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Edited Transcript

Roundtable Discussion

***Beyond The Electronic Health Record:
Anticipating the Direction of Future Technologię***

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List of Attendees

Cindy Bascetta

Director
Veterans Health and Benefits
Issues
GAO

Col. James Bengel, MD

Clinical and Program Policy
Health Affairs Office
DoD

Ronald Blanck, DO

President
North Texas University
Health Science Center

David Brailer, MD

National Coordinator for Health
Information Technology
HHS

Cliff Freeman

Director, VA/DoD Health
IT Sharing
VHA

Tim Ganous

Medical Technology Planning
University of Maryland Medical
System

Col. Bart Harmon, MD, MPH

Chief Medical Information Officer
Information Management,
Technology and Re-
engineering
Health Affairs Office
DoD

Janet Heinrich, DrPH

Director
Public Health Issues
GAO

Rob Kolodner, MD

Acting Chief Health Informatics
Officer
Veterans Health Administration

Col. Janice Lee, MD

Medical Chief Information Officer
U.S. Air Force

H. Stephen Lieber

President/CEO
HIMSS

Lance Manning

Predictive Medical Imaging
Commercialization
Prenosis

James Miller

Visualization & Computer Vision
GE Research

Ron Pace

Information Technology and
Acquisition Advisor
TATRC
Army Medical Research
And Materiel Command

James Peake, MD

Former Surgeon General
U.S. Army

Steven (Hank) Rappaport, MD
Enterprise Systems Manager Health Enterprise
Systems
Management Division
VHA

Pedro Rivera, MD
Chief Medical Officer
Health Net Federal Services

William Rowley, MD
Senior Futurist and CEO
Institute for Alternative Futures

Richard Satava, MD
Professor of Surgery
University of Washington

Diane Thompson
Senior Vice President
FasterCures

Alexander Tsiaras
President/CEO
Anatomical Travelogue Inc.

William C. Vanderwagen, MD
Chief Medical Officer (Acting)
Indian Health Service

Julie Wands
Deputy Director
Health Services Division
Bureau of Prisons

Kathleen Weldon
Professional Staff Member
House Ways and Means Committee

Scott Young, MD
Director of Health Information Technology
AHRQ

Michael Zamore
Policy Advisor
Office of Rep. Patrick Kennedy

James Zimble, MD
Past President
USUHS

Roundtable Proceedings

Dr. Zimble: I have to begin with a little bit of grouching. In 1981, when I was Medical Officer of the Marine Corps, I was promised that very shortly there would be a “smart” dog-tag for Marines and for the Army, and that it was working and was coming on beautifully. Then about five or six years ago, the Surgeon General of the Army was touting his dog-tag, which he waved to everyone, wore it around his neck; said this is my health record.

There is no question that the promises have been there, and the technology has been there for some time. I can go on the Internet and deal with my credit card companies; I can deal with my bank; I can write checks; it’s all secure, it’s all readily available to me at any time. I can download information whenever I want it — but I can’t do that for a health record. I would like to remind everybody of where we are today; this is my health record from Bethesda [Naval Medical Center], right here: volumes 1, 2, 3, and 4. I challenge any doctor who’s going to take care of me to be able to go through that and glean any reasonably good information from illegible documentation that is chronologically corrupted.

So, that’s where I see us today.

Keynote: Dr. David Brailer

I’m glad to be here, because we’ve been so caught up in the “here and now” with Electronic Health Records, we take a lot for granted about how quickly they’re going to change and evolve and do what’s happened to many other enabling technologies.

Today, we have underway efforts to urgently get definition about what the Electronic Health Record is. For example, we have here today people who can talk about the product certification effort that we have underway, which we see as an effort to set a minimum baseline — what is it that you have to have to be a legitimate record that’s used? There are efforts on a variety of areas trying to plumb the very northern limits of how far it can go. Where I’ve spent most of my time is not on what is it and how it does evolve, but what changes does it bring to the healthcare delivery system; how do we achieve the goals of a consumer-driven healthcare economy, an economy that’s accountable, where the value of output and the purchasing price for that output are aligned?

These are the things we spend a lot of our time on and are what brought the President to the Electronic Health Record as an enabler of a better healthcare economy. This roundtable focuses on the next step — technology will evolve, and where will we end up? I want to take poetic license to talk a bit about where I think some issues might be raised. I was at the Health Technology Center in San Francisco before I came here, and we really worked on a lot of very interesting future-oriented things. We looked at things that would happen seven to ten years from now, and we used those to try to map what regulatory, financial, organizational, and market changes needed to happen. The reason that future forecasters pick seven to ten years is that it's close enough to seem relevant, but it's far enough away that no one could ever remember what had been predicted. So, it's a perfect sweet spot for forecasting.

We actually did a very, very interesting report on the bionic man, about how devices and information technology and wireless would come together. DARPA thought about that 15 years ago, and they are far beyond it at this point. Let me then turn to three basic pieces of EHR and talk about where I think we're potentially heading. First is, where does the data come from? Think of the Electronic Health Record as data and information coming in. Secondly, the data are being stored and analyzed and subjected to various forms of filtering or algorithms, or as Ted Shortliffe said in 1977, decision-support is the combination of one or more facts with relevant knowledge and rules, so that it can be presented in a way that has insights that couldn't have been gleaned from looking at the facts themselves.

Thirdly, what do we do with the data? How does it come out and what do we do? So first, where does it come from? You know, I've spent a lot of my time, and so did many of us, trying to figure out how to get laboratory data and results into tools and lists of drugs and other related formulary things: hospital discharge data and abstracts; practice management data, so that we have operational, clinical and personal components of the record.

I think anybody today or in the next few years would say, if we can get together laboratory and pharmacy data, hospital data, financial billing, managed care data, personal demographics history, and then include some components of physician direct observation, like a physical exam, we'd be doing pretty well. This would be a breakthrough, and if you look at many of the financial pro formas that we've put together about where the benefits of the Electronic Health Record come, those unlock a huge amount of value. We know that they will unlock a large value in preservation of quality as an outcome of healthcare, reduction of errors.

Let me just throw out some things that I think we're on the cusp of having to worry about. In the hospital setting, direct-feed data from human dynamics, from pumps, information that's collected directly in the room from other related sensors, these are actually near at hand. I've seen projects that are not out on the cutting edge, where these were started to be collected. But, they are clearly not today considered part of the Electronic Health Record, nor have we started conceptualizing what we do with them and how we actually operationalize them. Let me go further. How about at work. You're sitting at a desk. Is your stress level, however we monitor it, part of the Electronic Health Record? How about the ambient environment? We know that indoor air pollution is a significant cause of morbidity. Do we consider that to be part of the Electronic Health Record, and if so, how do we collect that data? How about at home? Sensors that tell us about your ambulation; information that tells us about your diet, which may be more suitable on the shopping cart, so we can understand it at point of purchase rather than at home. How about the car? We're two years away from having the first car whose seat weighs you when you sit down in the morning.

Is that part of the Electronic Health Record? I think so. I believe that the Electronic Health Record is going to be feeding data more broadly than just direct observational data and deal with much more preventive point-of-issue information, because we would also take it back to those settings. I'm not suggesting that a car seat that's showing your weight going up will not allow you to go into a McDonald's, though maybe that's not a bad idea. But, that's a cartoon of the point, which is, if many healthcare issues are derivatives of issues that occur in people's lives, and they only transactionally get addressed in a doctor's office, how much can we get in front of this? We want to be able to ultimately take the information back out.

How about your response time in a car? If you have an accident, is that a reason to have a neurological evaluation? I am pretty sure the American Neurological Association would love to have that as an indication. Maybe Medicare will pay for it, I don't know. But my point is, it might seem a little bit outlandish, but so many things that happen in our activities of daily living have for so long been considered part of relevant healthcare. And, these are just examples of many things laid out as functional indicators that we believe have direct relevance to morbidity/mortality cost experience, and to the things that healthcare is trying to achieve. How about air pollution outside? There have been in the *New England Journal of Medicine* in the past three years seven articles showing variations in morbidity/mortality that result from variations in local ambient air pollution levels. In fact, one of my criticisms against small-area variations analysis, the Dartmouth Atlas [of Health Care], is that there are so many secular factors that they don't even take into account. It over-allocates variations to

factors that could be explained by many of those things. That doesn't mean I don't believe in reasonable variations. I think we do.

But, I think it's a bit of an overestimate, because we're now beginning to discover how many things that we take for granted are part of the biological model that we see showing up. We could also — and this is an element for the future — incorporate GPS, so we know where you have been, so we will know what ambient things going on in the environment could affect you. I think that's part of what we won't, too long from now consider the Electronic Health Record. Clearly, there are a lot of other sources of data. People have talked about genetics, and we're way down the pathway of looking not just at, should we do that, but, how do we structure the data? How is it used? What are the privacy considerations?

Remember that we will have a tripling of implanted devices in human bodies over the next decade. Right now, 7 per cent of Americans walk around with some form of device that is implanted in their body, whether it's a hip or a knee or an insulin pump, and we're talking about 20 percent of Americans having something in their body, and 30 percent, and the number will go to at least 70 percent within five years, of devices, including wireless data transmission capabilities. That means that we're going to have many, many people walking around with some device transmitting to somebody in some situation some information about their physiological status or about the status of that device or piece of equipment. We are going to have to figure out how to deal with that. I'd call that the Electronic Health Record. In fact, I would argue that if we don't consider that part of the Electronic Health Record, we're going to end up creating a whole new chain of healthcare things that we don't even understand, because of the data coming out. I think what we'll end up having is our device companies skirting the practice of medicine.

How about what we do with the data? Today, the data that's stored — let me just assume that it's standardized. It's *not*, but if I didn't make that assumption, I'd just have to go home and go back to bed. But, what do we do with that data? We apply some rules to them, some knowledge. Where does that come from? Every vendor has a starter set of 20 or 15 or 25 kind of rules. I consider those “demo” ware; not to criticize all my former peers, but those are specifically not intended for clinicians to actually use, because vendors are scared of liability and quasi prohibitions on their ability to actually formulate and produce knowledge.

Generally, what happens is that someone has a rules editor, and they can create a rule that fires in some contextual setting that says, if the lab result is this and if the patient doesn't have this allergy, then prompt the doctor to do this. So, if the hematocrit was 15 on

admission and now one day later it's 6, send the doctor a signal that says, do you want to check the blood results again, and, would you like the patient to have a higher level of care? Those are how rules work. That's trivial work, hardly combining new and relevant facts, but that's how they work.

I think the future of analysis is going to be — in fact we're already starting down the pathway of an organized infrastructure for knowledge, so that there is a set of public domain rules that are being developed with various subsets that could be proprietary or confidential, or ones that we want to be careful of their dissemination. For example, many people here know that work is being done on one of the treatment protocols for clinicians, to bring them up to snuff in the event of some form of WMD. Clinicians don't know that. They don't know what to do if somebody walks in and there is a radiation alert or something similar. So, these alerts are there, perfect. It's a great need. It's not just about doing them and standardizing them — how do we get them into the Electronic Health Record and how do we let the clinician choose?

Who is it that's really ultimately responsible for the arbitration of content? I think one natural outcome may be, when you submit an article to the *New England Journal* or to your journal of choice, you also have to submit a structured rule or rules to go along with it. The peer review process would peer review that rule, not unlike a review of the 72-page manuscript that they chopped down to 16 pages. Not that I write too long, and not that I'm bitter about having my pieces cut back by the editors. But, I think the point I'm raising is where knowledge comes from is not going to change in the next 10 years or 15 years. It's going to come from discovery and science; more hopefully from empirical observations of people's lives through things like we're talking about, but certainly the process by which knowledge really comes to bear on the clinician and is organized and delivered to the point of care is going to transform. This is something that we very much want to see happen. And, I think that's definitely part of the Electronic Health Record.

