

RFID Technology for the Health Care Sector

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Abstract: Health care is the linchpin of a developed society. The general trend in developed countries is to increase public spending to improve the quality of health care. However, the economic model applied to the health care sector varies from one country to another. There are models in which health care costs are mainly supported by governments. On the contrary, there are other economic models such as the “fee-for-service” model in which patients pay for the services like in any other service industry. Whichever model is used, technology can help increase the efficiency of the service and the reliability of the diagnoses. Specially, Radio Frequency IDentification (RFID) technology can drastically improve the processing times associated to medical records retrieval, dispensing of medications, personnel management, etc.

In this article, we explore some of the most relevant patents, which propose the use of the RFID technology in the health care sector. We provide an overview of the field and a classification of the patents in several categories, being the aim to facilitate the task of researchers, practitioners and managers when looking for patents in this field. Moreover, we analyse a recent and relevant patent application from Kodak™ that provides a system for monitoring the ingestion of medicines by means of digestible RFID tags attached to the medicines.

Keywords: RFID, Health Care.

1. INTRODUCTION

The modern concept of health care is like a jigsaw consisting of a large number of pieces. It is impossible to see the whole health care picture without fitting all pieces together.

Technology can help us see a picture of the health care sector, but sometimes we cannot see the wood for the trees. Technology can help the players of the health care game (i.e. patients, physicians, nurses, managers, etc.) interact more efficiently. Also, the amount of data that can be managed by means of the new Information and Communications Technologies (ICTs) is growing with each passing day, and these data must be properly used to improve the reliability, efficiency and quality of the health care sector.

In the previous fragment of the modern version of the Hippocratic Oath, Louis Lasagna emphasised the importance of the “hard-won scientific gains” achieved by physicians. We extend his view to other areas of knowledge (i.e. not only medicine) to say that health care evolves because it walks in the steps of scientists from many disciplines. Many new technologies are continuously being incorporated into the sector being the aim to make it better. Some of these technologies are mainly devoted to improve the exactness of the diagnoses (e.g. X-radiation technology for radiography and radiotherapy, computerised image analysis technology for computed tomography (CT), etc.), some others are mainly devoted to the management of medical records (e.g. databases technology), and so on.

All these technologies are extremely useful, but they are very specific and their application area is quite narrow. On the contrary, ICTs can be applied to the health care sector as a whole. They can be understood as glue that hold the pieces of the jigsaw together. Radio Frequency IDentification (RFID) technology will have an extraordinary impact over the health care sector in the near future. Although other approaches based on other techniques have been proposed (e.g. Multi-Agent Systems (MAS) [1]), currently, the conditions for the deployment of the RFID technology in the health care sector are optimal (e.g. many people, from manufacturers to governments, want the RFID technology deployment to be a reality). Moreover, RFID components used in logistics can be easily applied to the health care sector.

McGlynn *et al.* conclude in their study of the quality of health-care delivered to adults in the United States [2] that a major overhaul of the current health information system is necessary. Specifically, it is necessary to focus on automating the entry and retrieval of key data for clinical decision making. The RFID technology can dramatically help achieve these goals.

RFID devices can be seen as proper substitutes of bar codes since they are mainly used to identify objects. Unlike bar codes, RFID devices allow objects to be identified without visual contact and improve and automate many processes (e.g. product inventories). This is possible due to the ability of RFID tags for being read fast and in parallel. An RFID basic system consists of two main components [3]:

- RFID tags: They are small devices with a variety of possible appearances from stickers to small grains embedded in official documents. A tag basically

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¹Fragment of the modern version of the Hippocratic Oath by Louis Lasagna.

consists of a microchip and a metal coil, which acts as an antenna. In some cases, it can also contain a battery and some other microchips intended for increasing its computational power.

- **RFID readers:** They are active devices used to read the information stored in tags. In a nutshell, readers emit a radio wave so that all tags in their range answer by broadcasting their embedded information (i.e. a set of bits). This information, generally known as Electronic Product Code (EPC), is usually the identifier of the object into which tags are stuck.

The health care sector can obtain great benefits from the deployment of the RFID technology. By using RFID tags and readers, it will be possible to improve the efficiency of the system, to locate and track people and material easily, and the storage of patient data will become easier.

1.1. Contribution and Plan of the Article

In this article, we analyse some of the most relevant and recent patents which propose the use of the RFID technology in any area of the health care sector. Our contribution is threefold: (i) we provide the reader with an overview of the state-of-the-art of the RFID technology applied to health care, (ii) we propose an intuitive classification of the patents in several categories directly related to the main actors of the health care system, and (iii) we analyse a recent patent application from Kodak™ that provides a system for monitoring ingestion of medicines by means of digestible RFID tags attached to the medicines.

Our classification can be understood as a simple guide that will help researchers, practitioners and managers to easily obtain the information they need without being forced to waste their time reading an almost infinite number of patents. We aim to provide a general view and some starting points from which a complete image of the topic can be built.

