

Chipped Pharmaceuticals from Production to in VIVO (in body) Drug Delivery Becoming Reality

Erick C. Jones^{#1}, Shalini Gupta^{#2}, Felicia Jefferson^{*3}, Jamie Rogers^{#4}, Jae Bong Choi^{#5}, Joshua Bolton^{#6}, David Cochran^{**7}

[#]*Industrial and Manufacturing Systems Engineering Department,
University of Texas Arlington
420 Woolf Hall, Arlington, TX, 76079 USA*

¹ecjones@uta.edu

²shalini.gupta@mavs.uta.edu

⁴jrogers@uta.edu

⁵jaebong.choi@mavs.uta.edu

⁶joshua.bolton@mavs.uta.edu

^{*}*Department of Biology,*

Fort Valley State University,

1005 State University Drive, Fort Valley, GA, 31030 USA

³jeffersonf@fvsu.edu

^{**}*Industrial and Manufacturing Systems Engineering Department,
University of Nebraska-Lincoln,*

181 Nebraska Hall, Lincoln, NE, 68588 USA

⁷dcochran1@unl.edu

Abstract—Advances in medical technology rely heavily on the collection and analysis of measured data to facilitate patient diagnosis and business decisions. The healthcare industry, particularly pharmaceuticals and diagnostic processes, has an ongoing need to improve item tracking and data collection to improve the quality of care while reducing cost. The remote, non-invasive characteristics of RFID can facilitate the information needs of healthcare without imposing additional burden onto the patient or staff. Properly deployed RFID enabled devices can provide convenient and accurate data for disease diagnosis, evaluation of prescription non-compliance and identification of medication dosage errors. This paper describes an all-encompassing RFID tracking system that begins with compliance documentation from the drug manufacturer through confirmation of patient compliance by capsule extraction from the bottle, into a pill case and ultimately ingested or inserted into the body. This RFID system can provide data for decision-making and facilitate compliance with FDA proposed e-pedigree requirements. This transcript provides an introduction to healthcare trends in order to motivate the need for a biocompatible RFID system. An approach to research as well as an in vitro tabletop test method is presented in light of pending research. The overall goal of the pending research is to develop

biocompatible RFID tag components for use with systems beginning with the manufacturer and continuing through distribution to the point of interest within the patient's body.

Keywords— RFID; e-pedigree; pharmaceuticals; tracking

1. Introduction

The chipped pills concept was a very important technology and now feasible because of clinical trial results. Previous research by the authors theorized on how this would impact the medical/pharma supply chain and enable the e-pedigree initiatives. Technological advances such as micro electromechanical systems (MEMS), digital communications, and GPS/RFID applications coincide with the induction of electronic prescriptions, targeted drug delivery, nanoparticles, and biocompatible biosensors to create a new standard for medical service and new paradigm for personalized medical care for the patient. This paradigm shift to improve the quality of healthcare is toward more intimate patient-provider relationships and better medication management. The demand for improved communication between patients, doctors, medical insurance providers, and pharmacists now includes pharmaceutical manufacturers since the requirement for electronic-pedigree (e-pedigree), documentation of pharmaceuticals was instituted by the FDA (Food and Drug Administration).

Chronic and communicable diseases negatively affect

patient quality of life and increase the financial impacts of continued patient care. Future improvements in treatment methods and healthcare management rely on the collection of reliable data for decision-making. This transcript outlines a comprehensive view of pharmaceutical tracking and monitoring from the pharmaceutical manufacturer to ingestion by the patient. Preventable medication administration errors and patient non-compliance impose additional burdens to patients. Development of devices and systems for improved, convenient data collection and automated positive identification of medication and patient status can eliminate some of this burden.

Biocompatible radio frequency identification (RFID) tracking and monitoring systems can be used safely to facilitate the non-invasive collection of information to improve the quality of care to the patient. Integration of RFID technology for pharmaceutical tracking and tracing immediately provides increased potential to optimize product delivery and logistics, ensure product safety, monitor product administration, enhance patient compliance, and ultimately improve drug effectiveness. Such a system, capable of tracking patients, all of their medications, and their prescription compliance would also eliminate errors in medication administration, improper dosages, and adverse reactions to pharmaceuticals, which disproportionately affect the aging population. A wireless system capable of measuring and reporting physiologic data will not only facilitate current monitoring systems and data collection but may also create real-time methods to assess therapy and control chronic illnesses and communicable diseases. The benefits of a non-invasive, biocompatible RFID system and its potential for collecting and transmitting large amounts of data, extend beyond the clinic and into the daily activities of the patient. Such a system is a potentially invaluable tool to support the medical industry in its pursuits.

2. Background

2.1 Impact of Chronic Diseases

Most chronic diseases do not result in sudden death. Rather, they are likely to cause people to become progressively ill and debilitated. This is especially true if their illness is not managed correctly.” Chronic non-communicable diseases include cardiovascular diseases (heart disease and stroke), cancers, chronic respiratory conditions and type II diabetes and account for 60% of the deaths worldwide. These chronic diseases affect everyone., and are a significant cause of premature disability and death as indicated by the DALY (disability adjusted-life years) statistics in epidemiological studies .

2.2 Impact of Medical Errors and Patient Non-Compliance

Errors in medication administration, improper dosages, and adverse drug affects have been reported to occur at a rate of over 1.5 million annually. This phenomenon disproportionately affects elderly and chronically ill

patients and can have a huge impact on the spread of highly commutable diseases. Elderly patients have higher risk of miscommunication with their doctors, and often have multiple doctors treating a variety of age-related illnesses. Annual costs associated with reducing medication errors and monitoring, and confirming proper drug administration of patient medication is over \$1 Billion . There is a critical need to address these health issues using the technological resources available. An RFID biosensor that can confirm the ingestion of medications by people who are being treated for either communicable or chronic diseases and transmit that information back to the provider can be invaluable.