I would hope the clinicians would, when they read their journals or whatever else might happen, also download their favorite three rules that came from that; and by the way, given that science is a turbulent process of sometimes cannibalizing former truths, we might not know which rules to turn off, because it supersedes them, or perhaps we could develop some kind of a weighted mean outcome of that rule, given that sometimes we never know.

Finally, what do we do with the data? If we talk to clinicians, there are three things they want to do with data. They want to be able to, , see it; hardly a high standard. Secondly, they want to graph it. They love visual displays. And then they want to take an action. The

action involved is almost invariably an order that needs to be generated: I want that drug list so I can generate a refill or change the drug or something like that. How far are we then from having the Electronic Health Record integrated backwards into many of the things that we're already doing? I'll just pose a couple of questions.

I don't think we're that far, if we have rules, from having the Electronic Health Record be more of a "push" technology than a "pull," and what I mean by that is, it's more like an automated consultant. You go through it and ask the question, and it will tell you some answers or make suggestions that you don't have to follow, but it's completely contextual in your workflow. Can we get there? Yes, I actually think that it's not that far away. How about the Electronic Health Record outputs being pushed to all the other devices that we use? Pushing output to the drug pump to suggest right there, as opposed to on a computer screen in the nurse's station down the hallway, I'll change the pump. I can go on with a long list of those things. We're already getting to see these. If you look at Intelli ICUs, it's remarkable, it's a human voice link telling someone on-site what to do. The ones I visited are already standard-compatible.

I'd pose this question just in closing up, just to challenge you to think about how serious an Electronic Health Record that becomes forward-integrated in the life activities is. How long do you think it will be until the prescribing system is closed-loop enough — we'll be asking should we be certifying software to actually do prescribing for a consumer? It has access to the Electronic Health Record and all the rules, and knows what drugs to give. I don't think we're that far away from it. Now, there are huge professional issues with that. But, my point is not about the disruption to the professional ethos; it's about -- that's an example, be it one that may never happen for other reasons, that demonstrates forward integrations, so the Electronic Health Record not only gets data out of many situations, but puts it back out there. That's what's happened with every enabling technology that I think has come through, and I don't see this one being different.

It's really easy to think about all the cool data feeds, but I think it challenges our assumptions about healthcare to think about how the data goes back out in a way that makes it transactionally useful in many circumstances. Obviously, the ethics to science, national issues are huge, but I guess I'd summarize it this way. Mankind is outstanding. Machines are pretty cool, but over time, the combination of the two together is better than either alone, and I think the Electronic Health Record is right at that point. I'll be interested to see where we end up.

Comment

Dr. Zimble: My automobile is much further longer with the Electronic Health Record than we are: My car will tell me when its got a problem, and then if I can drive it to the dealership, the dealer has a computer that will immediately look over where the environment was, et cetera, and be able to make some diagnosis and prescriptions. You talk about the fact that 20 percent of people will have some sort of implanted transmission. Once that device is in, then the individual becomes his or her own health record. That would've been something that I know the military would have loved to have during the Gulf War, when we were concerned about who was where, when.

Presentation: Dr. Richard Satava

My particular reason for putting this conference on is twofold: first, to see where we are in state-of-the-art and see how many people are on the same pages, and to see what the Electronic Medical Record expectations are going to be; and second, to present technologies and processes that are in the laboratory and will be emerging within the next 10-20 years. From the aspect that if we were to build these new technologies, the medical record is going to have to support them. I didn't want to build a device that can transmit information but the record can't accept it. On the other hand, we would like on the technology side to understand what the requirements and standards are going to be, so when we actually build the device, it will be compatible with the record. It's kind of a two-way street here.

This is principally a technology-focused meeting; there is a lot of the future about it. Some of these things will never come to be, and others I think are passé because they're so simplistic, but we don't have them in the record today. I'd like to take a few moments here and tell you a little bit about the technologies that I'm aware of, technologies that DARPA is funding at this point in time.

To follow me will be Jim Miller, from GE Medical Systems, who emphasizes how other technologies that exist today in our standards of practice in non-healthcare disciplines, how these can be used within our healthcare system without investing enormous amounts of money; how can we transition what already exists elsewhere in the healthcare field. Tim Ganous from the University of Maryland will talk to us about not only technologies, but also the processes that facilitate technologies — how do you integrate these together to get the technologies to work? Our final speaker for the morning before the break will be Alexander

Tsiaras, who has a new book on the architecture of the human body, and will show us that the medical record can be not only a very important functional tool for us, but also it can bring aesthetics and beauty and ethical and moral values to those medical records.

What we're looking at right now is the concept that we're in the Information Age, and the future is here, and we're going to move forward with this, but it's time for change. But, I'll show you some of the concepts of why the Information Age is not really here after all. Historically, if you look back, how often does our medical record change? It's usually about every 50 to 70 years. It was back in the late 1870s when, for the first time, we ended up sharing medical information. One of the key components of this was the rise of surgery, where for the first time, with anesthesia and asepsis and pathology, surgeons had to share information. Before that time, everybody was a general practitioner; you had one doctor and rarely did one consult another. But, this forced the sharing of information, and hence the medical record. Therefore, our medical record that Dr. Brailer is putting into place right now is going to have to last for the next 50 to 70 years; we just don't change that fast, historically speaking. Consequently,, what we want to do is make sure, within the decade that we finally get this Electronic Medical Record, that it's not going to be obsolete by the time we actually have it.

A second vision: Healthcare is the only industry that does not have an information representation of its product, our patient. We are dealing with text; we are dealing with letters and words, and our patient is an image. We need to change from a text-based record to an image-based record. There are hundreds of billions of dollars in software and hardware that are used in all industries — except for healthcare — in order to do modeling and simulation — CAD/CAM, virtual testing and evaluation — speeding up the process and saving untold dollars. But, until you have an information representation of your patient, then you can't do all the things that every other industry uses for efficiency.

Third, in the information world, there is no difference between objects and information, between real things and concepts and processes. They become one, because you're taking real objects, 3-D images, and distilling them down into bits and bytes, and then you're taking processors and using them as flow diagrams, and they're bits and bytes. The computer doesn't know the difference between the real and the virtual world, and this is going to be extraordinarily important. It's one of the reasons that we need to go to the information system.

The Electronic Health Record is the only way possible to totally integrate the entire spectrum of healthcare, meaning the real world and the information world, and to change the

EHR, the Electronic Health Record, from a passive archive to an interactive tool. We've all been talking about this and around this, but this is what it's about. Up until recently, even in its electronic form, it's been nothing more than an archive. I go, I read it and then I transcribe something, and I may change it a little bit, but that's it. It is truly a tool. As I indicated, all other industry uses their information, a CAD/CAM if you will, as a tool, not only for prototyping but for quality assurance, quality improvement and so. This is possible, of course, because the new technologies that are emerging from Information Age discoveries can change the most basic approach of all facets of healthcare.

We're talking of more than just an image. By embedding the properties of the individual, their own specific vital signs, biochemical data and so on, what you now have is a three-dimensional image that is activated, if you will, by the patient's own data. What this allows you to do is what all other industry does — have a representation not only of the structure, but the function of the product; i.e., an airplane or a patient. Then you can take and do what-if scenarios in real time to see how that changes it. The data that you collect actually will change the medical record, which is indeed this image.

The Holographic Medical Electronic Representation, or HOLOMER. A HOLOMER is an entity. It lives and exists in information specs. It changes over time; it's a four-dimensional record, if you will. With the virtual soldier program, we are starting with the heart and going to make a virtual representation of the heart. We are going to do the model from that, take patient-specific data from a pig. We will wound the pig, gunshot wound to the heart, and then with that, we are going to predict two things. Based on the entrance and the exit wound, we'll tell you exactly what structures were damaged, and based on the change in vital signs, we will predict whether or not that pig will live or die, with greater than 0.8 per cent accuracy. We have confidence with the different types of parameters that we've been putting into it that this is going to be reachable, and we will be showing this approximately in nine months.

Other important things: wired technologies like robots, imaging and body simulation. We need to look at this from a different perspective. For example, a robot is not a machine. It's an information system with arms. A CT scanner is not a digital imaging system; it's an information system with eyes. If you look at the functionality of the tools that we use today, the technologies as information systems, we bring the real world down into the information world, and we can begin integrating the data that you have with the real objects, and then resurrect them back into the real world, if you will. The Electronic Medical Record, if it becomes a visual surrogate — the HOLOMER becomes a surrogate for the person in information space. We can take things that are happening in the real world, bring them

down in information space. We can integrate things that aren't possible to integrate, and then bring it back into the real world as a form of an action.

This is, in my view, the way that we're going to integrate healthcare to a level we haven't been able to before. For example, just in my discipline of surgery, the reason that robotic surgery is so important is the console that you sit at is going to be the information between the real and the information world. I can do mini-invasive surgery and open surgery via my robot. I can do remote telesurgery. I can do preoperative planning; If I have patient-specific data, I can plan that operation. I can do what all military and all aviation does rehearsal. I can do a surgical rehearsal of the procedure. I can try it a couple of different ways until I get it right, so that when I do the procedure, I'll do it right the first time, not making a mistake on my patient. We can use it for intraoperative image guidance, image-guided surgery, and of course, take patient-specific data and eventually build a library of different diseases that I can practice on rather than practicing on my patient.

These are the types of things that we have available today, but only if you use a robotic- or computer-based system. We collect data from the robot; it goes into these intelligent engines that process it for quality assurance, outcomes analysis and so on and so forth.

One of the biggest problems we have today is that we have an enormous amount of technology, and I continue to use the robot as an example, that is used for only half of its power. They're used to do surgery or to do manipulation, but they are nothing more than recorders. We need to collect things unobtrusively in the environment and be able to have them part of the medical record. We have systems that are both diagnostic and therapeutic and live in the information world — for example, hand-held portable ultrasound to which we're adding high-intensity focused ultrasound. An example from a group at the University of Washington: You can perforate the blood vessel of a pig, and when you turn on the Doppler and when you see a little red spurt in the left-hand corner, that's the blood leaving the blood vessel. You put the crosshairs on that spot, press a button, and the bleeding stops. When you redo the ultrasound, you find out the blood remains within the blood vessel. So, transcutaneously, we are able to — outside of the body — actually visualize the site of bleeding, press the button and coagulate it without ever having to operate. This is where we're moving today; energy-directed instead of mechanical systems that are going to be able to provide this.

All of these systems are controlled by information. We need to have massive distribution. We can't have it reside in a single place. It has to have real-time access, and access to references. The Battlefield Medical Information System is in the hands of a number of our

medics out in the far-forward battlefield for collecting the electronic medical record at the most far-forward point. In addition, it's compatible with the VA and the DoD records that are online now. We also need to have it mobile and connected.

Life support for trauma and transport [LSTAT] is being used in Afghanistan and Iraq as we speak. It is an intensive care unit: Absolutely everything that you have in intensive care has been reduced and is sitting here on a platform— ventilation, oxygen, suction, full telemedicine capabilities — sending vital signs from the far-forward area back to the local MASH. It was used as early as Kosovo and Bosnia: a wounded soldier was put on the LSTAT and put in the helicopter, stopped at the airfield where he was put in an ambulance, taken to the triage in the MASH hospital emergency room, operated upon in the operating room, and then taken to the recovery room. The entire medical record was able to be acquired. And yet, at any time, the MASH surgeon was able to look and see what the data was. We're looking at capabilities for actually changing things such as the respiratory, IV and so on.

