Re-imagining the

PatientID

A COLLABORATION BETWEEN

MICA's Center for Social Design
and Yale Center for Engineering Innovation and Design

Armstrong Institute for Patient Safety & Quality at Johns Hopkins
and Yale-New Haven Hospital

Aaron Lewis '16
Geoffrey Litt '14
Margaret Yellen '14

MENG 472 - Independent Study
Professor Joseph Zinter

Table of Contents

1. Introduction **3**
2. Understanding the Environment: Research with partner hospitals **5**
3. Problem Spaces & How Might We Questions **8**
4. Identification Technology Overview **11**
5. Concepts **17**
6. Our Solution **18**
7. Feedback from Yale New Haven Hospital **23**
Conclusion: **24**
Appendix A: Technology Comparison **25**
Appendix B: Smart ID screens **26**

Yale+MICA Final Report

4/28/14

Aaron Lewis, Geoffrey Litt, and Margaret Yellen

This report presents the results of an experimental semester-long collaboration between Yale and the Maryland Institute College of Art to improve patient identification systems in US hospitals. In cooperation with the nurses and doctors at the Yale and Johns Hopkins Schools of Medicine, we identified problem spaces and potential points for intervention. Based on our research, we designed an integrated system, involving a smart ID unit and a scanning application, to help improve the hospital environment for both patients and nurses.

1. Introduction

Every day, a single hospital in the United States might hold hundreds of patients, including inpatients, outpatients, emergency room visitors, and more. According to the CDC, around 51.4 million medical procedures are executed in the United States every year.[1] In such complex, dynamic healthcare environments, correctly identifying patients is crucial to providing consistent, error-free care. Increasingly, shorter work shifts have led to high personnel turnover; in one visit, a patient will interact with a wide range of nurses, doctors, and specialists.[2] How, then, can hospitals ensure that its caregivers provide personalized, accurate treatment to a sea of strangers?

Almost all U.S. hospitals use disposable wristbands to keep track of patient identity, which contain information on name, birth date, and medical record number, for both inpatient and outpatients. Many of these include one-dimensional or two-dimensional barcodes that allow nurses or doctors to scan and link a patient to his or her electronic record. By checking the bands before administering medicine, taking samples, or performing surgery, nurses can ensure that patients receive the proper care.

This system, however, is fundamentally flawed; a combination of human error and inadequacy of the bracelets have led to persistent identification errors. In one recent, high profile case, a sheriff received $12 million in damages from a Maryland Hospital that misidentified him and almost treated him for cancer instead of head trauma.[3] Similar errors abound; the National Practitioner Data Bank recorded 3,723 wrong-treatment/wrong-procedure errors in US hospitals over a period of 13 years.[4] Zebra ID technologies, meanwhile, estimates that around 5% of patient wristbands are missing or filled with incorrect information.[5]

These mistakes do not only harm patients—they also create a large economic burden for the already bloated healthcare system. The FDA estimated, for example, that simply implementing barcode-based medication dispensing systems would save around $93 billion in treatment costs over twenty years.[6]

The American medical community is well aware of the problems with the existing system. Since 2003, the Joint Commission, an organization responsible for monitoring hospitals across the United States, has listed "Improving Patient Identification" as its top goal for patient safety improvement.[7] Already, individual hospitals around the country are working to implement high-tech systems, using RFID or biometric technology to replace analog bands. Besides for barcodes, though, no single solution has gained relatively widespread acceptance—and, in 2013, improving identification remained at the top of the Joint Commission's goals.

This semester, we worked with a team of designers at the Maryland Institute College of Art to develop an innovative solution to the problem of patient identification. We spent the first part of the semester orienting ourselves in the space by speaking with healthcare professionals at Johns Hopkins and Yale New Haven, learning about prior art, and beginning to brainstorm potential solutions.

Ultimately, we designed an integrated system which caters to the needs of both patients and nurses. Our group at Yale focused on making a smart ID unit with an E-ink screen, active RFID, and modular wear. For much of the patient's visit, the unit would be worn on the wrist, like a bracelet; in the OR, though, it could be transferred to a different attachment mechanism, like a retractable clip. The E-ink screen would provide the patient immediate access to information about her visit, while the active RFID would allow caregivers to track patients through the hospital. The accompanying application, designed by MICA, gives nurses easy access to chart information and erases the gap between the band itself and key patient information. It will also provide alerts in the case of falls, for example. The solution section in the report provides in-detail information about the system's components, as well as its various benefits.

In order to provide motivation for our ultimate solution, we begin by presenting the results of our research and insights from our visits at the two hospitals; we then introduce the problem space by categorizing different issue areas in patient identification systems. Next, we turn to an examination of prior art by laying out the advantages and disadvantages of the three main identification solutions: barcoding, RFID, and, most recently, biometrics. Finally, we provide details on our E-ink solution, along with a glimpse at the design of the MICA application.

2. Understanding the Environment: Research with partner hospitals

Yale New Haven Hospital
Lori Ryder, the chief OR nurse at Yale New Haven, warmly welcomes us into her office, where we join two other nurses. For a while, now, they have been trying to find a good solution to the problem of patient identification—a problem that they encounter all too frequently. Yale New Haven hospital prides itself on its innovative tools and practices; in fact, the hospital recently switched over to a new electronic records system, called EPIC. Still, even with the improved record, the ID bands—crucial in linking patients to their information stored in EPIC—remain a huge problem. In particular, Lori and the other OR nurses are worried about bands being removed before surgery—and then never getting replaced properly.

Lori explains: "What happens is that someone goes into the OR, and they get their ID band cut off because of legitimate reasons—to place lines—and they come out, to the CT-ICU [Cardiothoracic Intensive Care unit], and they have no ID. So you could have 2-3 people coming out of the OR at the same time without ID bands. The anesthesia people, I'm sure, know who those patients are, but now you're bringing out those patients to an area unfamiliar with them, and you could easily see two white, bald obese men coming out at the same time."

The other nurses lean forward and nod in agreement. They can remember cases just like the hypothetical Lori mentioned—just recently, they tell us, a serious error occurred in the neurosurgery department. Two patients were in the OR at the same time, with their bands cut off; when the nurses printed new bracelets upstairs to replace them after the surgeries, though, the two patients received the wrong bands. Although, thankfully, neither patient was harmed, the incident still clearly demonstrates the high potential for error within the current system—even in an advanced, big hospital like Yale New Haven.