The rest of the article is organised as follows. In Section 2, we elaborate on several patents that propose the use of RFID for the health care sector. We classify the patents in different categories and we study them separately. First, in Section 2.1, we analyse some patents that tackle the problem of health care as a whole (i.e. considering all the aspects of the problem at a time). Next, we analyse several patents that address more specific problems related to patients, physicians and medicines. In Section 3, we describe a recent patent application from Kodak™. Finally, in Section 4 we conclude with some comments on the current state-of-the-art and we point out some future developments.

2. HEALTH CARE PATENTS USING RFID

In this section, we briefly describe a number of health-care-related patents that use RFID technology. There is a huge number of patents in this field and it is a difficult task for a researcher or practitioner to find something in this mesh.

In order to simplify this search, we provide a classification inspired in the main players of the health care game

(i.e. patients, physicians and medicines), and we describe some relevant patents in each category.

We have classified the patents in the next categories:

- **Global view patents:** In this category, we elaborate on patents that consider the health care problem as a whole. These are patents or research articles that try to tackle the health care problem completely instead of independently considering smaller sub-problems such as billing, monitoring, identifying, etc.
- **Patient-related patents:** In this category, patents devoted to patients are studied and classified in the next sub-categories.
 - **Identification:** Patients identification patents using RFID technology belong to this category.
 - **Monitoring:** Patents that control the state of patients are classified in this category.
 - **Payment:** This category comprises methods and systems that can be used by patients to pay for services.
- **Physician-related patents:** Patents related to physicians are summarised in this category. Although physicians and other medical staff can use the identification and monitoring methods described in the previous categories, we have included in this category methods and systems that are exclusively used by physicians and medical staff.
- **Medicine-related patents:** All patents related to medicines and medication control belong to this category. We have defined two sub-categories:
 - **Authenticity and tracking:** Patents that address the problem of verifying the authenticity of medicines are classified in this category.
 - **Delivery and compliance:** In this category we have summarised the most relevant patents that tackle the problem of delivering medicines and check for compliance.

This classification does not intend to be exhaustive. Its aim is to provide an introductory guide to the field of RFID technology applied to the health care sector.

2.1. Global Approaches Using RFID

In most cases, patents mainly address specific problems, namely patients tracking, medication dispensing, billing, etc. However, there are some patents that consider the health care problem as a whole (i.e. considering many problems such as tracking and monitoring at the same time). In [4], a system for managing the work-flow of a health care unit is described. The system is task-oriented and the RFID technology is mainly used to track patients, equipment and material. A number of problems are tackled, namely accounting and billing, distribution of personnel, inventory tracking and equipment movement, etc. During the registration, patients are provided with a wristband that has an embedded RFID tag, which identifies them. Whilst patients remain in the health care unit, these tags are read in order to determine their position. By using this location information, the system

is able to analyse how long the patients spent in a specific part of the medical environment and it is able to detect bottlenecks. Using RFID to identify patients reduces the number of medication errors which is one of the most dangerous problems in health care. RFID tags are removed from patients before they leave the medical unit. Fig. (1) shows an example of the improvement achieved by the system in a conventional physical work-flow path. By applying the proposed system, delays are reduced and the efficiency of the whole system is improved.

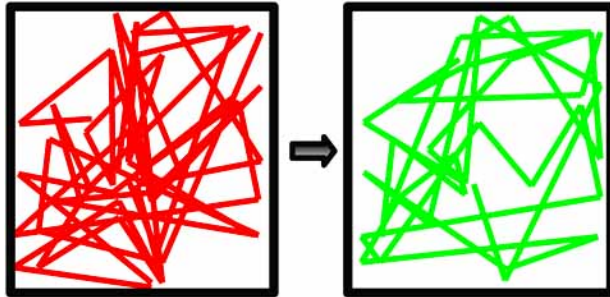


Fig. (1). Physical work-flow path example. (Left) Conventional work-flow path. (Right) Optimised work-flow path [4].

Li *et al.* described in [5] a mobile health care service (MHS) system based on RFID. The system uses RFID technologies and mobile devices for positioning and identifying people and objects, locating staff or instruments and keeping track of patients. Initially, the proposal was born to fight against the SARS (Severe acute respiratory syndrome) but it can be used to overcome other diseases. The point of using RFID is that readers and tags do not require contact or line-of-sight to transmit data, thus, it is possible to eliminate manual data entry and the productivity in difficult working environments can be increased. In the research carried out by Li *et al.* the RFID tag embedded chip was able to measure body temperature and transfer this information to a remote RFID reader located from 3 to 85 meters away. Thus, it is possible to monitor patients in a wide area.

2.2. Patients

Patients are the most important pieces of the health care jigsaw. Thus, many efforts of the scientific community and inventors are focused on them.

2.2.1. Identifying Patients

A wide variety of methods have been used to identify patients when they are in hospitals. One of the most popular methods is based on using a wristband in which a bar code is printed¹.

Before the appearance of the RFID technology, identification wristbands were no more than a number and some information that could be worn in the wrist. RFID technology opened the door to new inventions. For example, in [6] a wristband with a built in RFID is presented. Although previous proposals exist (e.g. [7] and [8]), the invention

presented in [6] is able to store location information thanks to a transponder that automatically and periodically generates and transmits encoded signals than can be read by an RFID receiver. Information read by the receiver is sent to a data processing system connected to a database in which all the information is stored (e.g. this kind of system can also be used to monitor prescription compliance [9]).