2.3 Data Collection needs for Healthcare Systems

The implementation of convenient and non invasive methods for patient care and data collection will provide the most intervention on which to make informed policy and healthcare decisions. The entire medical community can utilize the data collected in this way to improve the care provided to the patient from the context of a business plan to providing efficient and accurate diagnosis of chronic conditions and reliable methods improve the quality of life for those affected. RFID systems are an effective means to meet these objectives.

2.4 RFID Technology

Radio Frequency Identification or RFID is a unique identifier, similar to a bar code, generated by data-associated radio signals. The advantages of RFID over the bar code and other identification systems include the elimination of a required unobstructed visual line of sight and a significantly larger capacity to collect and communicate information. RFID systems consist of a host computer, an interrogator or reader,, a media (air) interface, and a transponder or tag. RFID tags can be passive or active. Passive tags utilize the energy of a reflected signal through inductive coupling to transmit information to the initiating interrogator; active tags are powered by batteries and can support larger memory chips for longer transmission distance and submit more information. Well-planned design and utilization of RFID systems can fulfil RFID mandates and provide value-added data for business and healthcare organizations.

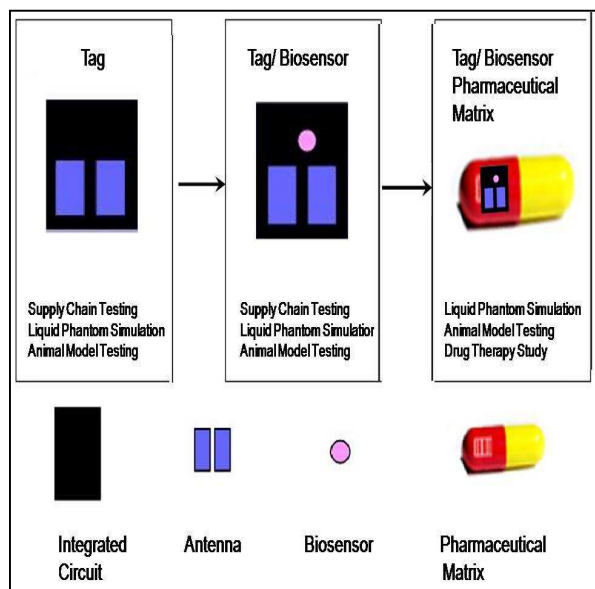


Figure 1. Progressive Research Path

The real-time experience between service providers and potential customers have potential for data collection and tracking of assets, patients, and patient care in the health care arena and improve efficiency in all aspects of the healthcare supply chain.

2.5 FCC Regulations and Standards for RFID applications

Part 15 of the Federal Communications Commission (FCC) regulation for low-powered devices applies to RFID technologies. Passive RFID systems are relatively low power; therefore, it is unlikely these limits will be reached in most circumstances [8]. It is important to note that a study initiated by the Centre for Devices and Radiological Health (CDRH) and the FDA found no adverse effects of radio waves in the body or on drug stability and are of no risk to product quality.

2.6 Biocompatibility

The biocompatibility and biostability are of highest priority in developing an ingestible RFID-tagged pharmaceutical device and reader. Similar devices have successfully been implemented, such as implantable RFID chips utilized for the tracking of livestock and household pets. Development of an RFID tag has challenges inherently unique to the intended functional environment. These challenges include issues of safety, toxicity, carcinogenicity, and physiologic responses. Manufacturers of medical devices must demonstrate device biocompatibility to ensure patient safety, proper device function, and to fulfill regulatory (FDA) requirements. The ISO 10993 standard provides principles for evaluation of devices, including in vitro and in vivo scenarios that can be applied to meet regulatory requirements.

For the development of the proposed RFID tag/biosensor, lubricity, blood compatibility, drug delivery, and anti-microbial surface properties are important considerations to reduce the chance of adverse reactions.

2.7 Research Objectives

How can the breakthrough in chipped pills extend to the usage of RFID enabled chipped pills and devices. We hypothesize that with these clinical trials that they can be expanded to include RFID micro chips described in the previous research. The test protocols and the political will for testing these innovations have come of age. We will describe how testing the RFID technology can impact the medical errors associated at different points in the pharma supply chain. The goal of this research is to develop a multi-purposed, ingestible RFID tag and biosensor to facilitate tracking and data collection at tablet level from the manufacturing lot, through the pharmacy, to consumption by the patient. This will involve the development and validation of a manufacturable, biocompatible RFID tag/sensor device for pills. This component of the system must be miniaturized to a scale easily incorporated into the pharmaceutical target and must maintain electronic performance while posing no or minimal risks to the patient. Consideration will be given to electronic effects upon existing diagnostic techniques, such as magnetic resonance imaging (MRI.) To reach the research goal we seek to accomplish two objectives.

2.7.1 Objective for Industrial Applications

Develop a biocompatible, micro-RFID tag/biosensor, incorporated into a pharmaceutical matrix, to create a system that will improve the traceability, e-pedigree and control of prescription medication.

2.7.2 Objective for in Vivo Applications

Develop an ingestible, biocompatible RFID tagged pharmaceutical and biosensor to provide confirmation of ingestion by the patient and to improve the non-invasive collection of data and monitor internal body conditions, such as pH, temperature, and perhaps one day determine the amount of drug released into the patient's system.

This paper describes a comprehensive view of pharmaceutical tracking and monitoring from the pharmaceutical manufacturer to ingestion by the patient. In addition, the FDA e-pedigree requirements and current research uses of RFID in medical practice are described and are part of the rationale for our research objectives.