Johns Hopkins Hospital
The practitioners at Hopkins face similar issues. Rhonda Wyskiel is a trained nurse and the director of design thinking at the Johns Hopkins Armstrong Institute for Patient Safety and Quality; she welcomed our MICA partners to discuss the problem of identification. At Hopkins, the protocol on patient identification is a dry five-page document, filled with bullet points and numbered lists—more like a government form than a helpful guide. Because of this protocol, she explains, failing to replace a removed armband could count as a minor rule violation against the nurse.

Still, she tells them, identification errors continue to occur. She gives a hypothetical example of a patient who goes in for gallbladder surgery; prior to the operation, the identification band will get cut off by the anesthesiologist. If it is not returned, the patient will arrive in post-op with no identification. Now, if a nurse has picked up the wrong patient chart, the patient may certainly get a new armband—but it may be another

patient's duplicate. From there, the problems can compound; blood samples, for example, might link back to the wrong person, who will then receive the wrong treatment.

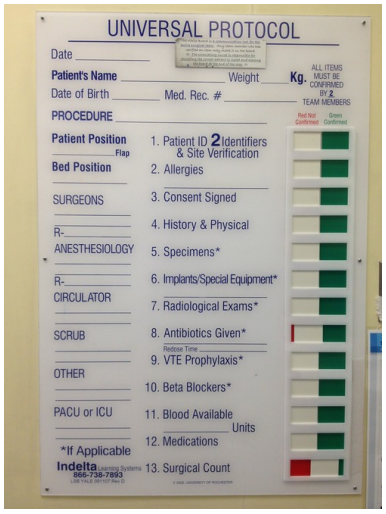
Nurse Wyskiel is ready for something new: "Armbands should be obsolete, in my opinion. I'm worried that we're working on an obsolete problem. Because we're so ahead of this, we're ahead of a plastic armband—we're technologically ahead of that."

Understanding the Process

To understand the different sources of error, we must take a step back and understand the journey of a typical patient through the hospital—and, in particular, through the OR, where most ID removals occur.

At Yale New Haven Hospital, patients begin their visit in the registration room. There, they check in and give their information to a receptionist, who prints a wristband for them on a Zebra printer. With the wristband secured to his/her wrist, the patient is taken upstairs to one of several pre-op holding rooms. There, a nurse will check the patient's identification; if anything is incorrect on the bracelet, the reception on the floor can print out a new, correct version. Once the patient's identity has been verified, nurses take urine samples, blood samples, and EKG scans in preparation for operation. After pre-op procedures have been carried out, the patient is taken to the operating room.

In some cases, the anesthesiologist cuts off the band during preparation for surgery. This removal usually occurs only in serious cases, like cardio or neurosurgeries, which require access to both arms or even legs, in order to insert lines.



Yale New Haven hospital requires a "Time out" procedure before all surgeries; preferably before intubation, nurses and doctors verify the patient's identity one final time. One person, usually the anesthesiologist, looks at the patient ID band (if it is still on the patient); another, usually a nurse, reads the patient information and surgery details off of the computer, then reads the consent form. Patients are also identified each time they are transferred to another caregiver, as well as at the end of an operation.

Currently, Yale New Haven is working to improve the Time Out process in order to provide clarity and reduce error. In particular, they are implementing new requirements about the timing of the questions; in the near

future, they will require care-takers to ask the questions before the patient has been intubated, in order to ensure that the patient can verify his/her name and birthday.[8]
Throughout the process, the hospital encourages doctors to follow the GLAD process:

- Greet the patient
- Look at the armband for name and medical record number, and compare it to the order of requisition
- Ask the patient to state their name while looking at the armband
- Deliver top-notch services.

If, at any point, a patient without an ID bracelet is not able to identify him or herself, s/he is given an identification number and an accompanying barcoded wristband.
Overall, potential problem points include:

- Any transfer between caregivers
- Entry into operation
- Exit from operation
- Administration of medication
- Labeling of lab specimens

The next section categorizes possible problem areas surrounding patient identification.

3. Problem Spaces & How Might We Questions

As our visits to the hospitals revealed, the problem of patient identification involves multiple users, from the patients to (perhaps more importantly) the healthcare professionals; a successful design, then, must take into account the needs of very different people and healthcare environments. Potential for misidentification emerges whenever the patient passes from hand to hand or department to department; "wrong patient" errors can involve administration of the wrong drugs or even surgical procedures. Patients must remain identified when they are in surgery or in imaging, when they are receiving or giving blood, when they are in trauma or in a post-operative recovery unit. The technology itself, meanwhile, must be easy to use and cost-effective for hospitals with strained budgets.

In order to better understand this multi-dimensional problem, the Yale and MICA teams devised a list of How Might We (HMW) questions. HMWs are specific, actionable questions that help identify opportunities for innovation. They provide a framework for concept generation that defines the scope of the problem, the users we are designing for, and the processes we would like to change. The process of creating these HMW questions pointed us toward specific and relevant issues that we believe are worth addressing in our eventual prototype.

How might we improve the accuracy of patient data entry?
The information on the wristband may be incorrect, due to transcription error or name similarities across patients. Accuracy may also be a problem in prescription orders; if a nurse writes down the wrong patient information during a phone call, the database will match the wrong medicine. For a comprehensive list of possible errors of accuracy, see the list compiled by the Institute for Safe Medication Practices.[9] These errors are particularly likely when two patients have the same full name, either because of chance or because of a dropped "Jr." designation. Related HMW questions include: How might we fix human errors that have already occurred? How might we design an input system to reduce human error?

How might we re-identify patients found without identification and provide temporary identification when patients' wristbands are removed before surgery?
A study in the United States found that 72% of all wristband errors came from patients not wearing wristbands.[10] Some surgical procedures require the removal of the wristband; the cut wristband is then placed around the bed or with the nurse. Although the wristband should be replaced as soon as possible, the lack of wristband creates potential for error, particularly if the patient is unconscious. According to nurses at Hopkins, around 10-20% of patients who leave the OR do not have identification bands. Not all surgeries require removal; in some cases, too, the problem can be avoided by placing multiple ID bands on the patient's wrists and ankles. Still, ID removal remains an important possible source of error in neurosurgeries, for example.