Another facet is that with patient-specific data, if you have a visual HOLOMER, then you can use it for training, for surgical simulation and for surgical rehearsal. In the area of educational training, not only should the medical record become an archive and an interactive tool, it also should be a training tool, and a training and assessment tool. Whether they be decisions that are made or skills that are being practiced, they can be acquired, they can be downloaded in the medical record and become part of it in order to do quality assurance and so forth.

Where are we in the state-of-the-art? One of the more sophisticated examples is endoscopic sinus surgery, in which you're able to perform on a head mannequin but use virtual images. For the first student, we use it as a game, but when they go to the intermediate level, it turns out that we use exactly the same game but it overlays anatomy. When you come down to the final resident or the faculty member, they can take patient-specific anatomy, put it in and actually practice on the patient, all on the same simulator.

Collecting information: the Blue Dragon. What is it? It's a passive arm; when you put the instrument in the arm, it's counterweighted for gravity. You move it around, and it follows your hand motions. It allows us to objectively assess performance. Rather than every three to five to ten years having to take another test, why not have it so that every time you operate on a patient, every time you make a decision about a pharmacologic action, that data is collected, you assess it and that becomes the continuous maintenance? You can tell the difference between a novice who's trying to tie a knot and flailing around, and the expert

who goes very specifically from point to point. These are quantifiable; we can measure them within milliseconds and within millimeters, and so it's a very quantifiable way to assess performance.

Many things that we do today are functions that have in other industries been replaced by robotic systems. There now are two examples of the first robotic scrub nurse, if you will. It's voice activated, and quite frankly, it does that portion of the scrub nurse's job that I think can certainly be replaced. It has always astounded me, why, after five to seven years of higher education, the nurse who is sitting next to me at the operating table does this: scalpel — clamp. Seven years of higher education to pick this up and put it in my hand. That is a function that she does, that I think can certainly be replaced by systems such as the robotic scrub nurse. In addition, it automatically records every instrument that has been moved and is able to do automatic inventory control.

That is one vision that I think that we can achieve within the next 10 to 25 years; it could become part of the electronic medical record rather than develop as a simple system for the operating room with the medical record over here and not attached to it. My vision of the future would be one in which the patient would come to the operating area, not the room, but the entire area, the holding area. They would be placed on a "smart" stretcher, an LSTAT, and placed in a position for their operation. They will be put to sleep in the right position, then they will get a total body scan, so we will be updated on the operating table exactly how they are at that moment. We'll have a full 3-D representation of the patient at that moment, also on the "smart" stretcher. Then, while that scan is finished and the patient is being taken to an area for sterilization — we've got some very interesting new plasma technologies that will allow us a new level of sterilization — the surgeon will be sitting at the console.

The surgeon will actually practice the surgery procedure while the patient is going to the operating room — an opportunity to do surgical rehearsal. How many of you have gone to a symphony and noticed that as soon as you get there, all of a sudden everybody runs out and starts playing? How many of you have seen a baseball player that runs out of the dugout and immediately starts hitting pitched balls? No, they all warm up. Surgeons all run as quickly as they can, usually relatively late, do a quick scrub and they start cutting; there's no warm-up involved. There are other components to this that are very, very important. For example, every time a surgical instrument is changed, three things happen: The patient is billed, a new instrument is ordered, and a request is sent down to supply to go back to the vendor to get a new one — all within 50 milliseconds and within 99.9 per cent accuracy, because the data is acquired real-time and put into these different processes.

So, there are numerous things we can do once we move into this type of information system. Let me just spend one moment on our new program at DARPA designed to address the issue for the military of how we are going to automate medical support to keep up with the rest of the military. The Senate Armed Services Committee had indicated that by the year 2025, one-third of the forces in the far-forward battlefield should be automated. That means that medical support will have to be automated as well. The question is, are we going to go to autonomous systems? The answer, I think, is partially so, for certain aspects in the near future. There's been an enormous number of analogies made between pilots and physicians, and particularly surgeons. If we look at what's happened to the pilots, in 2002, the undisputed king of the air was the fighter pilot, that Jet Jockey. Then came Predator, in 2003. Now, the most far-forward air missions are unmanned, not only for surveillance but also now for combat. We don't know, but it may well be that the last fighter plane that the Army funds — the last one was Joint Air Strike Fighter, which was in 2003, a \$220 billion program — may be the last airplane that we built for fighting that has a pilot in it.

We can build UACVs, Unmanned Air Combat Vehicles. We can build them at about 10 percent of the cost that it takes in order to build one in which we have to support a human and protect that human and make sure it gets back. So, instead of \$22 million per airplane, we can build UACVs at \$2 million, with virtually the same capability. So there's a lot of similarities, and if we look to the aviation and technology industry, we might be able to import some of them. We know the technology, and a lot of the technology lives in other industries, if you will. The future is not what it used to be. Things are rapidly, rapidly changing. An Information Age cannot be the future, because it's the present, and it can't be the present and the future at the same time.

The future of science that seems to be emerging is that information itself is very important, but it's not self-sufficient. Science is moving toward interdisciplinary fields, taking into consideration all dimensions, not only biology, but timing, and things that we cannot physically feel but have to be part of our research program. Clues to where this may be coming from can be found in Alvin Toffler's *Third Wave*, where he describes three eras, or Clayton Christianson, who came up with the idea of disruptive technologies; things that fundamentally revolutionized the way things go. Toffler described the three ages: Agricultural, Industrial and Information. If you plot out these various Ages, what you see is there's this long tail initially of discovery, and then there's this rapid phase where the discovery becomes the new revolution. Then, when all consumers begin using the technology, what happens is it goes from revolutionary to evolutionary. Nothing new is discovered, but the things that you have are made better. What is new in cell phones? They're the same idea that we had 20 years ago. The only thing is they're better, they're

smaller, they have integrated other capabilities — but they're the same technology. They're really nothing fundamentally different.

With the Internet, and with the communications systems that we have, we have reached an inflection point for information technologies. I don't think I've seen anything in the past decade that's new. I've seen a lot of really cool modifications of what we have, but I haven't seen anything *new*. Where I've been seeing new things is at the intersection of multiple technologies — the three fundamental sciences: the biological sciences, physical or engineering sciences and information technologies. The proof of the pudding is, if you go to any institution, academic or laboratory, government institutions, or even big businesses, what you see is new departments or divisions arising at the intersection of these technologies. We have bioinformatics departments; we have companies creating smart and intelligent things that are biomimetic, biomaterials. Our robots and our networks are becoming more and more intelligent. The engineering and the computer worlds are coming together.

There are a few global concepts that are important. There was a very great illustration that was given to me by Shankar Shastry from UC Berkeley out of their robotics lab there, a very, very interesting concept known as “smart dust” — tiny little computers that are as little as the size of the head of the pin that can be embedded in anything. He used the example of agriculture. For example, let's say that the farmer goes out and sprays the field with pesticides, fertilizers, seed, and maybe a couple of hundred billion of these tiny little microprocessors. Some of them are transmitters, some of them are acquiring information. As the plants grow up, they are embedded into the plants. Some of them sense how long they've been growing, some of them the amount of calories, some of them the amount of sunlight, the amount of temperature. As the harvester comes down, the plant communicates with the harvester — “pick me, I'm ready”, or “I haven't been out there long enough” or “my caloric value isn't up high enough, pass me by.” As the product goes through inventory, you are able to track it. When it gets to the grocery store, you take out your handheld and you talk to the artichoke. “How long have you been on the shelf, how many calories do you have; what's your protein content?” The information is in there, and it can share it with you.

We've now given intelligence to inanimate objects that they never had before. Right now, you cannot buy a razor that was made by Gillette that's not intelligent. In the year 2004, they've bought 500 million of these little RFIDs as experiments, and every one of the brand new plastic Gillette razors has its own identification — they track them. If you go to one of the two equipped Wal-Marts, you can walk out of the store and it will automatically charge your charge account for you. Rather than scanning, as many of us do today at the grocery

store, you can do a quick self-scan. These are transmitted within two to three feet, so as you walk past the counter, it will be able to check you out automatically.

So, these types of things are really out there at this point in time. Other technologies that show the power of thinking of the real world as a form of information: The bumblebee, with a sensor on its back, for anthrax — developed in 1999. This bumblebee, or a swarm of bumblebees that had these little sensors and transmitters on, was given to a squad at Aberdeen Proving Grounds, which sent them out on a mission, after some simulant of anthrax had been released. When the bees went through the cloud of anthrax, that information was transmitted back to the squad, and they were able to avoid the areas where the anthrax stimulant had been released. It's a matter, if you will, of combining the living world with the engineering world and the information world.

At the University of Wisconsin, Eric Spatinger put tiny little probes into the brain of the cockroach and was able to record the motion and the EEG activity in the brain of the cockroach as it ran around. The purpose for doing this was that the most efficient motion machine on this planet is the cockroach. It survives absolutely everything. [The Wisconsin researchers] were able to learn how this living system was able to become so efficient, and we're using it to program the robots. But, as students are wont to do, they snuck back into the laboratory and then reverse-engineered it. Instead of taking the wires from the brain and connecting it to the computer and watching the output, they connected it to a joystick, and they began actually driving the cockroach around the laboratory — \$2.5 million to drive a cockroach. But, had we had a number of these, and maybe put that tiny little camera from NASA on their backs, at the time of the World Trade Center or an earthquake, maybe thousands of people that we couldn't reach certainly could have been reached by something this small.

You may be familiar with the Pill Cam. It's an endoscopic procedure in which you just swallow a pill and it takes images of your GI tract as it passes through, transmits them to a recorder, and after it passes, you take the recorder back to the gastroenterologist and he reviews your endoscopy without your ever having to have a procedure done.

One of my favorite and one of the more recent DARPA programs is somewhat controversial: brain gate technology. These are multiple probes that go into the brain. Using a number of monkeys, what they've been able to do, with a single probe touching a single nerve, is sense what a single nerve is doing. When you have an array of those, you can get signals and you can process these signals and try to decipher what they are. In the experiment, they taught the monkey, using a joystick, to move a red dot onto a green dot.

When that happened, a robotic arm automatically came by and fed them. Then [the researchers] recorded the EEG output and deciphered it. The next step was to connect the brain gate directly to the robotic arm. It took the monkeys about two weeks to learn that they didn't have to move their arms in order to feed themselves. And now there are four or five universities working on this project that have families of monkeys sitting in front of computers thinking about moving the red to the green and feeding themselves. They can actually *think* and make the robotic arm move.

You can see the potential for this in terms of things like artificial prostheses. In the future, we may well be able to simply think and take over control of our body. We do have intelligent prostheses today. For example, the Harrington rod provides that feedback, in the sense that, in cases where cervical fusion is required, they maintain the distance and the tension in between disks and still allow you to be able to move your head. That's because you've got instantaneous feedback, automatic feedback, that allows you to move and still not crimp on the nerve or the disk space.

An area that I'm particularly interested in is that of suspended animation. We understand from some recent research on hibernation that animals do not hibernate because it's cold, they hibernate because some signal from their hypothalamus goes to their mitochondria and literally turns off every cell in their body, and it happens within a two-hour period of time. It binds whatever the signaling factor is — and we're looking for that now — actually binds on the mitochondrial membrane between NADH and acetylcoenzyme A. It's like putting a little widget between the two ends of the key that are supposed to come together. Their body literally turns off; their metabolic rate goes down from 100 per cent to 0.3 per cent. We've been able to measure the different parameters on that: Literally within a two-hour period of time, they turn themselves off. They don't need oxygen, they don't use oxygen and they don't make toxic products, as far as we know.