2.8 History of ePedigree

The USA Congress passed the PDMA (Prescription Drug Marketing Act) in 1987, which required a statement

known pedigree for selling a drug. The pedigree was supposed to have information about sales including date of transaction, names, and address and more. However, even after FDA published final rules to implement the pedigree in 1999, it was not in effect until 2006 due to strong opposition to pedigree law. One of the reasons the FDA delayed the effective date of PDMA was ePedigree. Industry promised that it would implement an electronic track and trace system by 2007, which obviously could meet pedigree requirements. However, since it was also obvious that industry could not do that by 2007, FDA published a notice mentioning no more delay of PDMA in June 2006. It published also PDMA CPG (Compliance Policy Guide) in December 2006 (FDA 2006). Each state government also passed its own laws against counterfeit and diverted drugs. Allowing each individual state to develop its own approach to the counterfeit and diverted drug problem has brought some issues related to standards. For instance, if 50 states in the US have their own regulations, and they are not on the standard format with pedigree law, it might give overwhelming burdens to small and mid-sized companies by increasing cost and operation difficulties (Gregory Conko 2013). Finally, the US president, Barack Obama signed Drug Quality and Security Act (DQSA) in November 2013. It required FDA to provide implementation guidance within 12 months and develop a national track and trace system to secure the pharmaceutical supply chain. It also required that all drug packages carry a serial number within 4 years (Phil Taylor 2013).

2.8 Pharmaceutical Regulations (FDA) and e-pedigree

The FDA regulates the commerce of pharmaceuticals and medical devices. The Prescription Drug marketing Act of 1987 (PDMA) and the Prescription Drug Amendments of 1992 (PDA) address the regulations enforceable by the FDA. 21 CFR Parts 203 & 205 specify that pharmaceutical wholesalers provide a statement, referred to as the pedigree, prior to each distribution of a product. The pedigree requirements include information about the wholesaler and the name, dosage, and strength of the drug, or the national drug code (NDC) number. Electronic pedigrees (e-pedigree) have been proposed to meet the requirements of 21 CFR §203. In the addendum to the FDA's Guidance for Industry, it is strongly recommended that prior transactions and lot control also be included in the pedigree or e-pedigree.

RFID technologies have been discussed as a viable method to meet the pharmaceutical e-pedigree mandate. One force driving pedigrees from paper to electronic forms is concern about counterfeit drugs and forgery of paper pedigrees. The FDA's Counterfeit Drugs Task Force stated in a 2004 report, "FDA has concluded that these-pedigree approach is a much more reliable direction for assuring the legitimacy of a drug than paper record-keeping requirements". RFID technologies can provide a platform to meet FDA requirements and are commonly suggested for both e-pedigree requirements and protection against counterfeiting.

2.8.1 Basic Concepts of ePedigree

One of two main concepts of ePedigree is the implementation of traceability and visibility for the pharmaceutical products. Based on the federal pedigree law, each product unit must have a globally unique serialized number and ePedigree system can track and trace the unit level of any product by inquiring its serialized number (Phil Taylor 2013). This unit level serialization enables not only wholesalers but also end users to authenticate the products that they buy, and it could support better secured PSC against counterfeit and diverted drugs. The other main concept of ePedigree is the authentication process. Based on pedigree law, it generally requires wholesalers or other participants pass the documented pedigree, which has product, trading partners' information, and their signature for authentication to the recipients. However, when it comes to ePedigree, the authentication algorithm could be different based on what standard the companies have integrated into their ePedigree systems. For example, Drug Pedigree Messaging Standard (DPMS) ratified by Global Standard One (GS1, <http://www.gs1.org>) in 2007 creates and passes pedigrees to the buyers, and the buyers add their information to the pedigree and so on. It seems similar to the way of document based pedigree systems but the only difference is the electronic document type and digital signatures. Since some states do require only paper based pedigree currently, ePedigree needs to support a document based pedigree feature by allowing the attachment of files and manual authentication (EPCglobal 2007). However, Electronic Product Code Information Services (EPCIS) does the authentication in different ways. Since Drug Pedigree Messaging Standard (DPMS) has its weakness in several aspects, GS1 proposed EPC network with EPCIS for ePedigree. The participant in EPC Network with EPCIS can exchange data when they need, which improves the data storage space needed with DPMS. The trading partners inquire the concerning data from other trading partners for ePedigree or traceability information. Each participant can have either local EPCIS repository or store the data in the centralized databases. Still there are lots of things to be discussed for this standard, e.g., how the trading partners pass or share the data to other partners, how much data the participant needs to share, who initiates ePedigree at first and many more.

2.9 Current RFID Tracking in Health Care

2.9.1 Medical Resource Tracking

Tracking strategies for patients, staff members, equipment, and information can be implemented to increase the efficiency of health care, as well as facilitate better patient outcomes. Studies have been performed to demonstrate the opportunity for resource utilization and efficiency increases when equipment location is facilitated with an RFID system. Sangwan proposes an RFID system for patients, charts, and equipment location within a multi-level hospital setting. This system includes an alert system to notify staff members when a tracked item is

removed from defined boundaries. Cypack has embedded RFID chips into pharmaceutical packaging to track patient compliance by monitoring when the package is opened, but has not integrated it into the actual medication. For surgical procedures, RFID tags have been tested for tracking and tracing surgical sponges in order to eliminate errors due to manual counting at the completion of a procedure. RFID tracking systems for patients have been suggested for containment of infectious disease. Regular monitoring of non-compliant individuals has been identified as a method to limit exposure risks. RFID systems can allow for this type of monitoring without the need for dedicated personnel.

2.9.2 Medical Record Data Collection

In addition to performing tasks in a clinical environment, staff is required to maintain records of many activities, including vital signs and administered medications. Accurate documentation of medications and blood products are critical for patient safety and mandated by regulatory bodies. The majority of these records are written manually or scanned with a bar code. The information contained in the bar code improves the identification of the units; however, the amount of information contained in the bar code is limited in volume and can only contain information available at the time the label is printed.