Nurse Wyskiel explains that anesthesiologists may remove identification bands simply because of inconvenience; if they happen to be sitting on the same side of the ID, they will remove it rather than changing their position. “You can’t standardize that,” she explains; other issues may arise, like bad veins on one arm. Clearly, then, absent a change in the ID system as a whole, hospitals need some kind of stop-gap measure to deal with the moments when anesthesiologists remove the bracelets.

How might we remind doctors to verify the patient’s identity at high-risk moments?
Healthcare professionals may fail to verify the patient’s identity, either by not checking the wristband or by not asking the patient for name and birthdate. Although standard practice requires verification of at least two identifiers (e.g. name and birth date), studies have demonstrated that many nurses fail to meet this requirement. Ideally, identity should be verified when:

- Prescribing medications
- Dispensing medications
- Transcription of medication orders
- When getting diagnostic test results
- When doing labs (taking blood, etc)

Professionals at both YNH and Hopkins explained that many nurses don’t want to appear stupid by checking the band of a patient whom they know well. “It’s the lowest thing on the priority list,” Rhonda says. “Because we’re thinking does the patient have blood pressure, is the patient breathing, does the patient have a heart rate.” Compared to important medical information, checking IDs seems arbitrary. Later, Rhonda adds emphatically: “We should fear complacency more, because we get so complacent in so many of the procedures we do, and in so many of our work processes…like I can press an IV pump now with my head turned around, but I don’t know if that’s good.” Related HMW questions include: How might we use technology to strictly enforce proper identification procedures?

How might we make the patient identification band more readable when a patient’s wrist is not readily accessible?
If a patient is sitting in certain positions, the wristband may be inaccessible; some wristband designs have tried to get around this problem by including as many barcodes as possible. For example, the company Honeywell introduced bracelets completely covered with QR codes, so that they can be read from any angle, as long as the wrist or ankle is exposed.[11] Bracelets must also be able to physically withstand hospital conditions; waterproofing, then, is essential but often absent.

How might we redesign the barcode scanner in a way that streamlines the identification process for nurses?
Current barcode scanners are not always easy for nurses to carry with them at all times. These scanners are often clunky and can become an inconvenience to service providers if they are forced to take them wherever they go. Barcode scanning technology could potentially be integrated into a device that nurses have on their persons more frequently such as iPhones or iPads.

How might we design a consistent system of identification across hospitals?
Some hospitals use color-coded bracelets to indicate information like allergies; however, studies have shown a large degree of inconsistency in coding between hospitals and even between departments of the same hospital.[12] Hopkins faces an even more severe problem; different departments use entirely different medical records systems. Thus, a patient may have multiple records *within the same hospital*, making coordinated care and accurate identification extremely difficult.

How might we design a durable solution that can also be comfortably secured to the patient?
Patients come in all shapes and sizes; wristbands may be too small or too large. Additionally, some fasteners on wristbands may cause discomfort. Here, choice of material becomes essential; many "improved" wristbands use slightly flexible material to accommodate movement and size differences. Sometimes, though, even flexible materials won't make the cut.

Rhonda, the nurse at Hopkins, explains: "we get a lot of GI surgeries here, when they're here in the OR for hours and they get liters and liters of IV fluid, and…the patient swells up—sometimes 30 kilograms up from where their weight was. So wherever you put [the ID band], it's now digging in." Indeed, in this case, ankle bands may generate additional bandages; nurses and surgeons may not notice the band digging into the swollen flesh.
In order to improve patient identification and known problems with hospital wristbands, companies and commissions alike have worked to improve the design of both the hospital identification system and the wristbands themselves. New technology, like biometrics and RFID, has emerged in some hospitals as a more reliable, consistent alternative to hospital wristbands. Related HMW questions include: How might we rethink body locations where ID can be attached? How might we rethink materials used to make patient ID bracelets? How might we make an ID that does not have to be disposable?

4. Identification Technology Overview

This section of the research memo will focus on the technological aspects of hospital ID systems. In it, we will explore barcode, RFID, and biometric technologies for ID, with a strong focus on RFID—because that is where the frontier of hospital scanning tech is right now. We will also review many solutions currently being used at various hospitals, to lay foundation for the solution we propose in part 5.

Barcodes

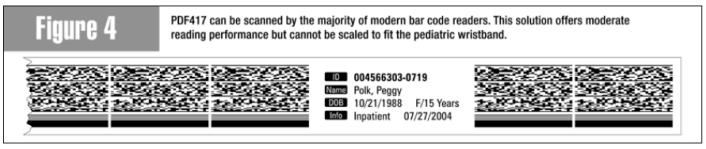
Barcodes are an extremely common technology for digital scanning applications—the most commonly used solution in hospitals worldwide now. There are a few core advantages:

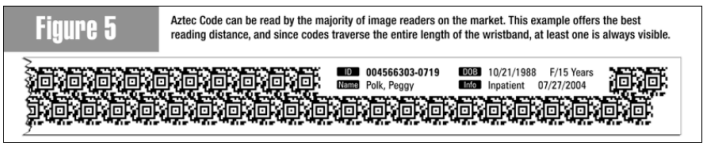
- **Simple and cheap.** This is the main reason barcodes are widely used now. They're essentially free to produce, and they're very low-tech.
- **Printable.** Barcodes can be printed along with patient info in one step. The only equipment needed is a standard printer.
- **No metal.** Because they don't use metal, they can be used in MRI machines.
- **Clearly targeted.** When scanning a barcode, it's obvious that you are scanning the right code. (not necessarily the case with RFID)

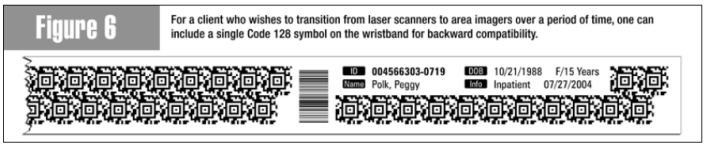
However, barcodes also have many limitations.