Wristbands are typically worn by patients from the time they are admitted to a hospital until the time they exit it; notwithstanding, other identification systems with longer lives can be used. In [10] a tooth-attached RFID tag is presented. This tooth-attached RFID tag comprises a chip for storing patient information, an antenna for transmitting this information, a housing for fixing the chip and the antenna, and a protective resin that protects the tag from food and saliva. Fig. (2) shows a scheme of the proposed system in which a tooth-attached tag is queried by a reader. The information gathered by the reader is transmitted to a user information database by means of a network. Although this invention can be difficult to be used in hospitals at this time, it will be a serious choice in the near future when the number of people with tooth-attached RFID tags will grow.

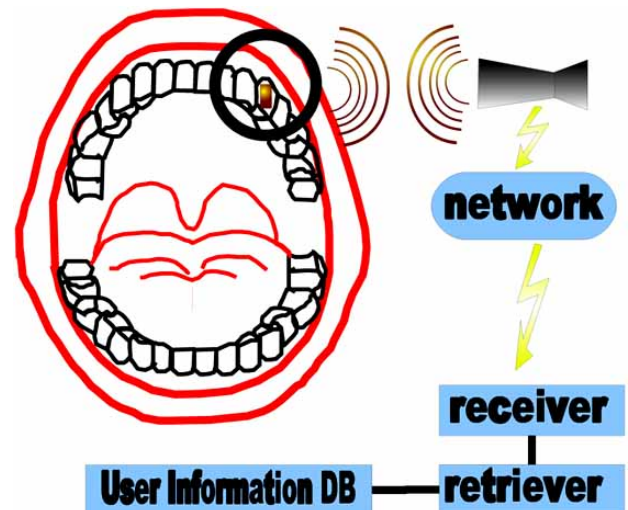


Fig. (2). Scheme of the system described in [10]. The circle marks the tooth-attached RFID tag.

2.2.2. Monitoring Patients

In some chronic diseases, continuous monitoring of patients is very important. RFID technology could be used to send information from patients to a control system. The control system could activate an alarm based on the received data.

¹Companies such as Precision Dynamics Corporation have been working in this field for more than fifty years.

Invention [11] discloses a system to monitor the glucose of patients. The system has a receiver configured to receive these data. Patients have tissues with piercing elements that have sensing areas and glucose sensors. These sensors are adapted to detect the concentration of glucose in the sensing area. In one embodiment, the glucose sensor information is transmitted by the tissue using RFID technology. The receiver maintains a continuous link with the sensor, or it periodically receives information from the sensor.

Another system for monitoring health signs of a patient is presented in [12]. The system has a sensor unit that communicates health signals from patients to a receiving apparatus over a wireless connection [13]. The receiving apparatus sends health signals to a destination node by using a network connection. The destination node determines whether there is an emergency condition. Components associated with the wireless transmission link are small and lightweight so that they can be clipped to patients garment. In an embodiment, receivers and sensors use the RFID technology to communicate health signals.

2.2.3. Financial Transactions

Depending on the health care system, patients must pay for the service that they receive. In addition, health care providers must be able to verify that a given patient is covered under a particular plan, what specific procedures, lab tests, and the like are covered under the plan, and whether dependants are covered. In this case, RFID can be used to identify patients. In [14] a device for processing a health care transaction is provided. The device allows a doctor or other provider to obtain insurance coverage information for a patient, receive payment for services, and obtain prescription information for the patient. Patients use a card containing some identifying information, in some embodiments the card may support swipe-less functionality whereby information can be read from the card by waving it in front of the reader. To do so, using RFID technology is necessary.

2.3. Physicians And Other Personnel

Physicians and medical staff can also benefit from the use of RFID technology. They can use all the identification and localisation systems described in Section 2.2. However, there is a number of methods and systems that have been specially designed to be used by physicians and medical staff.

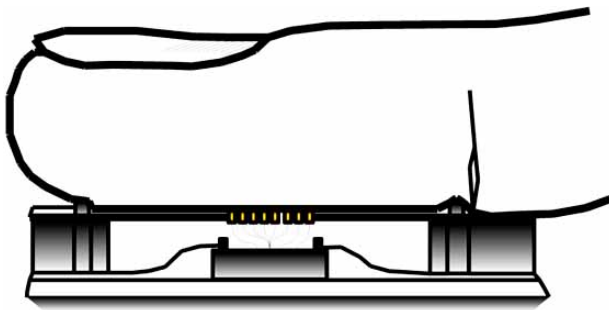


Fig. (3). Sectional side view of the surface in which users must place the finger to check cleanliness [15].