Sandler discusses a multi-write, passive RFID system to track and record unit information from manufacture/collection thru administration to the patient. Potential benefits of such a system include reduction of incidences of incorrect medication or dosages, accurate documentation in patient records, and consistent information delivery for diagnosis. An RFID system that also incorporates e-pedigree information can reduce the response time for diagnosis in emergency situations. Creation of host system software to compliment the collection and application of the data is limited only by the vision of system planners to impact day-to-day operations within a clinic. Large-scale implementation of RFID tracking systems in hospitals must overcome the physical limitations of current systems. However, currently available system components can be adapted for localized installation of systems in a clinical environment.

2.9.2 Patient Behavior Assessment

The assessment of a patient's behavior outside the clinical atmosphere has a large potential for accurate diagnosis and treatment. Common methods for data collection outside the clinical atmosphere are limited, and are often inconvenient and not representative of the true condition or behavior of interest. A non-invasive RFID monitoring system has been investigated for the purpose of evaluation of a person's ability to continue independent living. The RFID system is equipped with a sensor to detect motion of

the individual and tagged items of interest. In this case the tagged item of interest is the pharmaceutical. The data provides numerical evidence to evaluate the behavior and capability of the individual, thus reducing the labor required to perform the observation and evaluate the patient's capacity to continue independent living or to comply with medication administration.

Epidemiologic evaluation of the effectiveness of medication could be determined from an RFID system that tracks the behavior of patients with respect to administration of prescribed medications outside the clinical setting. The data collected could also be used as evidence of the dosage protocol for epidemiological studies or as evidence of the effectiveness of treatment plans for clinics or public health policies.

2.9.3 Implantable RFID tags

RFID tags have been accepted as a means to identify and locate both wild and domestic animals. Recently RFID tags were placed into rice sized (2.5 mm x 1.3 mm) glass capsules for subcutaneous implantation for the purpose of tracking livestock and other animals. The device is biocompatible as a subcutaneous, implantable, tracking device. However, adaption is not directly applicable to pharmaceuticals, for example, glass is not well suited for oral delivery of medication.

2.10 Research Question for In Vivo Applications

Can an ingestible, biocompatible RFID tagged pharmaceutical and biosensor be designed and implemented to improve the non-invasive collection of data and monitor internal body conditions, such as pH, temperature, or mass of drug released into the GI tract? Diagnosis of patient status requires accurate information about the patient's physiologic state. Health care providers generally prefer less invasive techniques when the function is of better or equal benefit to the patient. Consequently, new techniques and technological innovation tools for healthcare continue to immerge for corrective and diagnostic procedures.

2.10.3 Current Non-Invasive Measurement Techniques in Health Care

The acidic environment of the GI tract poses challenges to designers to develop devices that can survive in the harsh environment. Ativanichayaphong has investigated an implantable RFID tag for the task of diagnosing esophageal reflux. This device is viable for approximately two weeks in the gastrointestinal tract environment, and has a footprint of 40 mm². A reduction in the amplitude of the signal transmitted from the tag to the interrogator indicated the presence of acid.

A wireless endoscopy system known as the PillCam SB® used for gastrointestinal disease diagnosis has received FDA approval. This device is comprised of a

silicon chip camera, lens, LED, silver oxide battery and UHF band radio telemetry transmitter encapsulated in a disposable plastic capsule (11 x 26 mm.) It passes through the GI tract within 72 hours while transmitting color images. Another GI tract diagnostic tool, known as the “Smart Pill”, has been developed. This 13 x 26 mm ingestible pill utilizes MEMS sensors to measure pH, pressure and transit time within the GI tract.

3. Methodology

Realization of a functional biocompatible RFID system can be achieved with development of a biocompatible RFID tagged pharmaceutical and biosensor utilizing existing technological developments from MEMS, antenna design, biomaterials, material selection techniques, interdisciplinary engineering (industrial, electrical, biomedical, manufacturing), biochemistry, and medical research. However any RFID system designed must consist of individual components (tag, transmission medium, interrogator, and host system) that perform predictably and reliably in the environment of intended use.

Transmission strength and ranges, reproducibility and reliability, performance in specified environments, measurement capabilities, and durability in vivo will be considered in the experimental designs. Biocompatibility testing will be performed as necessary utilizing ISO 10993 as a guide. Successful tabletop testing of components and systems preclude any in vivo testing in humans or other living organism. Figure 1 demonstrates a conceptualized progression of the biocompatible RFID tagged pharmaceutical and biosensor for research and development. Advancement of the tag’s capabilities will build upon the technology developed during earlier phases of research. The advantage of this approach is relatively quick development of tracking systems that can be utilized for anti-counterfeit, FDA e-pedigree, and collection business metrics at the completion of the first phase: the biocompatible RFID tag. Optimization and acceptance of this relatively simple system component will improve the technology base for development of a pass-through RFID tagged pharmaceutical and biosensor. Implantation of RFID tags in humans is not widely accepted; evidence of the value and biocompatibility of an RFID-tagged pharmaceutical and biosensor in the GI tract will help answer concerns about the effects of RFID technology in close proximity to tissues in living beings. The ultimate goal is to develop an RFID-tagged pharmaceutical and biosensor that can safely pass through the GI tract and then be safely eliminated from the body. Conceptualized biocompatible RFID systems are pictured in Figure 2.