- **Short-range, line of sight.** Barcodes require the scanner to be very close to the code, and for the barcode to be visible. This is often inconvenient. If the patient is asleep on the wristband, he/she must be woken up. The nurse risks infecting patients by touching their skin while scanning. In contrast, the long-range, no-line-of-sight scanning of RFID tags provides many benefits.
- **Easily damaged.** Barcodes are frequently damaged during a stay by dirt and smudging.

2D barcodes are better than 1D barcodes. They encode more information and they are 100% reliable. The only reason to use 1D barcodes is that they work with older scanners.







RFID

RFID (Radio Frequency Identification) is a sophisticated wireless technology that has rapidly been gaining prominence over the last couple decades.
An RFID system consists of a reader and tags. The reader is usually an active, powered device, like a handheld device with a screen or a powered device attached to a wall. The tags themselves can be passive or active.

Passive tags - Passive tags are really small/thin/light, and are often in sticker form. For example, many libraries put passive RFID tags on the inside cover of books. A passive tag doesn't have a battery -- it gets its power from the reader wirelessly. A passive tag also can't provide information unless asked by a reader. Passive tags are cheaper than active tags.

Active tags - Active tags are a bit bulkier, because they include a battery and some more circuitry, but they can still be pretty compact. Active tags can initiate communication with a reader. A common use case might be connecting an active RFID tag to a sensor, and having the tag notify a reader when the sensor reports something. Active tags have longer range than passive tags.

RFID tags have some major advantages:

- **Long-range.** There are many different RFID technologies with vastly different scanning ranges. Maximum scanning range can range from ~5cm to 500 meters, depending on the tag and scanner used. Passive tags usually have a maximum range of between 20cm and a few feet. Max range can be specified based on the desired application.
- **No line of sight required.** A tag can be scanned without the tag being in the scanner's line of sight.

- **Relatively cheap.** RFID tags are more expensive than barcodes, but still relatively cheap. Cost estimate is around $0.15~$0.30 per passive RFID tag.

And some disadvantages:

- **More complicated.** RFID tags can't simply be printed with ink like barcodes. However, Zebra does make combined printer/RFID-encoder machines, which are similar to simple ink-based wristband printers.
- **Metal.** RFID tags would not be allowed in an MRI.
- **Targeting is more ambiguous.** Unlike a barcode, it's less obvious which tag you're scanning when you use a reader. However, the scan range can be limited so that only one patient is scanned if the nurse is close to the patient. There has also been some work on directionally targeted RFID scanners. As a last resort, a system could be devised to deal with situations where a reader returns the ID of multiple patients in close proximity.

> *"Each clinician in the pre- and post- operative process completes his or her work and then lets everyone else know, by scanning the RFID bracelet, that the patient is ready for the next step in the process. For example, a holding room nurse performs a readiness assessment, then creates a note on the computer system indicating that the holding room has cleared the patient, letting the anesthesiologist know that the patient is ready for him. When the surgery is complete, the patient's RFID bracelet sends a signal to the computer that the patient is leaving the OR, alerting a clinical team that the room is ready to be cleaned and prepped for the next patient."*

Current trends in RFID – Case studies

RFID is starting to become fairly common in hospitals worldwide. It can be used for tracking hospital equipment, patients, doctors—essentially any object in the hospital. Here are some examples that showcase different potential uses of RFID:

Basic patient identification

Although use of RFID for patient identification is not yet widespread, it is not difficult to find examples of hospitals using the technology. Orthopedic Hospital of Oklahoma implemented RFID bracelet patient tracking in 2005.[13] A news article explains: "The data on the bracelet is wirelessly transmitted to Sun Ray thin clients located throughout the hospital or Personal Digital Assistants (PDA) used by caregivers. Compared to bar coded bracelets in use at many hospitals today, RFID bracelets are welcomed by patients because they are far less intrusive." The NHS in the UK has also used RFID-enabled patient bracelets in a successful pilot program.[14] One important takeaway from that project is that 1D barcodes and 2D barcodes were printed on the RFID bracelet to ensure backwards compatibility with older equipment.

Although it is difficult to find actual statistics about how widespread RFID identification technology is, many patient identification vendors such as Zebra and Brenmoor sell

RFID-enabled bands.[15][16][17] This suggests that, at the least, there is enough of a market for RFID bands for major manufacturers to produce them.

Active RFID applications

Battery powered active RFID devices enable a range of powerful applications, including tracking patient location and patient temperature.

Figure 1 Active RFID tag used for patient location at Tan Tock Seng Hospital

Tan Tock Seng Hospital, one of Singapore's busiest hospitals, started using RFID in 2007 to track the location of patients in real time.[18] 556 RFID readers were installed throughout the hospital, and 868.4 Mhz battery-powered active RFID tags were added to patient wristbands, to enable tracking patients' movements. Yong Keng Kwang, deputy director of the hospital's nursing service, said, "For example, when a patient is discharged, housekeeping and the bed-management unit are notified in real time, and the bed is cleaned within 30 minutes. With advance notice, the emergency department could also better prepare their patients for transfer. Knowing the real-time location of patient also helps. When a patient goes in for an operation, ward nurses will be able to tell when an operation has been completed by virtue of the patient's location in the post-anesthesia care unit, and update the patient's family."[19]

Figure 2 ThermoSensor temperature monitoring active RFID device

Tan Tock Seng Hospital has also deployed a system for monitoring patient vitals, using active RFID ThermoSensor devices attached to patients' abdomens. The tags actively update a hospital system with constant temperature readings, alerting nurses when a patient runs a high temperature. The director of Cadi Scientific, the vendor firm that made the sensor devices, says, ""The new wireless temperature-monitoring system is already delivering enhanced patient care, as patients have more uninterrupted rest and nurses are alerted immediately once a fever is detected…It has also reduced the nurses' workload, as they do not need to manually plot vital signs into paper clinical charts, and clinical information is readily available to doctors who can log on anytime, anywhere, to view patient clinical charts. It is a major leap towards becoming a digital hospital."[20]

Baby matching

In 2008, the majority of birthing facilities in Ohio were being equipped with a Verichip RFID system to match infants with their mothers.[21] Babies receive an RFID anklet at birth and mothers receive matching RFID wristbands. This helps ensure babies are matched with the correct mother, and also ensures the security of infants—an alarm is raised if the RFID anklet is removed, or if the baby is removed from the ward.
The system was criticized by some privacy advocates, but Verichip defended the system, citing improved patient safety.