We are working with other groups, such as those, at Pittsburgh, where they are doing exsanguination experiments for reperfusion injury. We're learning how, for example, you can exsanguinate a dog until they've got a flat EEG, EKG, no respiration whatsoever, clinically dead. For two hours, you use hypothermia and perfuse this solution through them. At the end of two hours, you give them their blood back, and they literally shake themselves up and can stagger off the table. I actually watched this happen. It's absolutely astounding. Interestingly, two to three weeks later, when you test them, they remember the different tricks that they were taught, and you can actually teach them new tricks. So we think that we preserve cerebral function as well.

The question is, how is this going to be part of the medical record? If we turn you off for a couple of hours, do we turn off your medical record for a couple of hours? I really don't know. The issue that we have here, if you will, is that technology is absolutely accelerating in a logarithmic fashion. Business is not far behind to capitalize on it. But our society, and healthcare in particular, must be more prudent. You can't step on every bandwagon that comes along. We have to make sure that the technology is ready and usable. Another component is that these technologies are bringing forward some moral and ethical issues well beyond anything that we have ever had in the past. For example, genetic engineering; In 2003, the first genetically engineered child was born. Do we want to engineer our children in the future? This was a family had three boys and decided they wanted to have a girl, so they genetically engineered the egg so it would end up being a girl.

We know how to actually cross certain gene across species. We know what the gene in the hummingbird is for ultraviolet vision. We know what the gene in the pit viper snake is for infrared vision, and we can clip those out. Should we give that to your son and your daughter or your grandson, so that when they're born, they'll be able to see at night in infrared or the ultraviolet? We've shown such cross-species transfixion repeatedly. It's not a new technology, it's not something that can't be done. The question is, *should* we do that? Should we give our children genes that will allow them to do things that other people cannot do?

Total body parts. There are many, many different ones, whether it be prosthesis or the new artificial organs, that are coming online. Should we be replacing everything? What happens when 95 per cent of you is replaced; are you still human? You're now parts instead of the original. What is it that makes us human? The technology that's going to do that is going to be the technology of the residents and students who are being educated today. In 10 to 20 years, in the middle of their practice, this is the kind of stuff that they're going to be dealing with.

Longevity. There are three strains of mice that live at least two to three times their normal lifespan. Whether it be antitelomerase or apoptosis factor, the question that this new thing foretells is, how long should a human live? If we give your granddaughter antitelomerase, theoretically — if it continues to go as the science has shown — that daughter will live to be two to three times a normal lifespan. The longest normal lifespan is 123 years. So even if the average lifespan is 80, and you only double it to 160, what are the implications of the average person living 160 years?

Robotic intelligence. The human brain computes at four times 10^{19} computations per second. It turns out that the fastest supercomputer today goes at 3.5 times 10^{15} . So, we're only a thousand times slower in the computers than we are in the human brain in terms of doing computations. The question begins, is that computer becoming intelligent? What is intelligence? I don't know. Will they be able to communicate when they can compute as fast as we can? Will they remember that we made them? Will they even care? These were silly questions in the past. Steven Spielberg said there is no such thing as science fiction, just scientific eventuality. These are some of the technologies that we need to face that will bring those profound questions forward to us.

The importance of the Electronic Health Record in the future is that it's going to have to be multidimensional. It's going to be robust, distributed and interactive — a tool, if you will. It's capable of accepting and processing and storing all types of information, including those things that are autonomously or automatically acquired. It must be used for clinical practice, outcomes assessment, real-time education, applied research, financial management. It has to be an integration point.

Discussion

Dr. Zimble: I am concerned, and I think a lot of people here are concerned, about how we harness the technologies that are extant today, right now, and commercially available. Perhaps we should require people to be locked in a room and come up with standardization, the old ISO medical record. We have people from government, both the executive branch and legislative branch. We have people from commerce; we have people from regulatory and oversight agencies, and it seems to me we ought to be able to find a way to lock the right people up in the room and not let them out until they finally have the standardization necessary. I was impressed with the fact that just a few years ago, and even yet today, the people at Bethesda [National Naval Medical Center] cannot talk to the people at Walter Reed [Army Medical Center] on CHCS [Composite Health Care System]. Now, CHCS II is supposed to resolve that, but that's a question of standardization, it's a question of taxonomies and putting together zeroes and ones in such a way that they are transmittable across the board. To me, the secret has got to be an Internet-based medical record.

Dr. Satava: I think that is clearly an issue. I want to tell you about a virtual autopsy program that just started. We have just funded the Armed Forces medical examiner at the

AFIP to install a CT scanner at the mortuary in Dover. Effective December 15th, every casualty that comes back to go through the autopsy process is going to have a full 3-D total body scan as part of that. We feel that this is really important — it's kind of moving into the HOLOMER concept, if you will. The medical records of our troops in action are actually going to be full 3-D images, including images of the wound track. We will be able to use that data and feed it back to user groups like the armor developers and the tactical and operations planners, so we know exactly the type of wound that we've had and how it was created. They will extrapolate that back to what we need to develop or what we need to deploy out in the far-forward field.

Something that had disturbed me when I first went forward with the virtual autopsy program was that the federal government had stopped taking autopsy data in 1995. The national average in the 1980s was about 21 percent of all patients dying in the hospital would get autopsied. By 1995, it had gone to 9.5 percent, and it has not stopped going down. Why should we care? A lot of what we actually do in terms of determining healthcare policy is determined by the quality of the data that we get. Autopsies are critical in many, many facets. Wouldn't it be wonderful if every person who died in the hospital, as a regulation, had to have a total body scan? I personally know that many times I was called at 3:00 a.m. when Mr. Jones died. It turns out he was admitted for chest pain, and so his family says, "I don't want to do an autopsy." We know that about 7 percent of the people who die from heart attacks actually die from ruptured aneurysms. But they didn't have their autopsy to prove what it was. These are the type of thing, the validating of the final diagnosis on the death certificate, that's extraordinarily important information for determining healthcare policy. Many of the decisions we make about what we believe the deaths are may be in fact incorrect.

Dr. Blanck: My observation has been over the past few years that we are in some cases trying to do what technology makes possible. And that's a wonderful thing. But the way it ends up is that we focus on pieces. We now have the opportunity to take what you've been showing and put it into an overarching strategy — we need the architecture for strategy — the strategy itself to set up the standards, and then begin to build a base and decide what's included. How are you going to approach doing that — setting that standard? It must be a policy; it has to be a public policy that's developed on the basis of that strategy. CMS pays for it. How are you approaching that? It may be premature to ask, because it's far more complicated than my question would suggest.

Dr. Brailer: That's a question that, in some form or other, I've spent all my time on. I'll decompose it into two pieces. One piece is what we define today as the Electronic Health

Record, the software and the hardware and the various portable components and all the other changes that go along with that, versus the interoperability, or the ability for them to communicate and share information and be more outreaching both in data incoming and data outgoing. The reason I separate those two is that they have different solutions. Getting the EHR into the physician's offices on the standalone, non-interoperable basis, is fundamentally at this point law of supply and demand. And, we don't have supply limitations. We have significant demand limitations, and those come from the elephant in the living room, which is the way Medicare and all the copycat private plans pay for healthcare today, providing a profound disincentive, because quality doesn't get harnessed back to the bottom line, the doctor or the hospital. I think it's largely a reimbursement issue.

We are going to have to look at other things that might push the EHR onto the market, and I personally have a lot of reservations about more of a mandate or condition of participation, because in the end, we are not trying to get people to buy a product, we are trying to get people to change their businesses. It's a cultural, operational, behavioral process. I don't think a government mandate is going to achieve that.

Mr. Freeman: They are government-driven policy incentives, not mandates.

Dr. Brailer: I would view it differently. All that government has to do is take away the disincentives that are an artifact of a pretty old way of reimbursing for care, but let's be honest. We can't measure quality. The paradox of all this is we need the EHR to be able to measure quality so we can change reimbursement to reward quality.

All this I about trying to get a better way to create a zone of economic protection around the EHR, so we can get the data and start moving forward, pay for performance and start ultimately having a debate about fundamentally changing the way we pay for care. And interoperability, My concern is that if there is nothing to mandate, there is nothing to "incent;" it doesn't exist. Our nation has no capacity for interoperability. We've spent 25 years on standards, and because of that, we can now do something that is becoming interoperable, but that alone will never get us there. We have an RFI [request for information] on the street to ask people how we should build a national interoperability infrastructure.

I'm not sure exactly how our roadmap will play out. In February, we will be talking, hopefully, about we learned from the RFI, especially the legal, technical, privacy-related

issues, and how to finance it, how to operate it. I see that being the piece that is essential, that is our top priority. I think EHRs over the next 5-7 years will happen in many, many practice settings, because the evidence of health status benefit is so powerful that it is going to become impossible for clinicians to resist it.

Dr. Zimble: I Googled EHR. There are over 5 million entries regarding EHR, and again it's a question of interoperability. When I go to Home Depot or the drugstore or the grocery store, I take my MasterCard, I swipe it in the machine, I get something I can hit that says, I accept what I'm paying, I sign it electronically — and that's interoperability. I do it at the gas station, at the grocery store, the drug store, everywhere. Now why can't we have a Medicare card that's got a patient record on it? It has to be swiped in the doctor's office, the doctor's reimbursement comes from the patient having swiped his health record, and then the doctor's intervention is placed on that smart card.

We can put a gigabyte of information on those smart cards, and I would tell you that you have all the incentive you want if the physician gets immediate reimbursement for what he has put forward. This is something our technology can do; it's only a question of putting together the program and making the effort. Government can play the major role in this, To me it's appalling that we have two separate systems where 99.49 per cent of all patients in the VA come from the military and yet they have not been compatible until now. Finally we're putting together the interactivity that's necessary.

Mr. Tsiaras: Isn't there a danger, though, on one level of fragmentation of this data? One of the problems I'm having is that as a storyteller to the consumer, with this quantifiable information, I'm trying to envision how they would see it, or, often, you have to be able to view this as a physician. I would see a patient record as a story of their life — the history as well as the present.

Looking at all this fragmented technology that's out on the edges — the future is here, it's just not evenly distributed. I was an advisor to Time, Inc., before the days of AOL, who had been there for decades, and then all of a sudden they tried to get into the technology area, and you could see that they just were insecure about it. What happened was that they started setting up on the 44th floor of the Time, Inc., building all these young kids, and they're trying to get their younger brother to put in MBAs at the top, because they just didn't believe their own sense of storytelling in this new age. It was a miserable failure, because these saw these cool graphics — indeed, they were — but they weren't the *story*. They

bought AOL to fix their problems, and it was an even bigger fiasco, because they didn't know how to tell a story, either. So the problem here, for me, is that eventually this is going to have to be imparted to a new generation of physicians who are computer-savvy, and they're going to be into the consumer, and no one is even discussing the integration of all this kind of fragmented technology.

We basically could bundle: Each one could have an interface, but one of the worst websites you could actually go through is the NIH, the NCI — it's all fragmented, it's impossible to penetrate. My fear is that we will be going down the same path if we do not talk about this as a story of a person's history.

Presentation: James Miller

I work at GE Research. GE Research handles all the research and development for the General Electric Company, which includes all of our businesses, including healthcare, transportation, energy — all the businesses that we're involved in. I guess it's kind of a unique view of how technology can be applied across disciplines and across applications. In some sense, the care area of our work is the driving device in an IT mission. So you have all these departments within your hospitals — departments to do different tasks — and you have some clinical applications which are still bought by departments but, numerous, numerous different devices and applications are available.