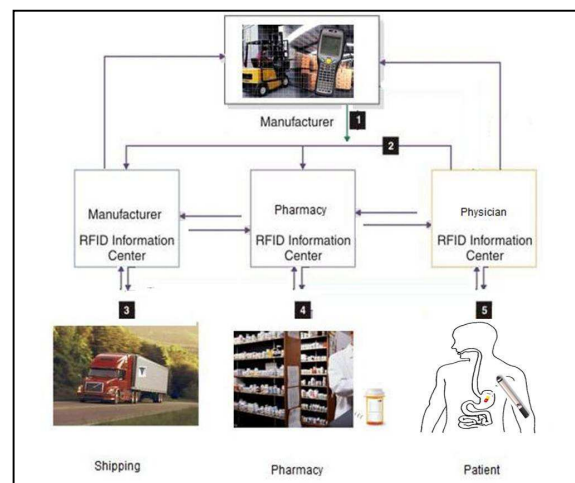


Figure 2. RFID ePedigree Flow Chart

Retail and warehouse RFID systems utilize an air interface as the transmission medium between the interrogator and tag. The electrochemical nature and high water content of the human body pose challenges to RFID transmissions. Previous research has been conducted on the interaction of RFID communication in the presence of humans. Tabletop simulation models have been created for compliance testing of mobile communication devices, evaluation of antenna designs in close proximity to the human body, and evaluation of RFID sensors in the acidic GI tract environment.

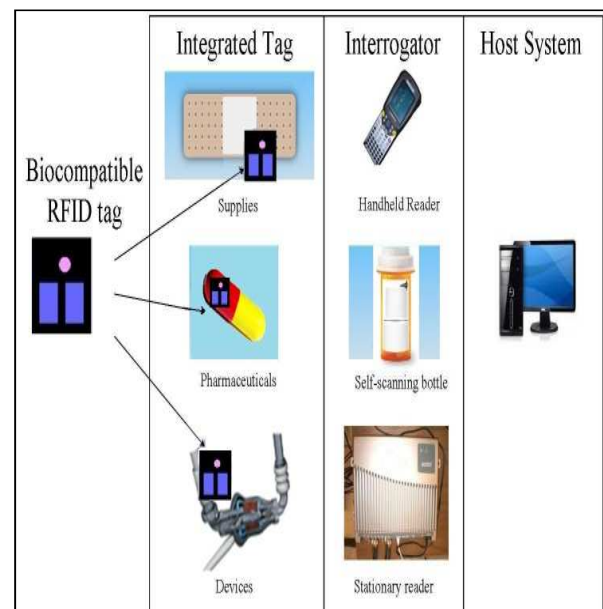


Figure 3. Biocompatible RFID Systems Vad (Ventricular Assist Device) Image Reprinted with Permission from Thoratec Corporation

4. Results

4.1 Proposed Medical Device

Flowchart Diagram and discussion of supply chain including e-pedigree integration. The BRTTP can be integrated into the medical supply chain. We envision that the manufacturer will program the BRT into the pharmaceutical, pills in our example. These pills then can be tracked from manufacturer, through the supply chain from the transportation system, to storage, to the supplier and finally to the consumer until ingestion. Furthermore this device will facilitate and automate pharmacy inventory reorder. The initial devices and scenarios we envision are described in below.

4.2 Device Components

4.2.1 Biocompatible RFID tagged Pharmaceutical (BRTP)

This BRTP, the embedded pill, will be able to contain information which includes the lot and manufacturer that it was created from to the retailer that sold the bottle to the customer. The BRTP is envisioned to use interoperable RFID standard transmission frequencies so that it can be scanned throughout the supply chain. It will follow e-pedigree standards but will also contain a temperature sensor to monitor temperature during shipping and storage. Feedback will confirm delivery to the pharmacy or other retail establishment. It will also allow the supplier and the retailer to monitor inventory thereby able to replenish the stock when a certain set minimum is reached. Physicians and pharmacists will be able monitor patient compliance with administration of the drug as directed and patients will be able to manage their medications with confidence.

4.2.2 BRTP Bottle/Cap Reader

This device shown in Figure 4 contains an interrogator that scans and records the number of RFID enabled pills within the bottle. The device can transmit this information by to a simple computer with downloadable software or Bluetooth.



Figure 4. RFID Tagged Bottle/Smart Cap

4.2.3 BRTP Wand Reader

The BRTP wand will be used to scan the abdominal wall to confirm that a specific pill was ingested as depicted in Figure 5. It is also envisioned that the design of the wand allows for in vivo detection for confirmation within 72 hours. Interrogation may also be performed during outpatient or surgical procedures.

4.2.4 Real Case Scenario

Consider a scenario in which a patient is prescribed medicine and must take the two pills 3 times a day. The patient does not recall if they took the medicine. The patient then proceeds to count the pills in the bottle and discovers that two pills are missing. They have confirmed that two pills were taken from the bottle, but are still not sure that they ingested the pills. The devices described below will allow that patient to confirm both. The BRTP bottle reader confirms that pills were taken out of the bottle, without the timely inaccurate process of counting pills. The BRT wand confirms that the pills were ingested within 24 hours. Of course this situation does not have to be limited to routinely prescribed medicine but there is great incentive for patients, physicians and drug manufactures utilize BRTP technology for medicines where compliance is critical to the outcome. For example, in infectious diseases such as Tuberculosis, this research could verify that pills were taken and assist in preventing additional outbreaks or the development of drug resistant strains of the bacteria.

