts General Hospital, in Boston, comes making tests involving the matching of patients' blood types on the wristbands against blood to be used in transfusions in the surgical suite, and is evaluating how much more effective and efficient RFID solutions are, compared with existing bar code ID systems, during blood transfusions. According to Walter Dzik, co-director of blood transfusion service at the hospital, the risk of transfusion of blood to the wrong patient is more than 100 times greater than the risk of transmitting an infectious disease through a blood transfusion (Framingham, 2004).

4.7. Tracking patient files

Often the original copies of legal or confidential documents like clinical reports, pathological test certificates, etc. need to be controlled. By employing a smart label tag on the documents and a tag on the actual person, in the form of a card, readers placed around a building can track documents and link them with the person in possession of them. In addition, the documents and the 'owner's' whereabouts can be monitored at all times. This also can be used as a security feature to ensure that only authorised personnel have access to specific documents (Raza et al., 1999).

The application of a smart label in this case will reduce handling, human errors and lead to manpower reduction.

5. Disadvantages and threats of RFID

The potential for operational improvement and increased shareholder value through RFID is significant; however, some perceived drawbacks need to be addressed before the technology truly enters the mainstream. These include the cost barriers, especially for small- to medium-sized enterprises, an absence of RFID standards, privacy and security issues, and a lack of sophisticated software to integrate RFID with business applications, such as supply chain management and Enterprise Resource Planning (ERP) systems

(Jaques, 2004). As these technical and policy challenges are mitigated, RFID will probably become the system of choice for global commerce. With regards to the absence of RFID standards, Table 5 summarises some of the relevant issues that should be kept in mind when considering the adoption of RFID.

[INSERT TABLE 5 ABOUT HERE]

Initial system and implementation costs are still being refined; in the short-term this could prove to be an impediment to large-scale adoption. Although RFID provides small- and medium-sized enterprises with new opportunities to compete in the global market, limited budgets, lack of in-house expertise, and a lack of access to new technologies could impede adoption of the technology. Stephen Smith, research vice-president of Gartner Group, states that 'RFID technology and the business benefits it promises will not arrive with a big bang' (Jaques, 2004). Interoperability across various RFID systems, companies, and countries is critical in achieving wide-scale deployment of RFID technology. Development of technical standards for tags, readers, interface systems and allocation of operational limits for frequency and transmission power will determine global interoperability.

The collection and use of personally identifiable information through RFID technologies represents a key public policy challenge to the deployment and use of RFID technologies. Much of this concerns the collection, use, and storage of data rather than the technology itself. Industry-driven solutions are beginning to include a combination of operational guidelines, technical solutions and educational campaigns. Most privacy and security concerns about RFID involve the use of RFID at the individual customer level, at or after the point of sale, rather than in supply and inventory tracking applications.

Privacy concerns revolve around whether and what notice is given to customers when RFID is used, whether options are provided to customers to disable the tag, what data is collected and how it is used or shared, and for how long and for what purpose the data is retained.

Applications of the technology, such as in immigration and border controls efforts, or the recent Federal Drug Administration approval for human-implanted chips[8] , have been cited as examples of 'big brother watching', and have generated some public concern (Flint, 2004).

In November 2003, a coalition of advocacy groups (e.g. the Electronic Privacy Information Centre, the Electronic Frontier Foundation, the American Civil Liberties Union) led by CASPIAN (Consumers against Supermarket Privacy Invasion and Numbering) released a position statement on the use of RFID in consumer products. This position statement called for a 'moratorium' on RFID technology to fully assess the impact of the technology. EPCglobal has stated that in order to unlock the potential of RFID and the EPC, it is important to address privacy concerns regarding the use of the technology. EPCglobal has proposed a set of privacy guidelines that companies deploying RFID can follow to complement existing national and international legislation and regulation dealing with consumer protection, consumer privacy, and other issues (EPCglobal).