For example, physicians should clean their hands regularly and thoroughly. However, the cleanliness of their hands is somehow subjective and there is a need for a device that can determine whether the hands of a given physician or medical employee are clean. In invention [15], an electronic sensor configured to be carried by a person is used to detect the cleanliness state of her/his hands. The proposed device consists of an identification mechanism and an electronic sensor. The device is able to control how long after the state of the person's hands has determined to be clean. It has a storage device that is able to store information about frequency, timing, and results of cleanliness measurements performed by the user of the electronic sensor. RFID technology is used to identify users (i.e. physicians or medical staff), and in order to avert problems with many people using the same device, the use of a monitoring room is proposed. This monitoring room has several readers that are able to detect how many people are in the room. In addition, these people can be identified by means of RFID. Fig. (3) shows how the device is used by placing the finger over the sensor. Notice that it would be very easy to deceive the system into thinking that your hands are clean (e.g. by using a glove). However, this device has been designed to help medical staff check whether their hands are clean, and it is not intended for control purposes. Moreover, the device should be cleaned after using it. We believe that this is its most important shortcoming.

In addition to control the cleanliness of their hands, physicians may be specially careful with their surgical instruments. These instruments are a very important part in the daily work of a physician. They are used in different operating rooms, they must be sterilised after each operation, and their management could be a problem. With the aim to cope with this management problem, in [16] an RFID workstation reader for RFID-enabled surgical instruments and trays is disclosed (in [17] trays are used to dispense medicines instead of storing surgical instruments).

The workstation comprises a reader apparatus having a substantially planar work top surface and some RF transponders which project an RF field onto the work top surface for activating RFID tags attached to the surgical instruments and trays. Once RFID tags return an answer, a reader collects the information and stores it. In some embodiments of this invention, a printer can be used to obtain a report indicating which surgical instruments are properly managed. In addition, by using the proposed workstation, it is possible to determine whether some instruments have been lost by comparing the detected instruments with the expected instruments (e.g. a database of instruments can be used).

In some health care systems, physicians bill patients for the time they spent with them. Determining the amount of time that should be billed could be difficult due to concurrency and discontinuous time. In order to cope with this problem in the special field of anaesthesiology, [18] describes an RFID-based system for tracking billable anaesthesiology time in a surgical environment. In this proposal, RFID tags are used to identify patients and physicians. RFID readers are located in walls or doorways and they control when patients and physicians enter the operation rooms.

Nurses can also benefit from the RFID technology. A patient lift provides a useful mechanism for nurses and medical staff to move an incapacitated person, but it could be dangerous if proper slings are not used. Lifting and long storage can wear slings down, and the risk of accidents increases. In order to overcome this limitation [19] presents a patient lifting system that comprises an RFID tag provided in the sling, an RFID reader adapted to communicate with the RFID tag, and some sensing means provided in the sling and adapted to communicate with the RFID tag. By means of the RFID tag embedded in the sling, relevant information such as production date, recommended number of lifts or recommended number of washings can be stored. By using a hand-held RFID reader the medical staff can update relevant information such as the number of times that the sling has been used in the lifting system or the number of times it has been washed. Then, if the number of lifts is greater than the recommended number of lifts, nurses can replace the sling and the security of patients and nurses is improved.

2.4. Medicines

Medicines are a very important part of the health care jigsaw also. If medicines are not properly managed, many problems can take place and patient lives could be in jeopardy.

2.4.1. Medicines Authenticity and Tracking

Ensuring the origin of medicines and their components is essential to guarantee their quality. Methods and systems that guarantee the origin of medicines are a real need, specially in pharmaceutical supply chains.

In order to deal with this problem, patents [20] and [21] propose a solution based on storing Electronic Product Codes (EPC) (e.g. a serial number) in RFID tags. Each EPC/RFID tag is attached to a drug unit. Thus, it is possible to track every individual drug unit and to verify its authenticity.

Although medicines can be authenticated by means of the aforementioned proposals, pharmaceutical companies must face other threatening worries. Theft and tampering with medications are not new problems, but the use of new technologies such as RFID has caused the appearance of new forms of breaking the law. Invention [22] discloses a method for detecting tampered with products. The idea is based on using multiple RFID tags. Every single product unit has multiple RFID tags attached. RFID tags comprise an adhesive label containing an RFID component. If a label/tag is tampered with, the conducting path that acts as an antenna is broken, and the RFID label cannot respond to an RFID reader. A missing answer of the RFID label indicates that the product seal has been broken. Thus, the products (e.g. medicines) could have been tampered with.

Authenticity and security are essential properties of medicines that arrive at a hospital or clinic, but arriving at a hospital or pharmacy is not the last step in the live cycle of medicines. There is still a long way until they will be used on patients. Thus, having an accurate control of drug inventories is crucial to the proper operation of a hospital. If each pharmaceutical product had an RFID tag, a health care application could control drug inventories. Invention [23]

presents an RFID tagging scheme to prevent tampering of RFID information, and it permits global tracking of customers and items. In addition, invention [24] proposes the use of RFID tags to control tests performed in hospitals or clinics. It comprises a test cartridge for use in conducting an analytical test and an RFID tag. The RFID tag stores the information relating the test cartridge and its associated test.

RFID data may be encrypted or it may be in Write Once Only format in order to increase security. In [25] a scalable private RFID tag identification architecture was proposed. By means of the readers distribution proposed in that work, it is possible to track RFID tags securely.