Human-implanted chips
VeriChip was the first and only FDA-approved RFID chip designed to be implanted under patients' skin.[22] It was marketed as a useful form of ID for people with chronic diseases, presumably to avoid them having to wear a wristband for their entire lives. It was also helpful for patients prone to tearing off their wristbands (e.g. Alzheimer's patients). However, the product failed because of privacy concerns. [23]

Tagging hospital equipment
RFID tagging of hospital equipment has become common. By tagging all equipment with RFID, a hospital can easily run inventory and track where equipment is in the building. The Bon Secours Richmond Health System introduced RFID equipment tagging and saw massive benefits. [24] Utilization of IV pumps went from 40% to 90%. Lost and stolen equipment incidents went down 50%. And through a combination of RFID tagging equipment and patients, operating room turnover time went down 50%.

In our firsthand research at Yale-New Haven and Johns Hopkins, we have also come across RFID being used to track equipment. At Yale, every sponge used in surgery has a passive RFID tag attached, and an operation cannot be ended until an RFID reader has been used to verify that no sponges have been left inside the patient. At Johns Hopkins, most large equipment can be tracked via RFID, and Rhonda Wyskiel expressed frustration that the same system doesn't apply to patients yet. "It's almost embarrassing. We can tell you where any pump or any pull or any big piece of equipment in Johns Hopkins is from a database at any time, anywhere in the hospital…but yet we can't do that with patients."

Biometric
What if you could identify a patient not by something they were wearing, but by their actual body itself? The Texas Health Hospital in Dallas identifies patients with palm vein scans, which are 100 times more accurate that fingerprint scans.[25]

This helps deal with the problem of two patients having the same name and birthday. For example: "There are 191 Margaret Allens born in the same year in its records system. Now think of a panicked husband who rushes his comatose wife into emergency and is asked her name, date of birth and Social Security number. 'Chances are he's going to miss at least one of the three,' Phillips says. 'You might find four or five women who are close to that information. The last thing you want to do is choose the wrong one.'"[26] However, a palm scan is a fairly intrusive procedure. It seems that Texas Health uses the palm scan only when a patient arrives, and uses a more conventional ID process throughout the patient's stay. There is an important distinction between identifying a

patient to give them a form of ID (e.g. a wristband), and identifying a patient who already has the wristband.

ID Technologies Conclusion

RFID is a versatile and powerful technology that can make hospitals more efficient; the minor drawbacks listed above are probably surmountable, and RFID opens up a world of possibilities that cannot be achieved with barcodes. Hospitals have seen very impressive results from implementing RFID tagging, which shows the technology is feasible and greatly beneficial.

5. Concepts

As we moved toward a solution, we compiled an exhaustive list of our ideas and discussed the ones that excited us the most. During these conversations, the concepts become more than just bullet points in a word document. We flesh them out and examine them carefully from many different angles, exploring all the ways they could work or break down. We were most interested in the following five concepts:

E-ink bracelets. On the more high-tech side, we discussed developing an e-ink bracelet to replace the analog wristbands. This e-ink bracelet could be more than just a tool for identification. It could track heart rate, body temperature, and other vitals during a patient's stay and alert nurses if something has gone wrong. The screen would make it easy to fix errors on the bracelet and display information about the patient's allergies—replacing the many color-coded wristbands that are currently used for this purpose.

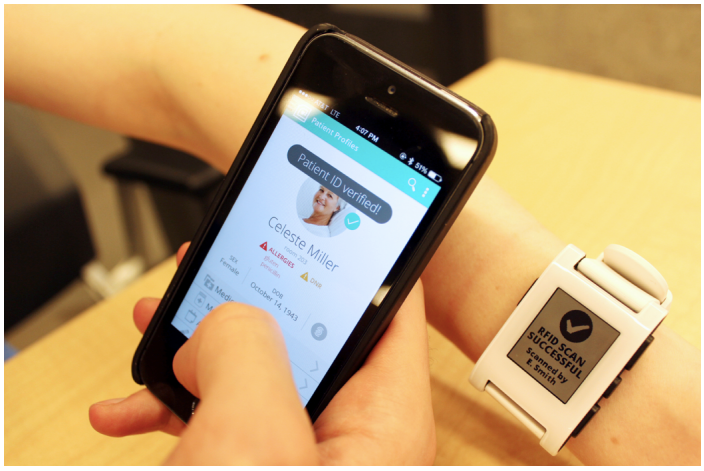
Smartphone/tablet scanning. If nurses were able to scan barcodes using a technology that is more likely to be on their person, the number of patient misidentifications would likely decrease. A smartphone or tablet scanning system would also make room for a system of accountability tracking; hospital administrators could see how many times each nurse had scanned patient identification, ensuring that hospital staff is following the necessary procedures.

Stickers for temporary identification. Patient ID wristbands could be designed to include peel-off barcode stickers. These stickers could be placed elsewhere on the patient's body if their wristband must be cut off prior to surgery or IV insertion. This temporary solution would give doctors and nurses an easy way of identifying patients at a very high-risk moment in the process.

ID enforcement via door scanners. Cars have mechanisms that prevent drivers from taking certain actions (e.g. putting the car in *Drive*) until the keys are in the ignition. Our thinking here is to do something similar in the hospital environment and use technology to enforce desired behaviors. Certain doors, for example, would not open unless the patient has been properly identified.

Smart bed. If the bracelet were to have a passive RFID chip and the bed an RFID sensor, the hospital bed could have a screen that displays who is in it at any given time. The data encoded on the bracelet could include what room number the patient is supposed to be in for his or her procedure. If the room number of the patient does not match with the bed's room number, the nurse or doctor would know instantly that the patient is in the wrong place. The smart bed's screen could also contain the patient's barcode and information about the patient's allergies, allowing hospital staff to scan the patient's ID even if they are laying in a way that obscures their wristband.