Key tenets of the guidelines incorporate principles of industry responsibility, providing accurate information to consumers, and ensuring consumer choice. The guidelines encompass practices for consumer notice, consumer choice, consumer education, record use, retention and security. EPCglobal also suggests that companies provide consumers with notice and choice when tags are used, including options to disable tags after the point-of-sale[9].

In January 2005, the European Union's Data Protection Working Party (set up under Article 29 of Directive 95/46/EC) published its first assessment report on data protection issues related to RFID. This working document raises concerns about the impact of item-level tagging using RFID on the potential for direct marketing and customer tracking. Applications that link RFID tags with consumer bank accounts were also stated as problematic. The report suggests that consumers should be given adequate tools to delete any information on tags embedded in goods they purchase, or the alternative, the ability to remove the tags after purchase. For passports and other identification mechanisms, the Working Party advises the use of standard authentication protocols (e.g. ISO) in order to ensure that the data is encrypted and unavailable to those without the requisite authorisation. The report identifies three main data protection areas related to the use of RFID: the first is the use of RFID to collect information linked to personal data. This link might be direct or indirect. The second is the use of RFID tags for the storage of personal data. The third and final area is the use of RFID for tracking purposes, without 'traditional' identifiers.

Finally, we must not forget the security challenge. Currently, RFID data security can be compromised by direct interceptions of RFID transmissions or by indirect access to networks where transaction data is stored. Typically, when RFID readers query tags in their vicinity, the information collected by the readers regarding the location, status, or condition of the item or product to which the tag is affixed is relayed or transferred to a data collection system. Security concerns may thus arise regarding data being compromised during wireless transmissions, data storage itself, and the physical security of the data storage site. It is worth noting that security vulnerabilities at the database level are not RFID-specific and could apply to any application where datasets are collected and stored, such as credit card or loyalty programme information.

6. Conclusions

RFID technology has tremendous potential to make life easier and improve human conditions. However, further innovation and industrial deployment of this technology should be done in parallel while carefully exploring all the related aspects. First, in order to avoid market fragmentation and unnecessary costs a concerted effort is needed towards the development of an international standard. Second, the development of RFID should not be the subject of monopolistic commercial development. Third, it should be fully understood that the effective development of RFID is not possible without considering issues related to data protection and consumer privacy. Finally, it is important to consider the ethical and sociological impacts of any innovation alongside the economic and technological issues.

An important application of RFID is in the medical and pharmaceutical fields. In hospitals, for example, RFID enables a fully automated solution for information delivery at the patient bedside, thus reducing the potential for human error and increasing efficiency. Its use is equally pivotal in the pharmaceutical industry, where electronic product tags on medication can curtail counterfeiting, streamline revenue distribution, reduce prescription errors, and decrease returns. When used in combination with lean principles, the benefits that can be obtained are enormous, in spite of the fact that they are not always easy to quantify. They include continuously tracking each patient's location, real time tracking of the location of doctors and nurses in the hospital, tracking the location of expensive critical instruments and equipment, restricting access to drugs, pediatrics, and other high-threat areas to authorised staff, monitoring and tracking unauthorised persons who are loitering around high-threat areas, and facilitating triage processes by restricting access to authorised staff and 'approved' patients during medical emergencies, epidemics, etc. A major strategic benefit is its contribution to the development of a responsive, adaptive, and learning organisation.

So far, RFID could be considered a starting part of a comprehensive digital hospital strategy. Nevertheless, healthcare delivery organisations can find difficulties when traversing the digital hospital continuum and it is not only due to the limitations faced by RFID. It is also related to the unique features of the healthcare industry. It is easy to understand that few other industries have to maintain 24 hour, 7 days a week, 365 days a year service without downtime. Additional challenges to be taken into account are staff and non-staff user population, complex and complicated transactions, and an enormous flow of information processing.