2.4.2. Drug Delivery and Compliance

Compliance can be defined as “*the extent to which a person’s behaviour in terms of taking medication(s) coincides with medical advice*”. Each year, non-compliance with effective medication regimens costs the US health care system at least \$100 thousand millions, including indirect costs in terms of lost productivity [26]. Thus, the health care sector must face the problem of enforcing patient compliance with prescription and health care regimens and therapies. To deal with this problem several solutions have been proposed. First, it is necessary to determine the correct identity of a patient (cf. Section 2.2). Once the identity of patients is assured, it is necessary to guarantee that a given patient receives the proper medicines. In [27] an automatic pill dispenser is proposed. It is based on a number of pill containers mounted on a rotatable chamber within a housing. The chamber rotates and dispenses pills when a filled container reaches a hole of the housing. The rotation of the chamber can be controlled manually or by means of a computer. The main shortcoming of this system is its lack of means to determine whether the proper medication is really dispensed and/or taken because no identification technique is used.

The invention [28] discloses a system for delivering pharmaceuticals and in particular controlled substances. Patients have an active RFID tag containing their prescription, i.e. the drug administration regimes. The tag can be attached to a transdermal patch, and it communicates the regimes to the delivery system. By means of this invention no medical staff intervention is needed to obtain the right drugs. Similarly, the method and system presented in [29] identifies patients, care providers, medications and/or medical devices that are to be used with RFID tags. RFID tags prevent the inadvertent or unauthorised use of medications, medical devices, or medical supplies. The system records patient events, so it allows to analyse the medicines that patients take, which devices have been used during the treatment, etc.

With the same goal in mind, invention [30] helps improve the compliance of medication regimens. The proposed system has three parts, (i) the local-end (i.e. the home of the patients), (ii) a back-end, and (iii) external entities (i.e. medical staff). The local-end has three parts: a system manager, a feedback indicator and a connector. Connectors link the local-end to the rest of the system. Medications of the patients are delivered in containers having embedded sensors. The function of these sensors is to

detect whether the medication container is opened. The sensor information is broadcasted to the system manager with a RF transmitter [31,32]. The system manager sends this information to the back-end and it is stored in a database. External entities can access the database to analyse the compliance history of patients. In some embodiments of the invention containers have several pillboxes identified with RFID tags. The local-end may include other peripheral sensors to measure and to provide data such as weight, blood pressure, pulse, etc. These measurements are sent to the system manager and stored in the database (back-end).

A different system to deal with this problem is disclosed in [33-35]. The system architecture comprises a patient, a compliance module, a user device, a controller, and a network. The compliance module identifies, detects, measures, determines, and/or encodes indications of health-care-related events associated with the patient. The compliance module may detect pill bottle cap removals, dispensing of a liquid, or health care regimen-related events. In some embodiments, the compliance module comprises a device capable of detecting proximity of a pill by means of modified necklaces or earrings. In this case, each pill has an RFID tag that can be detected by an RFID reader attached to e.g. a necklace. The RFID tag on the pill may only be activated upon exposure to saliva in order to reduce measurement errors.

Patents [17,36] present a device for dispensing medicines that has several trays (cf. Fig. (4)). Every tray holds one or more types of medicines, and it is configured to dispense medicines securely. Device trays store information such as type of medicines, physicians who prescribed the medicines, who is the patient designated to receive the medicines, the pharmacy where the tray was bought, etc. In some embodiments, this information is stored in an RFID tag, i.e. every tray has an RFID tag. The dispensing device has an RFID reader able to obtain information from the tags mounted on the trays.

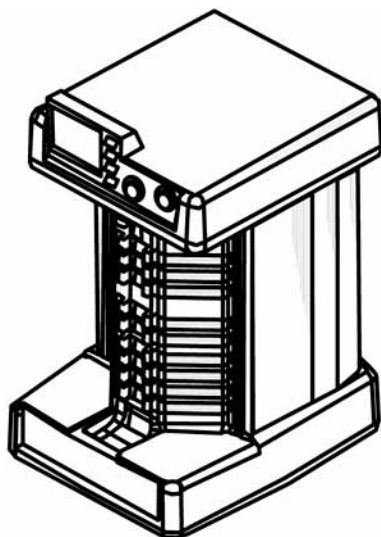


Fig. (4). Device for dispensing medicines [36].

The aforementioned system do not consider the overdose problem. With the aim to deal with this problem, a medication on demand delivery device is disclosed in [37].

Patients obtain prescribed medications when they need them. In order to avert drug overdose², the device controls the time between doses. It delivers a single dose of the medication after pre-defined time intervals. In some embodiments, the medication on demand device has an RFID reader, and patients have an RFID tag incorporated into their wristbands. Every patient RFID tag has a unique code, so the medication delivery device can identify patients and deliver their medication. Moreover, nurses or physicians can override the dosing intervals pre-defined by the device.

Invention [38] presents a system for drug delivery that comprises: a main device, several medical devices components and wired and/or wireless interfaces. In one embodiment, the system has a server-based (on-site or remote) component to support the following: remote party administration and intervention in medication and medical device use, a medical device programming, authorised third party medication regimen and patient health enquiry, regimen prescription downloading and ordering; and a variety of reporting and information presentation capabilities. The main device and peripheral components may be associated with a variety of sensors such as readers where said input devices are adapted with alignment indicia to facilitate the capture of coded data. In one embodiment the recognition input means are RFID readers. The drug delivery device is one medical device component of said system. The device can read RFID tags from patients and provide them with their medication.