Hopefully, you have an enterprise solution, which is your patient information records, your tax system, your imaging information, and all of that incorporated together. If you're trying to integrate across all the hospitals that the DoD is supporting, for example, very few of these devices or systems talk to each other. This is an IT problem; this should be a problem that you just put people together and solve. You should be able to say, "these devices have to talk to each other and this is how it's going to work," and it should be something that could be done; it's just an engineering feat. This happened a bit in the radiology realm, where every imaging company had its own image formats. If you got scanned on a GE system and somebody wanted to review it on a Siemens review station, you couldn't, because Siemens review stations didn't understand GE image. So, the hospitals came back to us and said, "we want one unified system," and this is how we got the DICOM standard, and at least at the imagery level, different vendors can communicate with each other. It still doesn't solve the global problem.

At GE Research, I work in a group called the Visualization Computer Image Group. We do research in a number of different areas — medical image analysis, aerial image exploitation, image data manufacturing, automated video analysis. We're talking security applications, we're talking reconnaissance applications, we're talking industrial inspection applications, and also medical image analysis. Among the different things that we were doing: from optical gauging, cancer detection; from imagery, change detection, aerial photographs. We work in computer division, we're doing image analysis for a number of different application domains. Our application domains are things like surveillance, computer-aided detection, surgery, reconnaissance, metrology, and we have a number of core technologies that we work in: segmentation, registration, tracking, recognition.

We have already invested a lot of energy, particularly in our reconnaissance world, that we're now putting into computer-aided detection. There is a lot of research that has been done that can be moved over to healthcare, and ultimately into the electronic medical record. In my group, we have 31 researchers, 19 PhDs. About a third of our work is in medical image analysis, and the other work that we're doing is in video and aerial reconnaissance. Unfortunately, when we go to transition this technology to a kind of a biological problem, it's not always a slam-dunk; the biological problems are just not as constrained as, for instance, in industrial inspection. In an industrial inspection setting, we can take a little thing that you want to measure the shape of, you can put it in a little fixture, which is going to hold very precisely; we can control all of the lighting and atmospheric conditions around it, and we can make very precise measurements. We just don't have that control when we get down to medical image analysis. Things are not that repeatable.

But as we go down, the complexity does increase, but the precision that we need is also decreasing. So, we do have some flexibility in inspection application. One that I have worked on is, we have wanted to measure shape deviations relative to about one-thousandth of an inch. Well, it's very rare that in normal medical image analysis that we would need that type of precision — it's more in the millimeter range. The first level are things that are kind of making a filtering analysis, wave analysis, wavelength analysis, that kind of round and image analysis, and are very easy to move from application domain to application domain. The next level, a little more high-level task, is segmentation, registration, tasks like this. These can be moved from application domain; it's a little trickier, but you can still do it. The areas that we're trying to get into now are higher-level things, where you're really trying to come up with what the object is or what event just happened. These are much more difficult to do in general, and if you had a solution in one application domain, you have the basic framework but you are going to have to do a lot of work to move it into another application domain.

Different platforms — we have imaging scanners, CT, PET, MR systems. Recently, in the past year or so, we have merged with Amersham in terms of GE Healthcare, so we're now doing more work in contrast agent analysis and biological cell analysis. Some of the ways that we have transitioned information technology: image-guided manufacturing, in which we're asking, is the object being made to tolerance? That's the big general question. To do this, we developed technology in calibration, registration; moving models to the actual space that something's being inspected in: shape analysis — is this the right shape? We've been able to move those types of things into medical image analysis in doing quantification of how big something is. The differential diagnosis: Has something changed, is something bigger than it used to be, how much bigger is it? These sorts of things.

Aerial image exploration: we did a lot of work in segmentation, classification, object recognition; this is fed into our work in computer-aided detection of lung cancer. Our automated video analysis work: We're looking at things like tracking people moving through public spaces, and event recognition — was something handed off between two people? Those do have applications in things like pathology, and drug discovery. So, these are new areas where all of this technology that we've been developing in [nonmedical] areas, we're trying to move into medical areas.

Registration is a common problem when we want to align two things. In the medical field, if we have the same patient scanned six months apart and find something in the second scan, we want to see if it is in the previous scan. We have to align that information so that we can make that determination. We got into this field from image-read manufacturing, and we can apply it to things like retinal imaging and multimodal imaging, interventional procedures. In a transportation industrial application, we were measuring our little turbine blades for our aircraft engines. We had to measure their shape to make sure they match their geometric model from the CAD system to within 1000th of an inch. We achieved high accuracy, and we moved that into a more flexible system so that it's more re-configurable. Another example of an inspection system we developed was for a major ultrasound system, inspecting composite materials using a laser to induce ultrasound vibrations. They can inspect a large piece of composite material, about 7-foot x 7-foot, without ever having to touch it. The problem is that they can scan just one 7-foot x 7-foot section, then they may have to scan from a different direction to see the rest of the part. So, they do a number of scans, but once they do these scans, they have to answer a question: Did we see all the critical area? The composite material flexes, so this is a little more difficult, and consequently, the tolerance is highest in the previous application.

There is some work in stabilization. We rented a helicopter and watched traffic move around our traffic circle outside of our R&D facility. We wanted to answer some questions about this: How the cars are moving, can we track particular cars? We took out all the motion of the helicopter, so that the ground's plane is staying constant and the video is changing over time. We identified all the cars, and that makes it easier to track them, and then we can put it on a map. Now, here's a medical application: retinal mosaic-ing. People with macular degeneration go in to get their complete retinal scan — somebody looks in, takes a number of pictures, and historically, looked at this suite of pictures and decided what the diagnosis was, what the treatment plan was, and then these would have to be put into somebody's record. But, they're kind of guessing that they looked at everything; they don't really have a good idea of what matches up with what. Through image analysis, we've been able to piece all of these images together into one image, as if we had a larger camera. And now we can answer some more detailed questions about disease progression as well as the treatment plan.

The longitudinal CT scan: We want to track a nodule found in somebody's lung. Let's say we had a previous CT scan or we had the patient come back a few months later, and we want to find that same nodule. What's currently done is, someone would go look at the first scan, see where the nodule was, go through all the images of the second scan to try to find where the same location was, and then make a determination as to whether it is changing. In lung cancer, there are some general rules that are applied in that if the lesion is growing too fast, it's an infection, and if it's growing too slowly, it's not cancer, and we don't need to worry about it. If it's in the sweet spot, it's cancer, and it's something that we need to figure out how we're going to treat: We work this time sequence or that time sequence, and we know exactly where it is in the next time series. This is done largely using the same technology that GE uses for an industrial application.

A multi-modal system. We took a typical mouse and put it in a PET scanner down at Sloane Memorial. We moved the mouse up to upstate New York and then we put it in a volumetric CT system — so we have a CT scan and a PET scan, with their structural information and the metabolism information. We needed to align them so that we can actually come up with some sort of correspondence between them. Cell systems are combined with CT-PET systems, which reduces this problem, but you're always going to have a situation where you have one modality taking up one place, another modality taking another. We need to get that information aligned, we need that information stored, we need those transformations — the combined information kept in a health record.

Registering MR imagery with spectrum imagery: This is some new work that we're doing with our medical diagnostics and our contrast agents people. In this particular application, they have an MR scan and an atlas, essentially. Based on this MR scan, they know what some key brain structures are; they want to take a spec scan on a particular patient, aligning the two data sets so that they can look up and say exactly where the sub-structures are that we're interested in. This alignment process is the same process we would use in an industrial imaging application.

Detection and classification is another big problem. Many years ago we began work in aerial image exploitation, developing some technology called perceptual grouping. The basic idea is, you have a picture, perhaps taken from an airplane, and ultimately, you want to say, what is that? Is there a tank there? Is there a jeep there or not? We took that same technology and applied it to computer-aided detection, starting about five years ago. We were looking at lung cancer. So we're using the same technology that we developed for photographs from airplanes for CT scans of people's chests to identify potential lung cancers.

It's a difficult problem, having an image of something: We can go through and detect all the boundaries that we see in the image, which are defined mathematically, and we are convinced we are finding some constraints right now. Are certain edges parallel to each other? What's the contrast between adjacent regions? Based on that, we can start building up models to say, a jeep usually looks like this, has a certain number of parallel sides, has a certain relationship between them. There's going to be a certain contrast because of illumination, and then there's going to be a shadow. We can build up these models and detect jeeps, and we can detect airplanes. In computer-aided disease management, we want to do the same type of things; we want to take imaging; we want to identify features of interest, we want to detect these things and we want to detect them thoroughly. Then, we want to determine whether there's been any change in a patient's state. So, we want to do quantitative analysis. Using an example from COPD, we want to measure emphysema or airway, we want to see how that disease progresses. We can identify the potential lesion, and we're trying to determine what the doubling time for the lesion is. We had to model what the shape is, in terms of how lesions normally appear in the image. It turns out that there are different types of lung lesions, and they have different severities that we need to be careful of. We had to do models in additional anatomies, so that we know that we're looking at a lesion, not a blood vessel, not an airway. We built up not only the base detection technique, but also put it into a classification network so that we can identify early lung cancer.

The problem was similar for chronic obstructive pulmonary disease. This work was funded with GlaxoSmithKline. The first thing we wanted to do was airway analysis — for bronchitis, how an airway wall is thickening, and is it changing over time? This is kind of leading-edge research; they don't know clinically what to do, but they want to monitor it, they want to measure it, they want to store it, they want to be able to retrieve it. We did the same basic technology that we used before to identify where airways were, and how to measure them. We also studied emphysema, where we looked at how the lung tissue is degrading over time. The goal is to monitor disease progression and see if the drug is effective in stopping progression of this disease, so they want to come up with real quantitative measures of how the lung tissue is degrading over time.

More advanced applications include tracking scenarios. There's been a lot of work in this, post-9/11, in various applications. There also are commercial applications in monitoring how people are milling about banks; how they are milling about car lots. What we're trying to do is apply those same monitoring technologies to things like drug discovery. Here's a tracking scenario: We have two outdoor scenes, people moving around; they attempt to identify people, and then we want to track where they go over time, and eventually, we want to get to the point we can analyze what their behavior is. Are they milling about suspiciously, or are they now just moving along? Is there a crowd? What kind of dynamics are there? There are numerous possibilities in terms of commercial applications, in terms of tracking how people are moving through a store and lingering at one place — things of that nature.

We have base technology to detect people and keep track of them as they move over space. We can track people's hands as they pick things up and look at them. Through face identification, can determine who people are and see if they're allowed through a particular entrance. In a camera hand-off scenario, we can track one vehicle through one camera, and when the vehicle goes out of the field of view of that camera, we pick it up in a different camera. If you want to monitor large sites, it's really difficult to have a single camera look at the whole thing. In a mosaic-ing application, we have a camera on an aircraft, and as the aircraft is moving, we're pulling up more and more information. We want to tie all that information together to get an overall view of what's going on. In gait analysis, as someone is walking, we can study the frequency and do modal analysis and identify key frequencies that people walk at, key motions that people have.

Let's move to some healthcare applications. We can track an airway as we go through a series of CT slices — if you wanted to measure how a particular airway is restricting, we can track it using this technology. A new area that we're getting into is drug discovery

applications and understanding biological systems. GE has a number of applications — dyes that they can color individual cells with, pre-fluorescent proteins that they can easily put into the system and monitor. They can actually track cells over time, and get more information and put that into the analysis.