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Notes

[1]HEALTHCAST 2010: Smaller World, Bigger Expectations is a view of the future from the healthcare practice of PricewaterhouseCoopers. To compile this report, PricewaterhouseCoopers conducted extensive desk research and commissioned a wide-ranging survey of more than 380 thought leaders. The HealthCast 2010 survey, referenced in this report, was conducted in the US, the UK, Scandinavia, Italy, Spain, the Netherlands, Germany, New Zealand, Canada and Australia. Those surveyed included a mix of government officials, policy makers and top executives of hospital systems, employers, physician groups, other providers, insurers and medical supply manufacturers. In addition, more than 50 thought leaders from Canada, New Zealand, Spain, the Netherlands, Switzerland, the UK and the US were interviewed at length about future trends and implications in the decade ahead.

[2]The percentage of hospitals with web sites grew from 12% in 1995 (Shepherd and Fell, 1996) to over 50% by 1999 (Katzman, 2000).

[3]According to a recent market forecast by IDTechEX, the value of the total RFID tag market, including systems and services, will explode from $1.95 billion in 2005 to $26.9 billion in 2015 (Myeroff, 2005).

[4]ARC Advisory Group, a research firm, expects that by 2008 the unit price will drop to an average of 16 cents for passive UHF tags, which vary by form factor, and to nearly 30 cents each for passive HF tags, although some tag manufacturers with high-volume contracts may be able to offer passive UHF tags for as low as 5 cents each (Ward, 2004).

[5]For example, the patient RFID tag could be encoded with patient name, social security number, birthday, sex, blood type, allergies, physician, admission date, contact person & phone number and ailment.

[6]According to Frost and Sullivan, (2004) the investments by pharmaceutical companies in RFID will reach $ 2.3 billion by 2011 (Barnes, 2006).

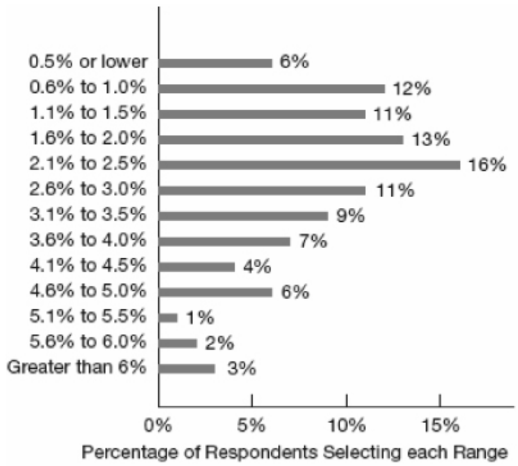
[7]On Dec. 15, 2005 Pfizer began to affix RFID tags to all U.S. shipments of Viagra in an effort detect counterfeit pills. The company plans to spend about $5 million on the project (Gilbert, 2006).

[8]The chips, designed by Applied Digital Solutions and known as 'VeriChips', are injected under the skin. These would contain a unique ID number that would be used to access medical records on a remote server maintained by Applied Digital Solutions. The stated objective of these chips is to provide better health care and reduce medical errors. RFID implants have also been used to enhance security at prisons (Best, 2004).

[9]Germany's Metro stores are demonstrating this concept at their pilot store in Dusseldorf. Once a customer has paid for a product, they can choose to deactivate the RFID tag. The RFID De- Activator allows the consumer to overwrite the EPC tag information with zeros (US Department of Commerce, 2005).

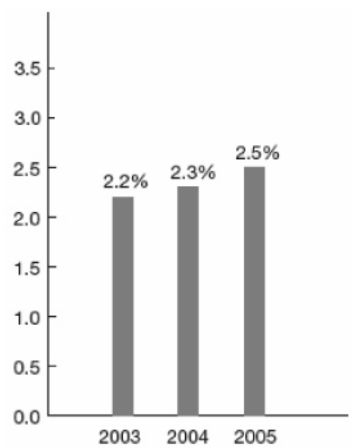
FIGURES AND TABLES

Figure 1 Percentage of hospital's operating budget allocated for information systems in 2005



Source: Modern Healthcare/PriceWaterhouseCoopers IT Survey 2005.

Figure 2 Percentage of hospital operating budget dedicated to IT



Source: Modern Healthcare/PriceWaterhouseCoopers IT Survay 2005.