Another system based on electronic pills for monitoring medication compliance is presented in [39]. The system has the following components: an electronic pill and a detector. The electronic pill includes an RFID tag. The detector is a non-invasive reader and it is used to obtain information from pills in the gastrointestinal track of patients. In some embodiments, the reader (i.e. the detector) detects pills when they pass through the oesophagus using a sensor designed to fit around the neck. The RFID pill broadcasts a unique code and some other information, for instance the body temperature and/or pH. The absence of temperature/pH information in the transmission code can serve to identify the transmission origin. Thus, it is possible to ensure that the pill is only active inside the body. Alternatively, the pill can be activated outside the body, prior to ingestion, and deactivated inside the body after coming in contact with body fluids.

The system disclosed in [9, 40, 41] allows an interactive prescription compliance. Moreover, it provides a remote and on-site verification of procedures related to the health status of a patient. The system activates an alarm when a deviation from a pre-programmed procedure occurs. The invention needs a set up box which is connected via wire, modem and Ethernet to transmit patients' data. Patients have an RFID tag with a unique code and, a drug dispenser, which incorporates an RFID tag reader. The drug dispenser identifies patients by means of their RFID tags and, it gives them the correct medication.

²Drug overdoses are sometimes caused intentionally to commit suicide or as self-harm, but many drug overdoses are accidental and are usually the result of either irresponsible behavior or the misreading of product labels.

As we have shown in this section, there are many systems and proposals to identify patients and control their medication. In the next section we will show in detail a system designed by Eastman Kodak™ Company that has the same goal.

3. A SYSTEM TO MONITOR THE INGESTION OF MEDICINES

As we have seen in previous sections, it is not trivial to monitor the ingestion of medicines. In some situations patients forget to take their pills or they interrupt the treatment when they feel better. In some other situations, patients take the wrong pills by mistake or they mix medicines incorrectly.

To deal with these problems, several ideas have been proposed. The most promising ones consider the use of RFID tags to identify the medicines that are prescribed to a patient by a physician. By means of RFID tags, patients and physicians are able to control the pills and the treatments. Most of the solutions proposed in the literature are based on the attachment of an RFID tag into medicine containers, but not in the medicine that is ingested. Thus, if medicines are removed from their containers, most of the proposed solutions are useless.

The solution to this problem is to attach an RFID tag to the medicines (e.g. to each pill). In order to do so, the utilised tags have to be innocuous (e.g. they should be edible). With this idea in mind, Eastman Kodak™ Company has applied for a patent entitled “System to monitor the ingestion of medicines” [42]. With the proposed system it is possible to provide a variety of services and devices:

- A lockable drug dispenser: With this device it will be possible to determine who is taking the medicines, and when are they taken. It would be easy to remind patients to take their pills. Moreover interactions could be controlled and avoided.
- A means of determining whether a medicine is taken or dropped down a sink: It is possible to design pills containing multiple tags that react to different substances. If a medicine is properly ingested, then tags will react and the system will be able to distinguish whether the pill has been ingested.
- A means of reminding the patient what medicine to take: Once a patient is identified, it is possible to monitor which pills have been taken and which pills should be taken next.
- A means of sharing information of the patient with medical staff: By means of a computer connected to a reader, patients can share information about their treatment with medical staff.
- A means of detecting medical interactions: Due to the possibility of identifying medicines inside the body of the patient, it is possible to determine whether ingested pills interact.

Next we describe the invention by showing the architecture and the main parts in different sections, and we provide the reader with some additional thoughts.

3.1. The Architecture

The main components of the architecture proposed in [42] are shown in Fig. (5) and can be summarised as:

- Fragile tags (cf. Fig. (5:22))
- A monitoring device (cf. Figure (5:30)). This device consists of a storage device (Figure (5:32)), an emitter (Fig. (5:34)), and a transceiver (Figure (5:36)).
- A computer (Fig. (5:42)): The computer is used to manage the information sent by the monitoring device, and a monitor (Fig. (5:44)) is used to visualise the information.

All these components are built together to obtain a system which is able to monitor medicines ingested by a patient. In the next sections we provide some details of the main components.

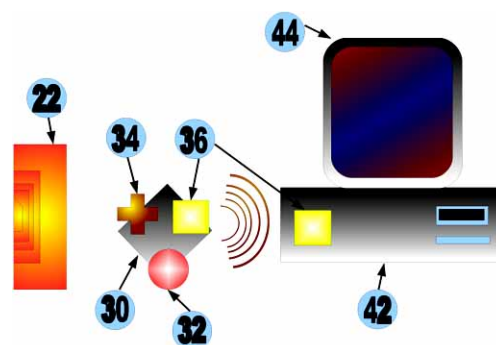


Fig. (5). System for monitoring ingestion of a tagged medicine [42].