Leukocytes moving through blood: there are several interesting things that you would want to analyze from this. One is, how fast are these moving downstream? You also want to know how fast are they transitioning into the surrounding tissue. This kind of gets us back to our tracking problems — identify something and follow it over time, but then also identify, is it lingering? Is it moving into the tissue? Gait analysis of somebody walking can be used for an actual cell system or neuron vibrating. The same frequency analysis that we did in gait analysis could be beneficial over in terms of quantifying how this cell system is behaving. Of course, once we do all this analysis, we need to store it and we need to be able to pull it back up. You can envision getting these things into pathology systems and then you'd want to keep that information. Object recognition is another computer vision problem; you want to identify objects from the library of objects in a cluttered scene. This harks back to aerial image exploitation and also image-guided manufacturing. If you're building a big aircraft engine-type system, you want to make sure all the parts are on the engine. This actually turns out to be a very big problem, because you have thousands upon thousands of parts that go onto an engine, and when it is serviced, they will be pulled off. Those same technologies could be applied to surgical applications. For example, with stents or catheters, you want to identify where they are in the surgical application. We can use image analysis techniques based upon the other technology that we've developed to pull that out and highlight where the catheter is, since it often can be hard to see.

A problem we're learning more and more about now is visualizing stents. The x-ray of dose is a major concern, not so much for the patient, but for the people working in the OR. If they're applying a second stent near where another one is, they need to know where the old one was so they can navigate around it. So, they need to be able to see the stents. So, we're going to try to bring our image analysis techniques to this to try to be able to identify where that stent is.

We've done work on facial reconstruction. The basic question is, if you found a skull lying in the woods, what did the person look like? So, you build up a database of people — a number of volunteers were CT scanned. We build up a model of what the flesh depth is relative to their skull, and then given a particular skull, we can estimate what the face looks like through this mathematical process. We're also doing work for the virtual soldier program. We can track a wound, with a list of all the cell structures hit as that bullet went

through. The ultimate goal is to know, for a given trajectory, what subsystems likely were affected by it. We're working on this technology, taking some anatomical shapes and applying them to a patient-specific instance.

Some big takeaways: Biological problems are less constrained than other computer-based applications, so they are harder to deal with. Everybody is different, and their systems are complicated systems that we are trying to analyze. There are different models of technology that can be changed. Some of them are just signal processing things that can be moved from application to application. Some of them are higher-level applications that take a lot of work to migrate. But, many medical and healthcare applications have these analogues.

Discussion

Dr. Rowley: The most important thing is to get the electronic medical record going now in practice. What you buy today is only going to be good for a couple of years, just like the computer you buy today is going to be good for a couple of years. We're going to learn, and the technology is going to evolve, and we're going to learn how to apply the technology. But, it seems that the big failing in healthcare was that it took so long to get it going, and if we had started really implementing it ten years ago, maybe we would be in much better shape because we would have gone through all these iterations.

Dr. Brailer: I think your point is right. I'll say two things about it. First, a byproduct of what we are trying to do is that the marketplace for health information tools, devices and software and related components should be seven to eight times, maybe nine times larger than it is today. That's going to attract a profound amount of innovation and new products, new price points. So, I do expect there to be a lot of turnover in systems that are in place, but that goes to the second point.

What matters is the business process, the clinical decisionmaking process. We're now focused on the technology, because it is a landmark for us. But soon thereafter, I think, what matters is that those processes that we're dealing with — how to communicate among clinicians in a new way; how to collect data in a different way, how to perform certain behaviors — are going to be more technology-independent. It won't really matter what's underneath. That will change over time. Surely, those are both going to happen, and so

right now, many doctors are just worried about, to make sure it's okay". It's a valid concern at this point of the lifecycle. I think three to four years from now, you'll see the leaders taking a different view.

Dr. Satava: The EHR itself, as well as some of the technologies that we've seen, are getting pretty mature. The thing that's been a great puzzle to me is that we've had untold numbers of clinical trials that have demonstrated that automatic analysis of cytology or mammography is clearly superior to anything that a radiologist or a cytologist can do. But nobody's using them now. How are we going to take proven technology, unequivocally, with good data to support its efficacy, and get our physicians to use it as part of the record? Mammography is still done by radiologists looking at it, and there's no question, every study that I've seen recently has shown that the automatic detection systems are better than the radiologists' reading it. But, nobody is going to allow the mammogram to be read automatically.

Dr. Brailer: It's easy to look at disruptive technologies, but I think we are coming soon to a place where we're talking about disruptive professional practices. You know, that's clearly going to be the wall. That's going to be a real challenge. I'm pleased, for example, to see NIH in its roadmap really say they have now two goals: one is to do fundamentally new discovery; but, two is to figure out how those things can translate their way back into clinical practice very quickly. FasterCures and other organizations are looking at the same thing. I know people are selling tools that are doing that, so I hope the gap gets closed. But, technology adoption is very erratic.

Some countries have dealt with it well because they have centralized technology plans. That's not going to be the U.S. model. If we have a market-driven approach, that means we have to have very good demonstration of value, vetting of usability, and we have to have a professional culture of acceptance when we get there. It's better in some specialties than others.

The one thing I think matters in the end, despite some of the flaws that we've talked about—I know this is true with new technologies that can reduce ventilation in ICUs and other non-barometric technologies across the board—is that when clinicians see evidence of real benefit to the patients, they will adopt it. And I think the EHR has just crossed that line. The benefit is undeniable to patients, and that's why I think physicians will do that. What I hope is that it will set a new platform where we'll suddenly be able to do a lot more things

technologically. But in the end, my fear is not they will have all these one-up technologies, it is that they won't make sense; they won't connect together, there won't be any new standard of what information means in care. And that worries me a lot more than whether or not we're going to adopt any given technologies.

Ms. Weldon: What do you see as the role of an actual consumer or the patient in all this? You talked about how you get to use your Visa card at every grocery store in town. I certainly wouldn't go to a grocery store that didn't take my Visa card. When are we going to get to the point where an individual patient is no longer going to tolerate having less technology at their doctor's office than they do at the bookstore or the grocery store?

I think with the advent of HSAs and more consumer-directed spending, are we going to get a true consumer demand, not a physician demand, for the technologies you talked about — a consumer demand for electronic prescribing and Electronic Health Record. I'm not going to go into my doctor every year and tolerate having a med student rewrite my medical record every year, which happens.

Dr. Brailer: It's a great question. The HSAs, I hope, are encouraging, and another example that actually I think is happening — and I'm not speaking to endorse these — is concierge practices. The primary reason that people enroll and pay the extra \$1,200 a year or whatever they pay, is so that they can get e-mail access to the physicians, and the physicians guarantee them access to their personal health record around the EHR.

The differentiating strategies for a lot of the big organized, bottom-line-preserving group practices like Kaiser and others is the electronic health record component for their consumers. So, there are some pockets, but it's not wholesale. The question becomes, how do we actually move consumers a lot more aggressively in that direction? I think it is going to be something that filters in over time, but in the end, I hope that consumers will use the data that is generated by electronic health records to choose clinicians and hospitals better. I hope they'll manage themselves better, using access to their data where they will. A lot of threads are going to come together that are actually going to end up with the kinds of change that we want — change in the end that we care a huge amount about.

Dr. Rappaport: I certainly value all of your efforts to try to make medical information more easily shared across practitioners, and part of the reason for doing that is understanding that multiple practitioners care for the same patient. Sharing information is one thing;

sharing plans of care and disease summaries is a different matter. You described to what degree you're trying to make sure that treatment plans are easily shared and interoperable across practitioners of care and disease monitoring and understanding of the patient's history of disease, not just the observations that have been disconnectedly entered into various medical records over time and space.

Dr. Brailer: There's no question that the concept of health information exchange today is a transactional one, that we're trying to share facts, and where intentions like a care plan, or insights like someone's diagnostic activities are shared, they are done so largely as text in a way that is frankly just not different than whenever you get the letter from the other doctor. There are not well-defined standards for how to share those intents and plans. This is where I see a lot of what we're doing. One of the things that's happening because of Medicare modernization that I think is a sleeper is the chronic care improvement demonstration projects, which are where clinicians and vendors and disease management companies or other kinds of new entities can form new relationships to create a way to have better chronic care across the continuum. It's never happened in the Medicare population before.

The demonstration projects, I hope, will show us that there's not just a technical capacity to do that, but there is value at the end of it. I was depressed to see the recent summary findings on disease management. If there is any place we're going to see value, it's in the Medicare population, where we have had a captive population for years. It's not just the technology though, it's the business practices. I think technology can quickly catch up with the very low standard of communication of treatment plans today. The question is, can we move the whole thing forward?

If you look at the companies that I ran before I came to government, we would do collaborative development across 15 sites of our company's offices, all using joint work products and internet space securely. I would go to my clinic, and I would in infectious disease take care of patients always with other doctors. I think the whole industry has got to move forward, and I hope that that's one thing that technology can demonstrate. So, watch those care projects. I think that they could really be interesting in what they teach us about how to move forward.

Dr. Zimble: By the way, the reason that autopsies are going down is because there is no DRG for an autopsy. As long as somebody pays for the autopsy, it will get done.

I've always remembered that the enemy of "good" is "better." As we look to see all of the promise, all of the great potential, all of the technological achievements that could be obtained with a medical record, we're still dealing with not what's good, but with what's really bad. If I leave this meeting and drive back home down I-95 and have an accident and have to go to an emergency room, I'd like the doctor to be able to know something about me. I have purloined all of my records from the hospital, because the hospital tends to lose those records. However, I defy any physician in the emergency room to go through this [one-foot-high stack] record to learn something about me, to learn what medications I'm on, what my last blood pressure was, what my weight was, when my last visit was. It's almost impossible.

As Dr. Satava has mentioned, we have spent the last 50 to 70 years with the current record, the only modification being Larry Reed talking about SOAPing a patient, but it's all been paper and pen. It's all been ink-based. But, we don't have to live in that environment anymore. We have zeroes and ones now. We are doing lots of our daily transactions with zeroes and ones. The one place that we're not yet doing it is in the health record. Although there are some people that have them — and by the way, those that have the patient records, they're not patient-centric in most cases. In most cases, they're still physician- or medical facility-centric.

The patient has to own the record and the patient has to decide how to distribute that record. It's an area that is achievable; it just takes the right people sitting around the table and making some policy and mandates.

Col. Lee: I think it takes more than policy and mandates though. We have the technological capability today to do more than we're already doing, and that point has been made repeatedly. As we talk about the interface between disciplines within science, as we talk about the interface between biology and the physical sciences and the information sciences, I'm not hearing a lot that addresses the social sciences. If we ignore that, we are setting out on a path that will be more difficult than it needs to be.

We have changed management within the medical establishment and the medical profession and all the policy issues that go with that, but also there are some substantial communication challenges and change management challenges in dealing with the patient, who is supposed to be at the center of all of this. People's willingness to accept technology varies according to many different factors, and the person who is willing to use an ATM card to go down to the nearest machine and take a few bucks out of their bank account may not be equally

willing to have some very personal health information accessible on a card. We already found, with the new ID cards that we have, these little CAT cards, which have a little computer chip in them — part of our DoD electronic health record was to include TMIP the theater version of our garrison-based systems, and in the ORD, it says that in combat situations, medical information will be carried on a personal identification carrier. In fine print, it says, at the time of this writing, the only joint personal information carrier is the CAT card.

Well, what we already encountered with a number of our pilots going into Iraq and Afghanistan was, they don't know what's on that chip, but it scares them silly. We have people popping out the chip on their ID card, because they were afraid that if they were taken as a POW, there was information on that chip that would make them more vulnerable. We have got to address the understandable fears that at least some patients are going to have: Who's going to have access to this information; how is it going to be managed and how is it going to be safeguarded? Everybody agrees with your scenario — if I'm in an accident and I present to the emergency room, I would sure love somebody to know everything that's medically relevant about me easily. But there are other angles of this, and we, as Americans, are very concerned about our privacy.