Figure 3 - Integrated IT solutions: new knights in the quality care crusaders

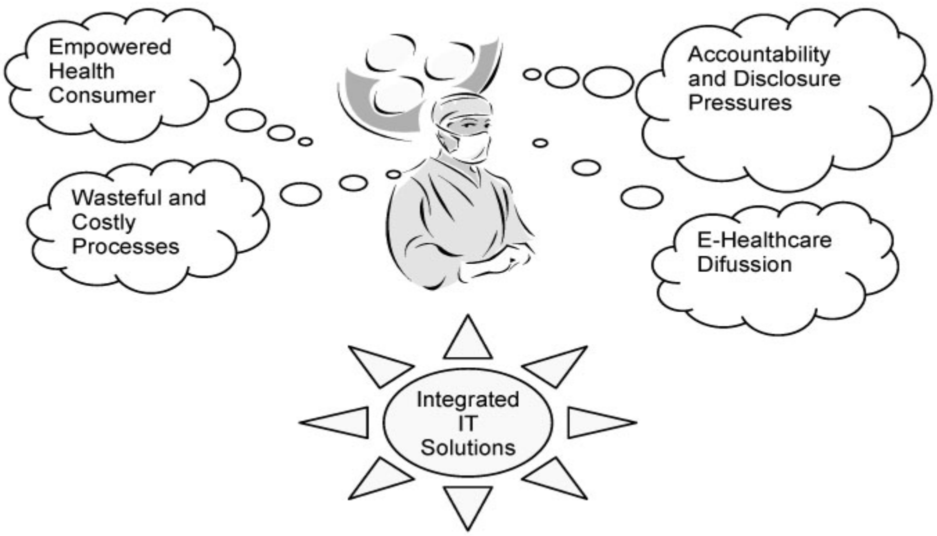
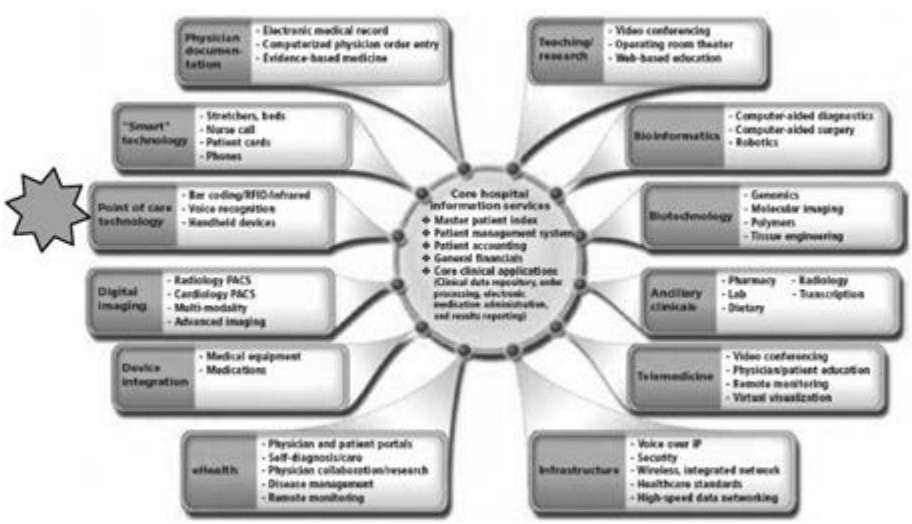


Figure 4 - Digital hospital applications and RFID technologies



Source: PriceWaterhouseCoopers, 2005b

Figure 5 A notion of ideal for healthcare (Jimmerson et al., 2005)

IDEAL
_ Exactly what the patient needs, defect free.
_ One by one, customized to each individual patient.
_ On demand, exactly as requested
_ Immediate response to problems or changes.
_ No Waste
_Safe for patients, staff and clinicians: Physically, Emotionally, and Professionally