6. Our Solution



After meeting with the MICA team, we decided to make the most of our remaining time by diverging into two separate teams, each focusing on a different component of an integrated patient identification system. The MICA team produced an Android app for nurses, which displays detailed patient information in a user-friendly interface. The app leverages the NFC capabilities of Android phones, which would allow for RFID scanning at short ranges. Our team at Yale, meanwhile, developed the hardware side of the system with an electronic "smart ID" that incorporates an e-ink screen and RFID technology. We believe these two solutions would work together to minimize error while improving the user experience of patients and nurses alike.

Smart ID

The "Smart ID" is the patient-side component of the greater identification system, and is the direct replacement for the physical paper wristbands which are the status quo. By including electronics and a battery, the Smart ID incorporates many useful features which are obviously impossible to include in a traditional paper wristband. These features serve to help nurses fulfill their goal of patient safety, but also go beyond that to provide functionality for patients, aimed at improving patient experience.

1. **E-ink screen**: The Smart ID features an E-ink screen and four buttons for navigation. The default view on the screen includes crucial information similar to the information now included on a paper band -- patient name, date of birth, an ID number, allergies, and "do not resuscitate" status. By pressing the buttons, the patient or nurse can navigate to screens with medication, scheduling information, QR codes (for backwards compatibility with old scanning equipment), and more.
2. **Active RFID chip**: An implanted active RFID chip allows for wireless identification. From afar, nurses can scan the chips to pull up patient records and verify identity on their PatientID app, designed by MICA. The app helps nurses

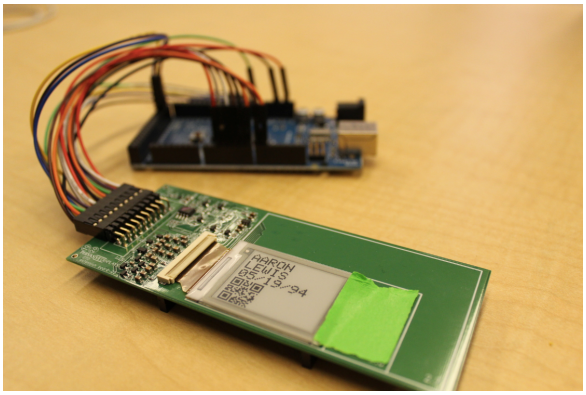
distinguish between RFID signals by providing pictures of each patient. In addition, the RFID chip can be used to track a patient's location in the hospital, in cooperation with RFID readers deployed throughout a hospital (which are commonly already installed to track hospital equipment). This enables useful features, such as alerting a nurse when a patient is detected in an operating room where they are not scheduled to undergo a procedure.

3. **Modular wear**: A simple bracelet solution wouldn't solve the problems caused by cut bands in the operating room; in order to keep patients identified at all time, we designed the unit so that it can be attached to anything with a loop or strap. When the bracelet is cut off, then, the anesthesiologist can easily attach the unit to a clip, anklet, or something else.

Combined, these three features cater to both patient and nurse users. Rather than simply serving as a stop-gap solution to address narrow problems in the system, the E-ink bracelet brings an array of new benefits to the hospital environment. The next several sections explain these benefits in detail and provide technical information on each component of the unit.

E-ink screen

The E-ink screen provides a low-power, low-cost option—ideal for the hospital environment. Hospitals have crucial safety concerns; all enhanced features aside, the ID+ must allow for patient identification at any time. Fortunately, E-ink screens can keep a screen on display without using any power; in case of battery loss, the screen would switch to the default identification view and lock the screen switching capabilities.



We experimented with a few different approaches for prototyping this project. We began using an Arduino microcontroller with an e-ink display component. However, we eventually settled upon the approach of using a commercially available consumer device as our hardware platform. The Pebble smartwatch is a watch with an e-ink screen and a miniature computer, designed to connect to a smartphone via Bluetooth. We found that it contained most of the functionality we desired in the Smart ID hardware (notably excluding an RFID tag), and decided that using the Pebble would best enable us to demonstrate the functionality in a somewhat realistic form factor. (Of course, were this device to be actually manufactured, it would be a custom hardware platform.)

The different displays which can be shown on the screen provide a wide range of information to patients; Appendix B shows a wide range of potential views. Ideally, we would like to allow hospitals to add their own views, depending on their specific needs or interests; once the bracelet is implemented, the marginal effort required to add, delete, or modify a screen at any time is extremely low. Potential information could include:

- **List of medications and dosages:** during a hospital visit, a patient might be put on new medications or taken off old ones. Providing the patient instant access to the full list of medication names, dosages and even side effects would minimize confusion and ensure compliance with medication regimes.
- **Allergy information:** Hospital environments contain a wide range of potential allergens; it is essential, then, to instantly inform nurses of allergens. The modular wear section details other ways in which our solution provides key visual cues.
- **Patient's daily schedule:** The schedule will include planned procedures, meals, and more.
- **Names/contact information for all care-takers:** A patient may interact with multiple specialists and nurses during an inpatient stay or even a single outpatient visit; by providing names and contact information for all practitioners, the patient will be able to direct questions or requests to the appropriate point of contact.
- **Information on procedures or conditions**: Internet searches frequently pull up terrifying, hyperbolic information about side effects, diseases, or conditions. By providing a small wiki with information on the patient's conditions or procedures, the hospital could minimize panic and improve patient comprehension.
- **Directions to hospital departments:** Although this component may be difficult to implement at first, we would like to direct patients to their next location, in
- **Motivational quotes:** Long hospital stays can be depressing--once we have a screen on every patient, why not use it to lift their moods?

For images of several of these screens, see Appendix B.

Active RFID

Although we were not able to experiment extensively with RFID, the technology is already quite well-established (see the technology section for more details on different kinds of RFID, along with current implementation in hospitals). Thus, we wouldn't expect integrating RFID to cause any large difficulties; the power source used to drive the E-ink screen will also power the active RFID. Because many hospitals already use RFID, often for equipment tracking, many nurses and other professionals already understand the technology; knowledge could spread horizontally, from hospital to hospital.