We've got some real challenges on our hands that we need to address in parallel with the technological challenges as we move forward. You know, I sit in my living room sometimes and hear my computer start doing things in the background; I hear the hard drive start to spin and there is not a human being within 15 feet of that thing, and I'm wondering, what's it doing and who told it to do that? I think we've got a lot of concerns that we really have to address.

Dr. Zimble: The first thing you mentioned I think is the most important. Those pilots don't know what's on that chip. A patient needs to know what's in his or her record. Whatever they have, they need to know about it, and they need to be in control, and I think we have to get it to them. Then of course, we have to look at certain exigencies where something has to be made more available than in other areas, but security as of today, you can get a level of a security in the system, but

Col. Lee: Yet today, we also have a higher degree of identity theft than we have ever had before. I would postulate that security is not all that it needs to be to give people a high level

of confidence that this is going to provide the good things that we're all looking for and not carry the risk along with it.

Col. Benge: Social transformation has to take place not only in a profession, but also in the population. We heard comments about how consumers can drive the change towards the electronic health record, and yet you have consumers who continue to insist that they need an annual physical exam; people continue to insist that the only pre-health care is across the desk from a physician, and I walk out the door with a piece of paper, a prescription in my hand. We have to change the social environment of the population as well as the IT providers.

Dr. Rappaport: As much as I dislike all the drug company commercials on television, it would be interesting to see Cerner or Siemens do an ad that shows a patient interacting with a doc who has a EMR [electronic medical record], and say, I really liked my last visit to the doc because he could show me everything on the computer system. Just as the patient's walking into the docs to ask him for the drug that they see on TV, it would be nice if they started asking for the EMR that they saw advertised on TV.

As for having all your medical information in a card that you carry, it obviously seems attractive to do that at first, but I would much rather see that stored on the Internet somewhere, so you don't have it personally yourself. That avoids all the problems that we've heard about the synchronization of data — you've got it in one place, you don't need to worry about; it's accessible to anyone you give permission to see, and there is only one copy of it.

Presentation: Alexander Tsiaras

One thing that we understand is that, basically, people have an insatiable appetite for health. If you take a look at the best-selling covers, if you look back in *Time*, the best-selling covers, back to the '40s, have always been on celebrities, and the number two best-selling covers have always been on health. If you really look at it, fundamentally, it's a \$1.7 trillion industry in America, and 10 percent of that is about information, so you have \$170 billion. On another level, about 13 percent of that is the consumer. So you have about a \$22 to \$23

billion industry, yet 92 percent of diabetics cannot define to you what they have. Which means the system is a dismal failure.

No one is accountable. Media is not accountable; pharmaceutical companies are not accountable, government is not accountable. You could sit there and say, people really want to know about themselves, but the information that's out there is just not compelling. We looked at that and said, if we took only 10 percent, we'd have a \$2.3 billion industry in the United States alone, and those numbers are the same in Europe. So what we did is, we created a company, and we're quickly becoming the industrial light and magic of science and medicine. We are making much more money underwriting our research than we ever did writing grants at the NIH.

Our company is divided up to three sections. In the front section, we write original algorithms and codes totally dedicated to medical information. The second part is, we have the largest library of high-resolution volumetric data in the world. The third part is that we have a media company. What we do is, we say, we're going to do the biggest story ever on cancer; we're going to do the biggest story on human development, we're going to do the biggest story on cardiovascular diseases. We go to different companies, and they fund us; they give us very large educational grants, in the tens of millions in some cases, and basically what we do is we create these content franchises. And our intent over the next four to five years is to completely control medical informatics for the consumer. One of the key elements, even though we are instructing about technology — technology is a given — one of the key elements is a fundamental story told well, and the information delivered beautifully. This is an example (video played: "From Conception to Birth")

The scanned embryos from the mode of conception up until we hit on the birth sequence is that scanned element of pregnancy in the third trimester that was under duress, and there are three-dimensional volumetric data sets. This was done in Italy, at the University of Bologna, and then FTPed to us. Then, using some of GE's 4-D technology, we could actually take some of the 4-D and map it to what they call the isosurfaces of the volumetric data, and they can view it. So, these are some technologies that we're working on. Among the elements that we are interested in is the fourth and fifth dimension, partly because when you do the scanning, you're stuck there, but basically people are moving and tissues are moving, and we're realizing that this has to be presented to people.

The problem that media has with this is that they look at statistics of how people are fascinated by health information. It was very easy for Discovery Health to raise \$400 million to launch, and it was very easy to raise the money to launch Web MD and Dr.

Koop's website. The problem people didn't understand is that just because people have an insatiable appetite, it doesn't mean that they will go to medical information if there is something more entertaining on. You have to make this content as good as "Law and Order," as good as any other program that's on, if you want to compete. That's why we need these kinds of quality programs. And in Discovery Health, their programs are costing \$100,000, and you compete against shows like "Law and Order," that have a budget of \$5 or \$6 million, and you just can't compete. The medical industry has that kind of money, the pharmaceutical companies can actually underwrite a movie like the *Titanic*. But one of the issues for them is that they are somewhat like the movie industry — they spend a great deal of money coming up with a movie and then you go into the second phase, which is basically getting great storytellers to tell about phase one. What happens to the pharmaceutical industry is that they dwell on the science; they ignore anything that was interesting about phase one. They could hire a Pulitzer Prize-winning journalist to tell the story of science and the model of a body when things go wrong, but instead, they are terrible storytellers. And, they become suspect. Only now are they starting to wake up to the fact that they have to have a certain element of benevolence: If in essence, they teach you about the disease that you may indeed have, with really great graphics, with compelling storylines — with a certain element of altruism — people will feel that you understand their conditions so well that they will indeed trust you to have a solution. They will trust you, because you basically have explained it to them better than anyone else has.

You know, one of the things that we're doing now is a new series, trying to understand health and wellness, which is a tough story to sell. It is easy to do disease and treatment. You have heart attack, there is drama in the storyline. Health and wellness is a much tougher sell because it's out there, and we can't take it seriously, because it's 15 to 20 years out there. So, how do you actually create a compelling storyline around something that may or may not happen? What we did was to quantify a person's first-time return to health, from A to Z — someone who's a really good story, and who really needs to be saved in some capacity, take them and see if we can scan every part of their body and measure their biomarkers over a period of time.

We took a guy who is a friend of mine, who is the lyricist for the Grateful Dead. Every imaginable drug has been in his body for a long time. We scanned him using Electronic Beam Tomography, the latest MRIs, pretty much every imaginable scanning technique, and basically created a multidimensional model of him. Then we stuck him in Kenyon Ranch for four months, and kept on measuring his biomarkers, to see if we could actually reverse his health. (Video Played)

We're taking in the record now, and we're basically translating it into an interactive website. The thing that we understand right away is that people know very little about how to interpret the data that's coming from a physician — they can't read their own blood report. You can tell him what creatinine is; you can tell him what hematocrit is. And he is fascinated by it, but he needs simple and compelling ways to understand it. So, you find a good character like John [the lyricist in the video] and you make him a peep show. On the website, you'd be able to strip his skin off, basically be able to control, very much the way the physician on a high-end workstation can actually control the volumetric data. It will be transmitted into Flash, but you'll have a sensibility that the physician can actually look through his data the way we do.

I'm always thinking, okay, how am I going to tell the story of that technology to a consumer or even to a physician? I'm always looking for an interface that is engaging that will allow me to tell the story of the results or the solutions. A patient record, for us is the story of that person; in reality, if they open the doors of that story, you have a virtual peep show into their mortality, vulnerability and history. If a person doesn't want to open it up, they should at least be able to see themselves that way, because obviously they have an interest in themselves. One of the things that we're doing next is a thing on sports. We're looking at the biomechanics of great athletes.

We just finished a book called *The Architectural Design of Men and Women*, which also is shown here at the National Museum of Health and Medicine. On the notion of content, we've always dealt with physician record content. We always make a book, a television program, an interactive website, a museum show, and these kinds of pieces are also a major cover story for a magazine like *Time* or *Newsweek*.

From the technological point of view, we have massive, massive amounts of data. We have approximately 4 and 5 terabytes of hard disk space, and we collect large sums of data from numerous hospitals. We have agreements with NIH, Paul Lauterbur, who was our partner on the Conception To Birth piece; just won the Nobel Prize for inventing the MRI. What we do is serious science. We always have a simple formula: quantifiable information that has a compelling story-line that is beautiful. If you take a look at the great anatomical renderings of the past — if we take a look at Da Vinci, if we take a look at Durer, if you look at these amazing paintings, if you take a look at Rembrandt — they really were studying these objects for themselves, but they ended up being so beautiful, a larger community could tap into that. And, that's very important. You want a large audience, you need aesthetics; you need a compelling story-line and you need aesthetics.

Whenever we go up to the NIH, these guys are looking for money from the Hill, and they need to tell their story so people really understand what they're doing. Our job is to push the science and then take that science to the next level by getting a very large audience that can really understand this data, and make it into information that is 4- and 5- and 6-D. We're actually doing a research for Albert Einstein on their four-dimensional metastatic breast cancer. We're working with Siemens on their ECT scanner, looking at the 4-dimensional imagery. So, the front end of what we do is pure science, but the result of it can actually speak to a much larger community, if it can be translated in a very compelling way.

Discussion

Dr. Satava: This goes back to the idea of a visual record instead of a text-based record — an information representation of a specific person that changes over time. What Alexander [Tsiaras] didn't show is that you can also do modeling simulation techniques — for example, give a patient digitalis and see what happens to his heartbeat. If you have a patient with an irregular heartbeat, you type in digitalis 0.5 milligrams *qid.* and see if the heart rate slows down or not. These are the technologies from modeling and simulation. As Dr. Brailer indicated, we have to look both at preventive and proactive medicine as opposed to reactive, to a disease that you have today.

By having your full total body scan that has your data in it — these are the type of things that you can do. If there is any one thing to get from this conference today, have a full body scan —but do it with someone who goes through your scan with you. It is probably one of the most extraordinary experiences that you can have. When it's you, and you're looking at your heart's being blocked, you're looking at osteoporosis or collapsings of vertebrate, it's not just an academic exercise, it's *me*. It's not the same as looking at text and saying, "gee, I got a blockage in my arteries or something;" you actually see what's happened to yourself. That's extraordinary. It truly is.

Dr. Blanck: We talked a bit about provider and consumer behaviors and how can you affect those and have that in turn affect what we do. This is really a way where, as you point out, if you see it in yourself, you are very motivated, as opposed to looking at somebody else's lung, to stop smoking, do better nutrition, et cetera. Now, there is an aspect in there of not just giving you the data and saying, "here have fun," but working with the patient. It really does affect those behaviors.

Dr. Satava: We're looking at this for health care. I would like to see every child, perhaps by the time they're teenagers, get their first total body scan and at that time. Health care is the only industry that doesn't do real science. We pretend to do science. We have no baseline; we don't know what we are like when we're well.

All industries, they do a 3-D model of what they have — when it's good — and then they can do testing and evaluation and life cycle managements and so on. The problem is we have no idea what we're like when we are well. The first time I see a patient is when they're sick. I don't know if they got sick in two weeks or twenty years. There's no comparison there. And with the variability between patients, I don't know if it's just a change from normal; their normal variation or not. Think of the power if, for example, our teenage child went ahead and took his or her image and put it into a computer game, and it turned out that this was our health and nutrition, and today's exercise was the effects of smoking, or they had to run races against other people. And then certain ones would smoke. Have a smoking simulation, and they would actually see how they would lose. They won't be able to compete because of their behavior. Looking at the behavioral modification would be in an important part.