Source: Jimmerson et al., 2005

Figure 6 RFID applications and 'the seven wastes of healthcare

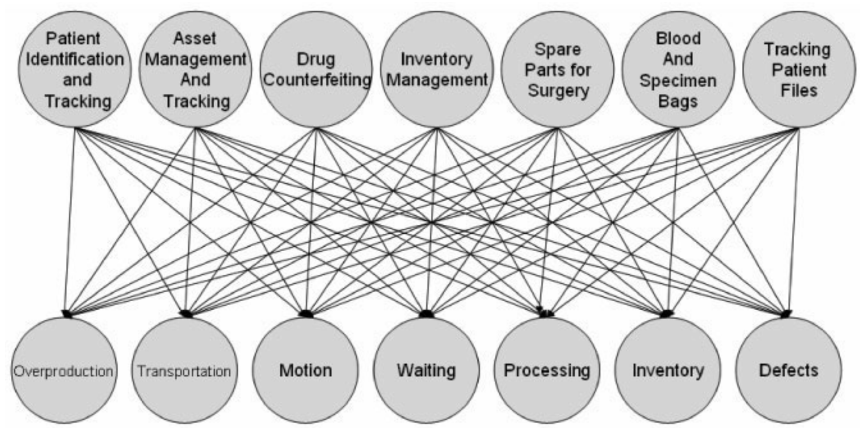


Table 1 - The Seven Wastes in Healthcare

Types of waste	Definition	Manufacturing	Healthcare
Overproduction	Producing more than the customer needs right now	Producing stock based on sales forecasts Producing more to avoid set-ups Batch process resulting in extra output	Pills given earlier than required to suit staff schedules Testing ahead of time to suit lab schedule
Transportation	Movement of product that does not add value	Moving parts in and out of storage Moving material from one workstation to another Moving equipment	Moving samples Moving patients for testing Moving patients for treatment
Motion	Movement of people that does not add value	Searching for parts, tools, prints, etc.	Searching for patients, physicians, documentation,

		Sharing tools, equipments, etc.	supplies, equipments, etc.
Waiting	Idle time created when material, information, people, or equipment is not ready	Waiting for parts, inspection, information, equipment, etc.	Patients waiting for bed assignments, admission to Emergency Department, testing & treatment, discharge, lab test results
Processing	Effort that adds no value from the customer's viewpoint	Paperwork Over-tight tolerances Awkward tool or part design	Excessive paperwork Retesting Unnecessary procedures
Inventory	More materials, parts, or products on hand than the customer needs right now	Raw materials Work in process Finished goods	Bed assignments Pharmacy stock Lab supplies Specimens waiting analysis
Defects	Work that contains errors, rework, mistakes or lacks something necessary	Scrap Rework Defects Correction	Medication error Wrong patient Wrong procedure Missing information Poor clinical outcomes

Source: Gemba Research

Table 2 - The Main Differences Between Bar Codes and RFID

	Bar codes	RFID
PROs	Low cost, but not reusable	Provides a per-item identifier
	Widespread utilization	No line of sight required sensors
	Readable by humans	Can store more data and can be combined with
	Reliable to read	Covert and hand to counterfit
	Work with virtually all products	Automated processing
	Can be printed before production or printed directly on items	Many tags can be read simultaneously

		Can have a longer read range
CONs	Only identify groups of products	Higher cost (expected to drop), though potentially reusable
	Line of sight required	Lack of broadly accepted standards
	Limited data storage	Passive reading dependent on conditions
	Must be read one at a time	Not always reliable to read
	Easily damaged (dirt, water, scratches)	Work with most products but have trouble with some (such as those containing metals and liquids)
	Have a limited read range	Must be programmed, applied, and verified individually, and data synchronization is usually required

Source: Unisys, 2004; Institution of Electrical Engineers, 2005

Table 3 - Active vs. Passive Tags

	Active tag	Passive tag
Tag power supply	Internal to tag	Energy transferred from reader via RF
Tag battery	Yes	No
Availability of tag power	Continuous	Only within field of reader
Communication	Long Range (300+ feet), Networking of tags & readers	Short Range (~9 feet), no communication between tags or readers
Multi-tag collection	Collect 1000s of tags from readers, millions of square feet	Collect 100s of tags within 9 feet from single reader
Sensor capability	Continuously monitor and record sensor input with date/time stamp	Read & transfer sensor data only when tag is powered by reader (no date/time stamp)
Data storage	Large read/write data storage directly on tag	Small read/write data storage directly on tag