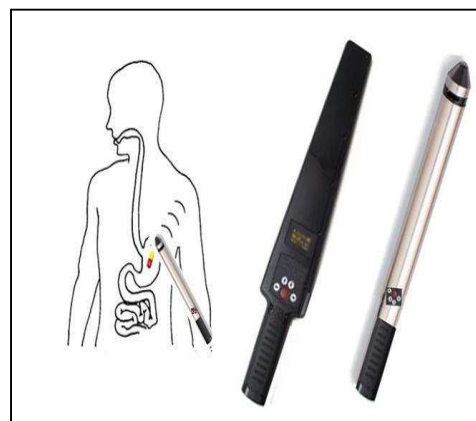


Figure 5. Wand or Interrogator

Table 1. Pharmaceutical Supply Chain challenges and their RFID enabled Solutions

	Issues and Challenges	Chipped Pill Benefits and Problems	RFID Solution
Research & Development	<ul style="list-style-type: none"> • Crisis Management in epidemic break-outs • Global demand for medicines overshoots the demand suddenly. • Product withdrawal during sales due to side-effects and expiry 	<ul style="list-style-type: none"> • Tracking specific medicine • More relevant and complete data 	<ul style="list-style-type: none"> • Readability in challenging environments • Read and write speeds • More relevant and complete data
Manufacturing	<ul style="list-style-type: none"> • Reluctant Govt. bodies to approve any Outdated Manufacturing Sites changes fearing Cross trading across Parallel Trade product quality • No track • Black market transactions in developing nations the borders of drugs coming in & going out of the country 	<ul style="list-style-type: none"> • Adaptable but tedious • Transmits data for tracking • First Medication Event Monitoring System • Creation/Expiration dates 	<ul style="list-style-type: none"> • Security features • Portability to multiple device form factors • Ready to go readers • Locating technology • Data integration
Warehouse	<ul style="list-style-type: none"> • Controlling wide supply chain with huge Stock • Complex Network Design Keeping Units • Reducing finished goods is becomes very difficult • Training difficult & education cost to the stakeholders is high • Integration of domestic and international businesses. • Sales 	<ul style="list-style-type: none"> • Fast inventory • Location guided solution • System integration • Must have transmission device • Limited data 	<ul style="list-style-type: none"> • Interoperability • Industry oriented solutions • Cloud based platforms • Cross functional collaboration
Hospital	<ul style="list-style-type: none"> • Ethical requirement of Little Incentive for Reducing Inventory Out of stock situations are unacceptable • Medicines & patent lifespan is Exceptionally long cycle times and lots of low High price of drugs • Counterfeit Drugs • Security • Inventory Easy to fake prescription drug labeling worldwide 	<ul style="list-style-type: none"> • Location of medicine • Large data clogging system • Electromagnetic radiation 	<ul style="list-style-type: none"> • Ecosystem of partners and solutions • Performance of devices • Pricing and total cost of ownership •
Pharmaceutical	<ul style="list-style-type: none"> • Degradation of Managing perishable products • Managing Pharmaceuticals the medicines as they move along the supply chain which results in allowing substandard products to be dispensed to the patients • Typically more focus is given on Maintaining temperature control Manufacturers can't have control once Pharmaceuticals are Shipping of expiry products • Docked to wholesalers 	<ul style="list-style-type: none"> • Ingestible • No illegal sharing of pills • High cost • Easy access to pill data 	<ul style="list-style-type: none"> • Continuous ROI/Benefits • Interoperable trading partner solution • Protection against evolving standards •

5. Discussion

The ability to use RFID methods to track logistical movements of pharmaceuticals from the manufacturer to the pharmacy is possible with current RFID technology used for retail applications. RFID tracking of pharmaceuticals at the pill level through its entire life cycle from the manufacturer to ingestion by the designated patient is achievable. The challenge remains to develop and incorporate this technology into the medication in a manner that is suitable for consumption. Pharmaceutical e-pedigree requirements can be fulfilled with minimal labor with the incorporation of an RFID tracking system at the pill level. Community health programs and epidemiological studies can utilize data collected by a pill level RFID tagged pharmaceutical and biosensor to support policies and study results. Deployment RFID systems with pill level tags in a clinical environment can assist the staff with monitoring inventory, positively identifying medication administered, and confirming the drug was administered as directed. Potential drug interactions or adverse side effects can be identified quickly to reduce the burden on the patient.

Outside the clinical environment, management of medications can be a challenge for patients. Monitoring and communication with the patient can improve patient compliance, especially in such cases when it is necessary for healthcare professionals to oversee the administration of each dose, a common practice in the treatment of tuberculosis today.

Devices that can measure physiologic conditions real-time have the greatest potential to minimize the impacts of chronic and communicable diseases. Advancing the reach of non-invasive RFID data collection to the in vivo point of interest requires development of unique ingestible biosensors.

The information provided by these biocompatible RFID systems can enable the healthcare provider to making real-time adjustments to suit the individual patient needs and improve the business dynamics with stake holders, manufacturers, pharmacists, doctors, patients, insurance carriers, researchers and patients. Biocompatible RFID tag deployment via the GI tract can be more convenient for the medical staff and less painful to the patient than allowed by current measurement techniques. This convenience will increase patient compliance for repeated testing or long term monitoring, and as a result, improve the quality of life for the patient. Ultimately the patient is the beneficiary of improved healthcare and overall health.

This biocompatible RFID system is easily adaptable to address the needs of the elderly and those taking medication daily or for extended periods of time. Incorporation of the BRT onto a pill box can reduce medication errors and help to ensure that medication is administered as prescribed. Future goals are to provide a RFID enabled platform for continuous tracking of the pharmaceutical to measure therapeutic impact. We theorized potential for targeted, controlled, RFID enabled drug delivery systems will one day enable us to monitor the release of drugs through the gastrointestinal tract. This further enhances the medical capability of measuring bioavailability of drugs that are absorbed into the bloodstream to determine the efficacy.

6. Conclusion

It is an exciting opportunity to reduce medical errors and costs in the pharma supply chain. With the new breakthroughs in research including clinical trials, and the implementation of the e-pedigree the benefits of RFID chipped pills can be recognized. The use of the RFID standard to enhance the capabilities and reduction of cost using the smart pills has come of age. If you are interested in further information on our studies feel free to contact the researchers. Outside the clinical environment, management of medications can be a challenge for patients. Monitoring and communication with the patient can improve patient compliance, especially in such cases when it is necessary for healthcare professionals to oversee the administration of each dose, a common practice in the treatment of tuberculosis today.