3.2. Fragile Tags

Fragile tags are cornerstones of the proposed system. As any other RFID tag, a fragile tag contains an antenna. Normally these antennas are made of biologically inactive metals such as gold. Fragile tags are easily destroyed by interactions with the body and therefore they do not need to be removed from patients because they are digested or assimilated. Thus, it is possible to attach a fragile tag to a pill. Then, when the pill is ingested, the antenna structure is destroyed over a period of time by the body.

Fragile tags can be designed to breakdown only in the presence of certain substances (e.g. the ones in the stomach). Moreover, they can be designed to breakdown under mechanical stress, thus, they can be used to detect the degradation of implants (e.g. a hip prosthesis).

There is a variety of fragile tags that can be used, namely simple fragile tags suspended in a capsule (cf. Fig. (6) drawing (1)), compound fragile tags (cf. Fig. (6) drawing (2)), active fragile tags (cf. Fig. (6) drawing (3)), fragile tags with acoustical properties (cf. Fig. (6) drawing (4)) or fragile tags combined with non-fragile components such as quantum dots (cf. Fig. (6) drawing (5)).

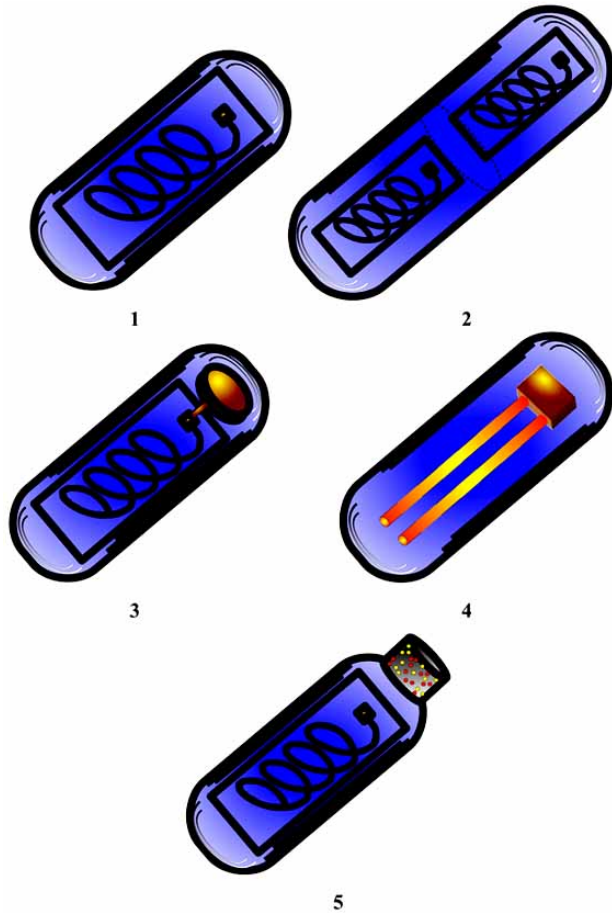


Fig. (6). Some examples of fragile RFID tags [42].

Depending on the fragile tags used, readers and other components of the system must be adapted to perform a variety of different tasks.

3.3. Monitoring Devices

Monitoring devices use their emitters (Fig. 5:34) to send a signal that travels through the body of patients and causes resonance in the fragile RFID tags described in Section 3.2. This resonance is captured by the transceiver (Fig. 5:36) and tags can be tracked at any point desired.

Monitoring devices can be classified in two categories:

- Stand-alone devices: These devices are somehow independent and can be incorporated in different articles to be worn on the body of the patient. The articles to which the monitoring devices can be incorporated are diverse, some examples shown in Fig. (7) are collars (Fig. 7:52), lanyards (Fig. 7:53), belts (Fig. 7:54), earpieces (Fig. 7:25), handheld devices (Figure (7:56)) or medicine dispensers (Fig. 7:57). Moreover, arrays of devices can be mounted on an overhead apparatus (Fig. 7:58) or a wall (Fig. 7:59).
- Integrated devices: Monitoring devices can be integrated in more complex structures such as a medical

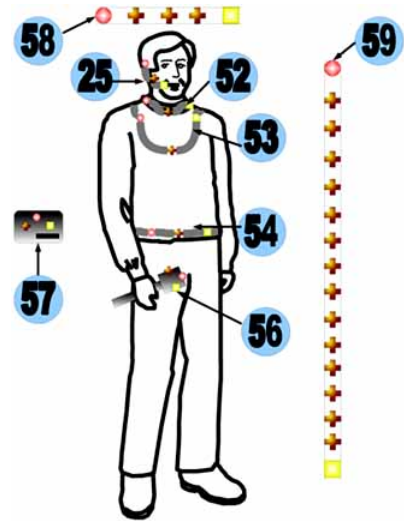
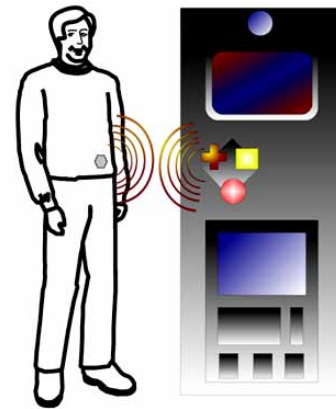
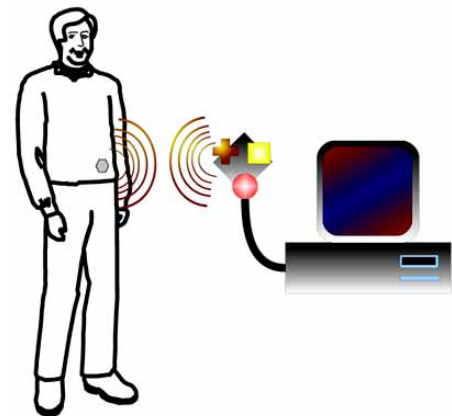


Fig. (7). Stand-alone monitoring devices [42].