Source: HealthCare Pilot, 2005

Table 4- Main frequency bands used for RFID systems

Frequency range	Low Frequency (LF) 125 KHz	High Frequency (HF) 13.56 MHz	Ultra-High Frequency (UHF) 300-1200 MHz	Microwave 2.45 & 5.8 GHz
Read range	<0.5 metre	1 metre	100 metres (active)	10 metres (active)
Power source	Generally passive tags only	Generally passive tags only	Active or passive tags	Active or passive tags
Typical current applications	Access control, vehicle immobilisers, animal tracking, POS applications, Healthcare applications	Item level tracking, smart cards, Healthcare, patients tracking	Pallet tracking, toll collection, baggage toll collection, handling	Asset tracking, collection, baggage toll collection
General	Largest current install base	Wide acceptance due to Smart Card adoption	Not allowed in Japan. Europe uses 868 MHz, USA uses 915 MHz	
Data transfer	Slower	←→		Faster
Energy absorption	Less	←→		More
Energy efficiency	Higher	←→		Lower
Ability to read near wet or metal surfaces	Better	←→		Worse

Table 5 - RFID Lack of Standards

RFID data standards
The immense global potential of RFID-based applications is being hindered by the lack of established international standards for both specifications of the technology as well as applications. With the exception of electronic product codes, there has been a fragmented approach to the setting of standards. This lack of standards may mean that organisations will be forced to incur high costs to ensure compatibility between multiple readers and tags.
Currently, there are several projects underway to develop and refine technical standards for tags and readers, whereas common standards remain a pending goal (Edwards, 2003; Budnikowski, 2003). Likewise, the differences in operational frequency ranges, allowable

transmission standards, and allowable power limits in different countries continue to serve as operational constraints.
The Auto-ID Centre at MIT has been aiming to develop standard specification item-level tagging in the consumer goods industry, called the EPC. This has led to the formation of a new group, called EPCglobal, which is a joint venture between the Uniform Code Council (UCC) and EAN International. They maintain the UPC/EAN bar code system among others. As indicated in the name, the primary goal of EPCglobal is to make the final EPC standard an official global standard.
The EPCglobal model involves a number of components that include: the EPC, the ID System (EPC Tags and Readers), Object Name Service (ONS), Physical Markup Language (PML), and Savant. Basically, the EPC is a number designed to uniquely identify a specific item in the supply chain. The tag is able to communicate its EPC number when interrogated by a reader. The reader then passes the number to an Internet service, known as the ONS. ONS tells the computer systems where to locate information on the network about the object carrying an EPC. This information is held by the manufacturing organisation in what is called an EPC Information Server (EPCIS), which is linked to the EPCglobal network. Physical Markup Language (PML) is used as a common language in the EPCglobal Network to define data on physical objects. Savant is a software technology that acts as the central nervous system of the EPCglobal Network. Savant manages and moves information in a way that does not overload existing corporate and public networks.
The current thrust of EPCglobal is known as UHF Generation 2 (UHF Gen 2), a Write Once | Read Many tag with more memory (96 bits vs. 64 bits) than the preceding Class 0 and Class 1 tags. UHF Gen 2 is designed to work internationally and provide a bridge to the eventual Class 2 High Memory full Read Write tag. Prior to UHF Gen 2, Class 0 and Class 1 were being used for EPC, but there were not compatible. Consequently, a retailer who used an EPC solution would need different RFID readers to read different tags, or force all of their suppliers to use one technology. The EPC data standards developed by EPCglobal are only one set of data standards that are being developed. The International Standards Organisation has also released a new standard, ISO18000, which defines UHF and other frequency passive tag formats. Additionally, international organisations are developing their own competing standards such as Japan's UID (Ubiquitous ID) and China's NPC (National Product Codes).