The MICA app does present a few challenges, though, given the current functionality of smart phones. Android phones and tablets make use of feature Near Field Communication, which allows the user to scan RFID tags at a short distance (around 4 cm); future iPhones may also incorporate this feature. To maximize the usefulness of our combined products, though, the reader would need to communicate with RFID tags from several feet; this level of functionality, at least for now, would require a hardware attachment to the phone. Given that some hospitals are already experimenting with having nurses and doctors use mobile devices to view and edit patient information, buying additional hardware attachments would probably not be cost-prohibitive.

Modular Wear

The main complaint that inspired this project centered on the removal of bands during surgical procedures; the nurses at Yale New Haven hospital asked us to make a kind of stop-gap solution to ensure that some form of identification remains on patients at all times. Although our final solution addresses a more expansive suite of problems, we wanted to ensure that we solved the problem that sparked the project.

Thus, we allowed for modular wear; the primary unit, which contains the RFID chip and the E-ink screen, can be attached to a wide range of buckles or straps. The image at right, for example, shows how the unit can be attached to a retractable strap; this strap, in turn, could be attached to the patient or bed, either through adhesive or with a clip. The innovation, here, is decoupling the source of information from how it is attached to the patient.

Cost of Smart ID unit

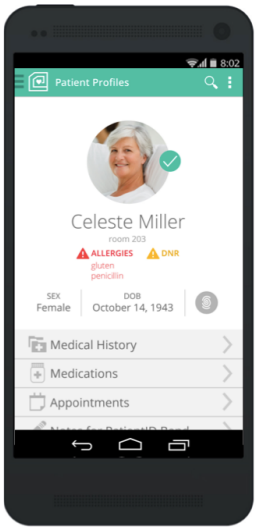
Because these units can be re-used after sterilization, they are cost-effective in the long run, especially when we account for the wide-ranging benefits they confer on the hospital environment. For our back of the envelope cost calculation, we used the current retail price of the Pebble smartwatch ($150) as a benchmark. According to the CDC, the average inpatient stay in the United States is around 4.8 days; in a year, then, a single band could be worn by approximately 76 inpatients. Assuming a one-year lifetime for the device, that gives us a $1.97 per-patient cost. For comparison purposes, the more relevant cost is per inpatient day, which would be $0.40. These cost estimates, however, are conservative; we would expect a wholesale price of less than $150 and a lifetime well over one year.

Still, even these conservative prices would be feasible for hospitals; after all, the average US hospital bears a cost of $1,625 per inpatient day. For a cost of $1.97 per patient or $0.40 per inpatient day, the smart ID unit would bring enormous benefits to the hospital environment. It would increase efficiency and reduce costly errors, helping hospitals deliver services more effectively and avoid paying damages.

The improvement in patient experience can also pay--literally. When we brought up cost with the nurses, they told us that hospitals get reimbursed from Medicare and Medicaid based, in part, on patient experience surveys called HCAHPS.

Overall, then, we believe that, even with conservative cost estimates, the smart ID solution would be economically feasible for hospitals. Hospitals face systemic problems across the board; our solution would leverage technology to help bridge gaps in the system without expensive overhauls.

Patient ID Scanning App



Our partners at MICA worked on designing an Android phone application to help nurses easily identify and access information on nearby patients. Although they focused primarily on UI, their designs provide a thorough indication of the potential power of the fully developed application. As mentioned above, MICA selected the Android platform because of its NFC compatibility; in future years, though, iPhones will likely feature NFC as well. Ultimately, of course, full use of the application's features would require a hardware attachment to scan the active RFID from a distance.

When the phone scans a bracelet, the nurse sees a screen with a patient picture and key identifiers, including name and date of birth, essential medical information, such as allergies and fall risk information, and room number. The application also allows nurses to look at information on all of their patients; it can also show alerts if a patient falls, for example.

7. Feedback from Yale New Haven Hospital

After completing initial work on our prototype, we brought it to the nursing staff we had been working with at YNHH. The nurses were very excited about the prospect of using our smart ID band to improve the patient experience in the hospital—as one nurse exclaimed, "I don't understand why they can make technology work in grocery stores, but they can't get it right in hospitals."

New Insights & Ideas

The nursing staff was particularly interested in the idea of giving patients access to their schedules on the smart band, as patients currently complain about their lack of access to information. Our smart ID band would give them an easy way to see what is planned on any given day. The nursing staff was also on board with the integrated "call for help" button and suggested that the current nurse call bell could be easily replaced by our band.

The wide variety of form factors was also seen as a big benefit because there are many patients for whom a wristband simply wouldn't work (e.g. amputees). The nurses suggested several interesting features, including an accelerometer in the band that would detect when a patient had fallen and notify staff that they are in need of help. They added that the band could interface with MyChart—a 3rd party platform that allows developers to pull data from Epic.

Concerns

When we presented our concept to nurses, their main complaint was the lack of visibility of key information like allergies or fall risk. During hospital visits, patients are generally given additional colored bracelets--similar to the standard ID bracelet--in order to alert nurses of such conditions. In order to easily replicate this system while maintaining the simplicity of our design, we designed colored bands which could be slipped onto the bracelet. Again, though, the modular wear allows a wide range of options for visible alerts. For example, if the patient is a fall risk, the entire attaching band could be red to instantly communicate the risk to distant nurses.

We also learned that YNHH has many of the same software problems as the Johns Hopkins medical center; Epic has different systems for inpatients and outpatients, which means that patients are sometimes given multiple wristbands and profiles in the system. As previously mentioned, our solution addresses this problem by integrating a patients' many profiles into one single band.

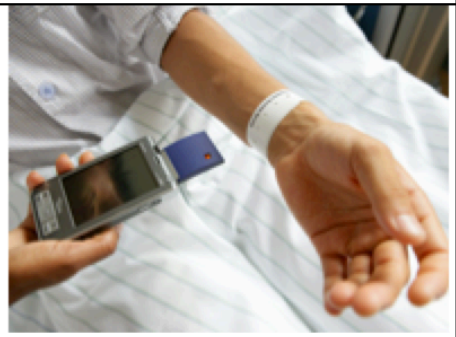
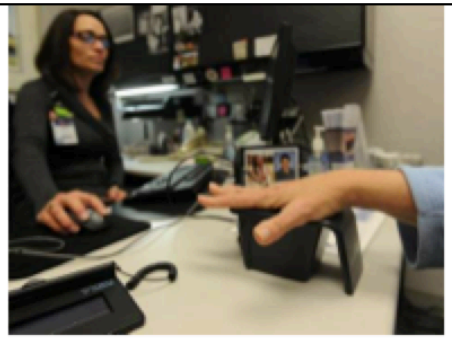
The nursing staff was also concerned that they would lose devices due to negligence or theft. The RFID in the bracelets, however, makes their location trackable, which would help mitigate the problem of lost devices. The nurses were also worried that our smart ID band would not be accessible to children, the elderly, or patients with bad vision. The QR codes on the screen make the bands backwards compatible, so patients would not have to interact with the more advanced features if they didn't want to or were unable to. Overall, the nurses agreed that our solution is better than the status quo for most patients and maintains the status quo for those who can't access the other features.