If you don't think this is real, look at the multi-billion-dollar simulation and modeling and gaming industry today. It's probably one of the largest growing sectors. Multi-person gaming on the Internet today is over \$3 billion a year. It blew my mind away. I thought it was just some petty thing, but over \$3 billion a year worth of games are being played by our younger generation, and most of them are in their late teens and early 20s. They're playing interactive games, embedding their imagination themselves in their characters. What would happen if that character were their real selves, based on their own information? And, they can watch themselves die on the Internet if they didn't do what was appropriate? Very, very profound ramifications there.

Mr. Tsiaras: One of the things we are working on is a game on human immunology systems for kids with leukemia. Basically, they love these shoot-'em-up games, and there is no greater gladiator than the human immunology system. So, it's a great game, and if these kids actually can get their data and fold it in there, they will really have a fundamental understanding of the system and also of themselves within the system.

Dr. Rappaport: I like your idea of the whole body scan when you're well. I would ask you to make sure that if you do it, you find a way to document that it was done when you were well. Because, just like you have this paper chart—I challenge you to find, not only your echocardiogram, but your echocardiogram when you were doing well as opposed to sick. Understanding the context for the observations that go into that morass is crucial if we're going to make any sense out of it.

Presentation: Timothy Ganous

To view the EHR as a transformation issue is probably its most trivial way to look at it. The reason I feel that way is, right now, we're in what I call the Tool Age of an information-based culture. Health care is only coming into that Tool Age. Other industries are well into it. The risk, I think, we have in developing the EHR is, what is the likelihood that what we build today will not just be out of date in two years, five years, ten years, and might become a barrier to really engaging in some of the evolution that's taking place in information technology? At the University of Maryland, I manage a project that's a cooperative arrangement with the U.S. Army on the operating room of the future. We're looking at using advanced technologies in a new peri-operative system that we're developing under that cooperative agreement. So, we took a look at what we're currently dealing with in the ORs, and what we find is that the OR is inherently chaotic.

We have, 60, 80, 100 times a day, to get the right patient into each of the ORs; the right set of instruments; the right supplies; the right surgeon and the right support staff and the right information. To do that 60, 80, 100 times a day creates this huge amount of background noise — not what you hear, but there's a lot of chaos going on and a lot of possibility of error. That background noise tends to be picked up in the data we save about that medical encounter or that surgical event. Thus, we have a real problem with dirty data moving forward in the EHR because of this chaotic environment in the OR — that event of getting the right things into that room a 100 times a day, or into a set of rooms 100 times a day. We didn't use any more technology than a high school booster club president uses to get a concession stand managed Saturday afternoon for the big hometown game: fax, e-mail and telephone, that's exactly what we're using. We had some scheduling databases that were used, but they weren't driving the process forward.

Particularly in the OR, systems aren't designed for unplanned events, but there are lots of unplanned events. I've been in discussions with Walter Reed Health System, which has a real crisis brewing, because a couple of times a week, they've got 20, 30 surgical cases

flying in at night completely disrupting the schedule for the next two days. They have a real chaotic environment there.

We know this: Too much effort is devoted to making the process work rather than patient care, which is a serious flaw in the system. Numerous supporting business processes — what takes place in the basement in terms of creating surgical packs, that type of thing — are prone to errors, because we are using human labor to do the types of tasks that are replete with errors, and that's another problem.

Because of all this, we've developed sub-cultures of workarounds. We have nursing staff who are hiding surgical supplies in little cubbyholes; you have to know some secret way to get a hold of somebody to find out where they are or what they have to offer to the process. In fact, this caused complete shutdown. We built a brand new surgical campus in Baltimore, and the day we moved from the old to new, we had thought to migrate over into the new facility. Those needed processes. In spite of all the training we do, what we're seeing is that humans are at their limits of their capabilities successfully participating in this process without some error. Error is just a natural fact in surgery today. What we have, though, is very dedicated people who are usually overcoming that error just in time.

We analyzed what are called our “points of pain.” Right at the top of the list were missing supplies, missing instruments, missing consent forms, a missing patient, nobody knows where the patient is; and pretty far down the list is missing clerical information. We ask ourselves, how are we going to lever ourselves into this operating room with a future scenario? We arrived at the conclusion that how we interact with information, what value information adds to that process — the right information at the right time and the right place — was probably not a sufficient paradigm to overcome these problems. Even with decision support, all our staff were at their limit to engage in more transactions. Our information systems were going to have to do more of the heavy lifting. In other words, we had too much labor, too many people doing tasks that simply had to be automated. They've been automated for years in other industries.

The way we interact with information is spread over what I call the evolution of information in our society, the first level being the subsistence level, hunting and gathering. We're still very much paper-based, with physicians interacting with their patients on a case-by-case basis, usually paper-based. We're out hunting and gathering information. To overcome those system problems, we have staffing levels in our ORs that do nothing but run for information. Where's this, where's that? We have runners for information. We need to get rid of those.

The next era in the way we interact with information I call the planting and harvesting phase, where you have networks, spreadsheets, html and use of databases, which we're all very used to. I think health care is very much in that phase. The third phase is the Tool Age, where we have computer-assisted everything, computer-assisted devices, computer-assisted expert systems, knowledge management — everything is computer assisted. Other industries are well into that phase and are heading out of it. The next stage, where I think we really ought to be and where I think the real revolution in information technology is taking place, is what I call information as an active participant. We partner with information, with active participants in the process in our workspaces and in the work processes we use. Characteristic of that phase are going to be distributed artificial intelligence, multi-agent systems, the semantic web, and very important developments that were instigated by DARPA. The DARPA Agent Markup Language is a very critical standard for what we're trying to do at the University of Maryland, putting everything on a web services platform. How do we want this information to participate actively in our processes? Well, on a cognitive level, we want information as an equal partner with us to understand our intent and the consequences of our intent, as we engage information and go through processes.

I want information that is seeking me out; I don't want to have to go seek information. I want information to be intelligent enough to seek me out, to let me know, I need information, I want information to adaptively assume roles beyond my capabilities and the capabilities of my team members, and to carry that heavy load, and I also want information that have goal-seeking behaviors that are built right into it.

Right now, there is a lot of breadth and not much depth in health care. We are spread out all over the place and are well into the hunting and gathering phase and moving slowly into the Tool Age, and we aren't anywhere near where information is evolving right now. As you see other industries, they're very focused on their investments in information. There's got to be a payback. One of the characteristics of actively participating information that I think structurally will need to be developed — and we're beginning to incorporate — we want objects of information, whether they be your name, address, your health history in your EHR, your patient record, to have independent functionality. In other words, we want information to tell us, if you invoke me, I will be able to deliver you these services. So, if somebody is looking at a piece of information about your pathology information in your record, that piece of information can say, "you know what, you're looking at me right now, but I can link you up with an x-ray exam, I can tell you that my record was associated with other types of lab tests in the last year, and heaven forbid, I was also part of a malpractice

suit in the last year.” We have information objects that are tagged enough, intelligent enough, that they can provide you other services and connectivity with other information in the health record.

That way, we can make health records very functional and very lightweight and very context-appropriate, and staged so that you’re not having to create a system that drills down through a huge clinical data repository to pull up your health record, the version of your health record. We want actively participating information to seek out, in an intelligent way, other aggregations of information and services that best support a desired outcome in the process you’re engaged in, and we really want to do it, to be able to do that unsupervised and autonomous. And, you know what — this sounds like a *robot*. We know we could create the most functional robot in the OR with information, not with mechanical objects. In our project on the Operating Room of the Future, right now, we’re focused on three primary initiatives, the first one being the use of workflow engines adapted from other industries. We’re particularly interested in workflow engines that were developed in aircraft design and manufacturing, because the complexity of the systems are roughly similar; those workflow engines have multi-agent intelligent systems built into them to seek out process information — predict train wrecks, that we’re going to have a busted schedule here if you keep going down this pathway and you don’t have the right instruments in the OR. Or, it will be able to look into the future and say, “we’re about to have a train wreck; stop what you’re doing, let me calculate a workaround and be proactive about bringing the system back in line.”

We are focused on machine-interpreted situation awareness, computer visualization in work spaces, based on a computer looking into an OR and seeing the collection of people in there, the collection of equipment that’s in there; inferring wavepoint, and the association with people and equipment during the process of a surgical event, inferring wavepoints in the process flow — surgery start times, room status, surgical team readiness, that type of thing. We’re also very interested in making the OR bristling with sensory information, RFID being our first task here, and that is tracking objects that are in motion. Everything in the OR is in motion — the patients, the surgeon, the instruments, the supplies. It’s critical to track all those objects while they’re in motion, know where they are, know what their life-cycle is in that process, and make decisions based on sensory-rich information in the OR.

I’d just make a general comment about this. We’re taking the ability to collect information and interact with information at all different levels involved in a peri-operative process, and make the information flow very dynamic. We have a workflow engine which is synchronizing process with other activities — updating a surgical event record, for example, which is a short-lived record that is created during a surgical event, and then it’s used to

interact with other legacy systems, the patient record system, our supply and ordering and other medical coding. The workflow engine is tracking the process in the OR using a critical object broker or some kind of broker integration. As it's tracking the process, it's taking data elements and it's sending them out where they need to be during the process. At the end of it, a discharge summary can update the electronic patient record.

One of the things we did in terms of a human-centered systems integration of technology — that standard greaseboard, where they're writing things up on little tags as surgery progresses during the day — we took that computer visualization and put interactive displays of all the ORs above the greaseboards, so whoever is coming to update the greaseboard can say, "All right, I need to see what's going on in room A," and they have a visualization of room A. They can validate whatever is happening, rather than sending up one of the runners for information, to go and look in the window of the OR. We're upgrading that a bit, and we're making the greaseboard more automated. We've developed little objects — a little horse here, little turtle, little rabbits — that are embedded with information that we want to show in motion on that greaseboard: who the surgeon is, what the patient is, some information about the patient, what the procedure is, that type of thing. The reason for having these little magnetic tags that interact with nodes on the electronic greaseboard is that we know that the staff is very used to interacting with this greaseboard; it's part of the culture, it's a very smooth process. So, they had to have this tactile feel of interacting with the board, and we gave them their own little objects to move around the board. They felt like they were part of the schedule for the day.

We thought we were going to use a completely electronic system, but we realized that was going to be a disaster; because people had a culture around that greaseboard. The other thing we're doing, in terms of this active participation information, is that all our systems now, all our information systems, have to be on a web services platform with standards, so that we can mobilize everything, distribute information, so that clinicians in motion are connected to information at all times. It's another key element we're doing.

I'd say we're just at the beginning of all this; these are baby steps. But we really are enthused about this idea of information as an active partner with us rather than us having to expend time and energy seeking out information and manipulating it.

Discussion

Col. Harmon: Just one comment. I thought I heard implied in a lot of the words today that we face "either/or, *but* something else"-type decisions, and I'd encourage folks to try to break past that and think "yes *and*" in terms of the paradigms. What we've done within DoD is try to have a vision, and we put specifics on the vision that may have to change before we get to the whole vision. We're always making decisions towards the vision, but you're having to make small tactical compromises on the way to the vision, and it's a *yes and*, not a *no but*. It's very important to have a distinction like that. Doing things for small incremental improvements isn't at odds with getting towards the vision, necessarily.