References

- [1] Alexandra Olgin, "Arizona Hospitals Cope With Drug Shortages" Retrieved From [Http://Kjzz.Org/Content/30656/Arizona-Hospitals-Cope-Drug-Shortages](http://Kjzz.Org/Content/30656/Arizona-Hospitals-Cope-Drug-Shortages), 2014.
- [2] Bethesda, "Summary of the Executive Session on Critical Threats to the Pharmacy Supply Chain and the Effects on Patient Care", *Am J Health-Syst Pharm—Vol 70*, 2013.
- [3] Cder, "Drug Shortage Management", Center for Drug Evaluation and Research Map 6003, 2012.
- [4] Cherng-Min Ma, Yen-Hung Chiu, Chung-Chun Chen And Ronlon Tsai, "Design An E-Pedigree Service For Healthcare Environment Using Cloud Computing Technology", International Conference On Innovation And Management, Kuala Lumpur, Malaysia, 2011.
- [5] David L. Laven, "Introduction: Drug Diversion And Counterfeiting, Part 1", *Journal Of Pharmacy Practice*, 2006.
- [6] David Miller, "Food Product Traceability: New Challenges, New Solutions", 01.09 [Www.lft.org](http://www.lft.org), Foodtechnology, 2009.
- [7] Dirk Rodgers, "A Semi-Centralized, Semi-Distributed Pedigree System Idea" [Http://Www.Rxtrace.Com/2010/09/A-Semi-Centralized-Semi-Distributed-Pedigree-System-Idea.Html](http://www.rxtrace.com/2010/09/a-semi-centralized-semi-distributed-pedigree-system-idea.html), 2010.
- [8] Donald J. Degabrielle, Jr, "Pharmacist Convicted Of Purchasing Chinese Counterfeit", [Http://Www.Justice.Gov/Criminal/Cybercrime/Press-Releases/2006/Georgeconvict.Htm](http://www.justice.gov/criminal/cybercrime/press-releases/2006/georgeconvict.htm), 05-25 2006.
- [9] Epcglobal, "Pedigree Ratified Standard Version 1.0, 05-01-2005.
- [10] "Federal Authorities Cease Sale And Distribution Of Counterfeit Lipitor", [Http://Www.Fda.Gov/Newsevents/Newsroom/Pressannouncements/2005/Ucm108483.Htm](http://www.fda.gov/newsevents/newsroom/pressannouncements/2005/ucm108483.htm), 2005