1



2

Fig. (8). Integrated monitoring devices [42].

kiosk (cf. Fig. (8), drawing (1)) or a home system (cf. Fig. (8), drawing (2)). A medical kiosk is a device that performs tests on a patient (e.g. blood pressure, weight, etc.). With fragile RFID tags reacting to specific drugs, it could be possible to use the medical kiosk to test prescription or to detect illegal drugs in the bloodstream of the patient. A medical kiosk is equipped with a

fragile RFID tags dispenser, a computer that stores information, and some sensors to control different variables such as proximity. By using the computer of the kiosk, a doctor or supervisor can visualise and study recorded information of a given patient.

A home system is similar to a medical kiosk. It is designed to be used by housebound individuals, elderly or people living in remote locations. The system, which works with a simple personal computer, a computer on wheels (COW), a laptop or a PDA can be used to monitor the evolution of a treatment, to remind patients to take their medications, etc. Data gathered by the home system can be sent to a physician who will be able to analyse them and monitor the evolution of the patient.

3.4. The Logic Behind the Hardware

We have described the main architecture and components in the previous sections, but they are useless without the proper logic (e.g. software). In [42], a complete explanation and a number of flowcharts are given. However, we believe that the logic of the system can be reduced to monitoring whether there is a change of state in the RFID tag.

Once a medicine (e.g. a pill) containing a fragile RFID tag is ingested by a patient, the system will be able to detect it. Let us assume that the pill was not detected until it was ingested. Once the pill is detected a "change of state" event is raised and a number of procedures can be started:

- Check compliance: Once the pill is detected, it is identified by means of the RFID tag and, by using the patient history it can be determined whether the pill is correct.
- Check time: It is also possible to check whether pills are being taken at the right time.
- Check interactions: If more than one pill is taken, the system can use a database to determine whether the ingested pills will interact.

After that, if a tag is not detected a "change of state" event raises, and different actions are taken:

- Remind the patient to take medicines.
- Use the medicine dispenser to provide the patient with the right pills, etc.

In conclusion, the system presented in [42] uses existing technologies to build a very useful tool. The main novelty is the use of fragile tags. Thanks to the use of fragile RFID tags, a large number of tests can be done, and patients will benefit from this invention. However, we believe that a long way is still to be followed by scientists and inventors to produce high quality edible RFID tags.

Although the invention is recent, relevant and useful, there is a lack of privacy in it. If the communications between tags and readers are not properly secured, the privacy of patients can be in jeopardy. A reader can be used to obtain information about patients without their consent. Then, this information can be used by an intruder to blackmail patients. Thus, we believe that a future extension of this invention may consider the addition of a security module that guarantees the privacy of patients.

4. CURRENT & FUTURE DEVELOPMENTS

Health care is an important sector that can obtain great benefits from the use of the RFID technology.

In this paper, we have analysed several patents that propose the use of RFID in the health care sector. A great number of patents related to health care and RFID can be found and that can be a problem when trying to find specific applications. In order to obtain a global picture of the field, we have proposed an intuitive classification of these patents in several categories, and we have summarised some patents in each category. Moreover, we have analysed a recent patent by Kodak™ and we have pointed out its privacy shortcomings. With this work, we aim to provide a brief overview of the field of RFID applied to the health care sector, and we hope it to be a useful guide to researchers and practitioners in this area.

Although a number of great ideas and systems can be found in the literature, there is a number of issues that have not been analysed yet, and some other have to be studied in more detail. Next we summarise some points that should be addressed in the near future:

- Reliability: RFID-based systems can fail due to several reasons (e.g. RFID tags can be destroyed accidentally or, communications can be broken due to interferences). There is a need for real-time fault tolerant RFID systems able to deal with situations in which patients lives could be in danger.
- Security: RFID components interact wirelessly, thus, attackers have plenty of opportunities to eavesdrop communications and obtain private data of the patients. These data can be used by the eavesdropper to blackmail patients, or by an insuring company to raise prices to their clients. Security and privacy in RFID technology is a very active research field that has the challenge to design scalable and cheap protocols to guarantee the privacy and security of RFID users.
- Standardisation: Although many efforts have been done on this direction (e.g. EPC Global Generation 2), there is still an open field to work in.
- Materials: Finding new materials which can be eaten and digested without putting the health of patients in jeopardy is also a challenge. We have seen that edible/digestible tags are or will be a reality very soon, and the study of new materials and their combination is a research field full of opportunities.

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I will respect the hard-won scientific gains of those physicians in whose steps I walk, and gladly share such

knowledge as is mine with those who are to follow.¹ **Louis Lasagna, 1964.**

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