Conclusion:

Our hospital system plays a central role in maintaining a thriving population; in delivering care, practitioners should be able to leverage the best technology. Despite the highly skilled doctors and nurses who help patients every day, hospitals still face severe challenges in efficiently and correctly treating patients. The Cheesecake factory mass-produces high quality food and service; grocery stores efficiently deal with thousands of inventory items. Given the importance of the work they do, hospitals must be able to deliver high quality care to scale.

With the PatientID system, including the Smart ID and the PatientID app, we believe that we can use technology to help bridge the gaps in the current systems. Too many hospitals are caught in the past, and the status quo can no longer make the cut. By working to develop and implement our system, hospitals would increase efficiency and improve the experience of both nurses and patients.

Appendix A: Technology Comparison

	Barcodes	RFID	Biometrics
Appearance			
Description	Barcodes are the most common tool for hospital identification; most hospitals have transitioned to 2D barcodes, although some still have 1D for backwards compatibility. Some bracelets also include ID for easy visual identification	RFID bracelets use radio communication to retrieve information from a chip embedded in the bracelet. Passive RFID does not need to be powered; active RFID, meanwhile, can actively transmit information like patient location.	Biometric technology has recently been implemented in several US hospitals, which generally use palm scanners. When a patient checks in at the receptionist, he/she places a hand on the scanner to check identity.
Advantages	• Simple and cheap • Printable • No metal—so they're MRI safe • Clearly targeted • Can be waterproof	• Long-range • No line of sight needed • Relatively cheap ($.15-.30 per passive RFID chip) • Many possibilities for use (see text)	• Can re-identify someone without a bracelet—good stop-gap measure • Helps avoid entry error caused by similar names or birthdays.
Challenges	• Short range • Line-of-sight needed • Easily damaged	• More complicated than barcodes • Contain metal—not MRI safe • Targeting is ambiguous: potential for noise if patients are clustered together	• Can be invasive • More expensive than other solutions

Appendix B: Smart ID screens

[1] http://www.cdc.gov/nchs/fastats/hospital.htm
[2] WHO report
[3] http://healthcare-executive-insight.advanceweb.com/Columns/Case-Files-Legal-Issues-for-Healthcare-Executives/Patient-Identification-Simple-Measures-Big-Benefits.aspx
[4] Samuel Seiden and Paul Barach. "Wrong-Side/Wrong-Site, Wrong-Procedure, and Wrong-Patient Adverse Events." Arch Surgery (2006).
[5] "It's all in the Wrist: Improving patient safety with bar ode wristbands" Zebra white paper, 2010: http://www.zebra.com/content/dam/zebra/white-papers/en-us/its-all-in-the-wrist-en-us.pdf
[6] ibid
[7] http://www.jointcommission.org/standards_information/npsgs.aspx
[8] The process at Johns Hopkins is extremely similar, but some key differences stand out. First, the nurses at Hopkins print out multiple ID bracelets at registration, along with barcoded stickers which patients can place on their belongings and blood tests to maintain consistent identification.
[9] http://www.ismp.org/newsletters/acutecare/articles/20110310.asp
[10] Howanitz, P. J., Renner, S. W. & Walsh, M. K. (2002) Continuous wristband monitoring over 2 years reduces identification errors. A College of American Pathologists Q-Tracks study. Archives of Pathology and Laboratory Medicine, 126, 809–815.
[11] https://www.honeywellaidc.com/CatalogDocuments/redefining-the-patient-wristband-whitepaper.pdf
[12] http://onlinelibrary.wiley.com/store/10.1111/j.1365-2753.2008.01026.x/asset/j.1365-2753.2008.01026.x.pdf?v=1&t=hrtbwxxr&s=ff935cfe8f6320f0f33bac3164eff2e8988d3bac
[13] http://www.hoise.com/vmw/05/articles/vmw/LV-VM-03-05-10.html
[14] http://www.connectingforhealth.nhs.uk/systemsandservices/clinsafety/projects/bloodpilot/implementation/lessons/wristbands
[15] http://www.brenmoor.com/rfid-wristbands/
[16] http://www.rfid-in-china.com/news-detail-39.html
[17] http://www.zebra.com/us/en/products-services/supplies/wristbands.html
[18] http://www.rfidjournal.com/articles/view?4560
[19] http://www.rfidjournal.com/articles/view?4560
[20] http://www.rfidjournal.com/articles/view?4560
[21] http://www.wnd.com/2008/01/45542/
[22] http://pqasb.pqarchiver.com/latimes/doc/421904983.html?FMT=ABS&FMTS=ABS:FT&type=current&date=May%2009,%202002&author=DAVID%20STREITFELD&pub=Los%20Angeles%20Times&edition=&startpage=&desc=First%20Humans%20to%20Receive%20ID%20Chips;%20Technology:%20Device%20injected%20under%20the%20skin%20will%20provide%20identification%20and%20medical%20information.
[23] http://www.antichips.com/is-the-threat-real.htm

[24] http://www3.gehealthcare.com/en/Services/~/media/Downloads/us/Services/Hospital%20Operations%20Management/Case%20Studies/HFMA_HCC_Bon_Secours%20Feb%202011.pdf
[25] http://www.dallasnews.com/business/columnists/cheryl-hall/20130126-texas-health-hospital-system-uses-palm-scans-to-id-patients.ece
[26] http://www.dallasnews.com/business/columnists/cheryl-hall/20130126-texas-health-hospital-system-uses-palm-scans-to-id-patients.ece