- [11] Fda, "Pdma Cpg", Retrieved From [Http://Www.Fda.Gov/Ohrms/Dockets/98fr/06-9211.Htm](http://www.fda.gov/OHRMS/DOCKETS/98fr/06-9211.htm), 2006
- [12] Fda, "Fda Conducts Preliminary Review Of Agency's Diversion And Counterfeit Criminal Case Information", Fda Preliminary Report: Review Of Counterfeit And Diversion Criminal Case Information, 2011.
- [13] Fda, "Protecting Patients From Counterfeit And Other Substandard Drugs/Supply Chain Threats", Fda 2nd Annual Health Professional Organizations Conference, 2012.
- [14] Fda, "Strategic Plan For Preventing And Mitigating Drug Shortages", Food And Drug Administration, 2013.
- [15] Fda Oci, "Paul Daniel Bottomley Pleads Guilty In U.S. Federal Court", Retrieved From [Http://Www.Fda.Gov/Iceci/Criminalinvestigations/Ucm349880.Htm](http://www.fda.gov/oc/ceci/criminalinvestigations/ucm349880.htm), 2013.
- [16] Fdasia, "Fact Sheet: Drug Products In Shortage In The United States", Retrieved From [http://Www.Fda.Gov/Regulatoryinformation/Legislation/Federalfooddrugandcosmeticactfdact/Significantamendmentstotheact/Fdasia/Ucm313121.Htm](http://www.fda.gov/regulatoryinformation/legislation/federalfooddrugandcosmeticactfdact/significantamendmentstotheact/fdasia/ucm313121.htm), 2012
- [17] Gregory Conko, "State-Based Drug Tracking Puts Americans At Risk", <http://Thehill.Com/Blogs/Congress-Blog/Healthcare/302783-State-Based-Drug-Tracking-Puts-Americans-At-Risk>, 2013.
- [18] Gs1, "Gs1 Standards Document Gs1 Global Traceability Standard Issue 1.3.0", [http://Www.Gs1.Org/Docs/Gsm/Traceability/Global_Traceability_Standard.Pdf](http://www.gs1.org/docs/gsm/Traceability/Global_Traceability_Standard.Pdf), 2012.
- [19] Gs1 White Paper, "The Gs1 Supply Chain Visibility Framework", Retrieved From [http://Www.Gs1.Org/Docs/Gs1_Supplychainvisibility_Whitepaper.Pdf](http://www.gs1.org/docs/Gs1_Supplychainvisibility_Whitepaper.Pdf)
- [20] Jim Kerper, "Boosting Security in the Pharmaceutical Supply Chain with Serialization", [http://Www.Healthcarepackaging.Com/Trends-And-Issues/Traceability-And-Authentication/Boosting-Security-Pharmaceutical-Supply-Chain](http://www.healthcarepackaging.com/trends-and-issues/traceability-and-authentication/boosting-security-pharmaceutical-supply-chain), 2013.
- [21] Julie Golembiewski, "Drug Shortages in the Perioperative Setting: Causes, Impact, and Strategies", *Journal of Perianesthesia Nursing*, Vol 27, No, Pp 286-292, 2012.
- [22] Julie Rovner, "Maine Once Again Allows Mail-Order Canadian Drugs to Cut Costs", [http://Www.Npr.Org/Blogs/Health/2013/06/27/196325173/Maine-Once-Again-Allows-Mail-Order-Canadian-Drugs-To-Cut-Costs](http://www.npr.org/blogs/health/2013/06/27/196325173/Maine-Once-Again-Allows-Mail-Order-Canadian-Drugs-To-Cut-Costs), 2013.
- [23] Jurgen Muller, Conrad Popke, Michaela Ubat, Alexander Zeier, And Hasso Platter", A Simulation of The Pharmaceutical Supply Chain To Provide Realistic Test Data", First International Conference On Advanced In System Simulation, Ieee Computer Society, 2009.
- [24] Ims, "Accelerated Recovery Initiative Managing Drugs In Short Supply", Accelerated Recovery Initiative, 2013.
- [25] Kate Traynor, "Fda Seeks Advice on Track-And-Trace Systems", *American Journal of Health-System Pharmacy*, 2011.
- [26] Kff, "Total Retail Sales For Prescription Drugs Filled At Pharmacies", <http://Kff.Org/Other/State-Indicator/Total-Sales-For-Retail-Rx-Drugs/>, 2012.
- [27] K. Namgung Et Al, "The Development Of E-Pedigree Model For Securing Transparent Pharmaceutical Distribution Channel In Korea", *Ichit, Ccis* 310, pp. 226–234, 2012.
- [28] Lan Lancaster, "Trends: Holograms And Anticounterfeiting", [Http://Www.Pharmtech.Com/Pharmtech/In+The+Field/Trends-Holograms-And-Anticounterfeiting/Articlestandard/Article/Detail/505361](http://www.pharmtech.com/pharmtech/in+the+field/trends-holograms-and-anticounterfeiting/articlestandard/article/detail/505361), 2008.
- [29] Laura A. Stokow Ski, "Drug Diversion In The United States", [www.Medscape.Org/Viewarticle/572103](http://www.medscape.org/viewarticle/572103), 2008.
- [30] Michael Witworth, "Ensuring Traceability of Clinical Information", *Drug Discovery & Development*, 21-03-2012.
- [31] Nabp, "Wholesale Drug Distribution: Protecting The Integrity Of The Nation's Prescription Drug Supply", [Www.Nabp.Net](http://www.nabp.net), 2013
- [32] Neil H.Mermelstein, "Moving Ahead On Traceability", *Foodtechnology*, [Www.Ift.Org](http://www.ift.org), 2011.
- [33] Nytimes, "Contaminant Found In China-Linked Blood Thinner", Retrieved From [Http://Www.Nytimes.Com/2008/03/06/Business/Worldbusiness/06iht-06heparin.10755857.Html](http://www.nytimes.com/2008/03/06/business/worldbusiness/06iht-06heparin.10755857.html), 2008.
- [34] Nytimes, "U.S. Identifies Tainted Heparin in 11 Countries", [Http://Www.Nytimes.Com/2008/04/22/Health/Policy/22fda.Html](http://www.nytimes.com/2008/04/22/health/policy/22fda.html), 2008.
- [35] Paul Chilcutt Et Al, "Integrity Of The Pharmaceutical Supply Chain: Product Sourcing For Patient Safety", *Am J Health-Syst Pharm—Vol* 61, 15-09-2004.
- [36] Patricia Van Arnum, "Epedigree in the Pharmaceutical Supply Chain", *Pharmaceutical Technology Pharmaceutical Ingredient*, 2008.
- [37] Pfizer, "Case Study: Lipitor in Us Recall", [Http://Www.Pfizer.Com/Files/Products/Lipitorusrecall.Pdf](http://www.pfizer.com/files/products/lipitorusrecall.pdf), 2007.
- [38] Phil Taylor, "Obama Signs Drug Quality And Security Act Into Law" [www.Securingindustry.Com/Pharmaceuticals/Obama-Signs-Drug-Quality-And-Security-Act-Into-Law/S40/A1906/?Cmd=Printview&Nosurround=True](http://www.securindustry.com/pharmaceuticals/obama-signs-drug-quality-and-security-act-into-law/S40/A1906/?Cmd=Printview&Nosurround=True), 2013.
- [39] Rob Stein, "How A Drug Shortage Hiked Relapse Risks for Lymphoma Patients", [www.Npr.Org/Blogs/Health/2012/12/26/168038307/](http://www.npr.org/blogs/health/2012/12/26/168038307/)

How-A-Drug-Shortage-Hiked-Relapse-Risks-For-Lymphoma-Patients, 2012.

- [40] Sandra R. Stovall, "Drug Pedigrees Are Here, But In What Form", *Journal of Pharmacy Practice*, pp: 161-164, 2006.
- [41] Sanjay Jain Et Al, "Development of a High-Level Supply Chain Simulation Model", *Proceedings of the 2001 Winter Simulation Conference*, 2001.
- [42] Spitzer, "Charges Announced In \$70 Million Drug Diversion Case",
[Http://Www.Ag.Ny.Gov/Press-Release/Charges-Announced-70-Million-Drug-Diversion-Case](http://www.ag.ny.gov/press-release/charges-announced-70-million-drug-diversion-case), 2006.
- [43] Suppyscape, "Combining Epcis With The Drug Pedigree Messaging Standard", Retrieved From Tracelink.Com/_Literature_48903/Unified_Dpms-Epcis_Approach, 2008.
- [44] Susan F. Pararella, "Drug Shortages in the Emergency Department: Managing A Threat To Patient Safety", *Journal Of Emergency Nursing* Volume 38. 05-09-2012.
- [45] Thomas Sullivan, "Policy and Medicine", [Http://Www.Policymed.Com/2012/09/Ftc-Approves-Accelerated-Recovery-Initiative-To-Reduce-Drug-Shortages.Html](http://www.policymed.com/2012/09/ftc-approves-accelerated-recovery-initiative-to-reduce-drug-shortages.html), 2012.
- [46] Virginia Herold, "California Prescription Drug Pedigree Requirements", Retrieved From [Http://Www.Pharmacy.Ca.Gov/About/E_Pedigree_Laws.Shtml](http://www.pharmacy.ca.gov/about/e_pedigree_aws.shtml), 2014.