Critical IT role in Healthcare: National Agenda, Applications, and Technologies

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This article starts with a broad overview of the critical role of IT in healthcare and a vision of better healthcare facilitated by IT. From among a large number of information technologies needed to address various healthcare needs, we pick two to discuss here: process management involving distributed resources and collaboration involving multimedia patient data. An array of applications of these technologies provides a broad overview of unique and complex IT needs in support of healthcare. We then discuss parts of two programs that researched, prototyped, trialed and commercialized these technologies. These programs were unique in that they involved government co-sponsorship of join ventures involving healthcare professionals and organizations, researchers and technologists, and IT companies.

Jack Corley presents the broad overview, Amit Sheth presents the technologies and their applications, and Warren Karp provides a healthcare perspective on the role of technology in improving one of the clinical applications.

Acknowledgements

This work is partially supported by the NIST Advanced Technology Programs in Healthcare Information Infrastructure Technology (HIIT) and Healthcare Information Technology Enabling Community Care (HITECC), in partnership with Healthcare Open Systems and Trials (HOST) consortium.

A portion of this article appears as the lead article in the special issue on Healthcare IT of Silicon India, October 1999. Summary can be found at: http://www.siliconindia.com/magazine/Oct99it.html

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Healthcare Information Technology

We share a widely-held vision that tomorrow's health care will be delivered by a distributed team using a knowledge based process that is focused on prevention and wellness. Caregivers will be able to treat and monitor patients where and when needed, capturing data as a natural byproduct of care delivery. Clinical teams with a wide range of skills and expertise will deliver consistent, quality care based on timely, situation-specific knowledge and guidance derived from outcomes evidence. That same knowledge will support advances in healthcare research and education. Home care and remote medicine will increase, reducing the need for high-cost hospitalization. The health care community will realize virtual integration through knowledge tools that deliver appropriate knowledge to care providers at the right time.

Information technology is one of the keys to attaining that vision. Although information technology is already transforming many aspects of health care, further information technology advances are needed to meet the increasing demand for reliable, broadly available health care information and knowledge. In addition, those advances must help alleviate cost and quality pressures coming from an aging population and an associated increase in chronic disease. However, current health care information needs frequently go unmet even though both the health care community and the patient suffer from an overload of data that is often redundant, inaccurate, uninformative, or confusing. There are still challenges that must be overcome to make knowledge appropriately available in time to meet consumer and health care community needs.

For the U.S., a commitment to improving health care is paramount. In 1997, U.S. health care spending rose to $1.5 trillion per year. HCFA[1] estimates that by 2007[2] direct health care expenses will increase to approximately $2.1 trillion, an estimated 17% of gross domestic product. Within industry, high health care costs strongly affect a company's net revenue.[3] In addition, indirect costs such as lost productivity have added over 25% to the national cost impact. However, health care is not just a cost issue, it can also be a significant contributor to quality of life. Industry, paying a significant portion of costs, has recognized that health care cost can not be evaluated independent of quality and is moving to evaluate the health care delivered to their employees on both cost and quality[4]. At the same time, the HEDIS[5] model and a derivative being developed as a "standardized Medicare Report Card"[6] are beginning to provide well-defined health plan performance indicators. These emerging standard performance indicators enable employers to compare quality delivered by health plans. However, substantial information must be collected if these comparisons are to be meaningful. Information technology is also a key to collecting the needed measurement information.

To meet these technology needs, the HOST consortium[7] has been defining an investment strategy for healthcare information technology. This strategy, based on the contributions of a number of HOST

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[1] Health Care Financing Administration (HCFA), the federal agency that administers the Medicare, Medicaid and Child Health Insurance Programs. HCFA provides health insurance for over 74 million Americans through Medicare, Medicaid and Child Health. The majority of these individuals receive their benefits through the Fee-for-Service delivery system, however, an increasing number are choosing managed care plans. HCFA Home Page http://www.hcfa.gov.

[2] *Wall Street Journal*, 9-15-98

[3] For example, one Fortune 50 company, GE, spends over $1B annually on healthcare for its employees and retirees – this comes from company profits.

[4] Thomas R. Beauregard and Kevin R. Winston, "Employers Shift to Quality to Evaluate and Manage their Health Plans," Managed Care Quarterly, 5(1) 1997, p.51-56.

[5] Health Plan Employer Data and Information Set (HEDIS) guidelines, first released in 1993 by NCQA, are designed to help health plans specify, calculate and report information about five categories of performance: quality, enrollee access and satisfaction, utilization and financial data. The HEDIS criteria cover more than 60 specific performance measures. "HEDIS Report Cards--Heed This or Else?," Nicholas K. Zittell , Medical Tribune. July 18, 1996.

[6] HCFA and the Kaiser Family Foundation initiated the development of a standardized Medicare Report Card

[7] HOST is a consortium with broad-based membership from the healthcare industry, created in 1994 to promote the development of information technology to improve healthcare.

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members, includes perspectives of many individuals known for their visionary views of healthcare. The strategy emphasizes the need for flexible, standards-based, healthcare information systems with functional applications for clinical, administrative, and financial management across all points of care. These functional applications require the support of knowledge services that will: inform the consumer, furnish decision support to care-givers, deliver professional training and education, and support collaboration among the care-giving team. Advances in information infrastructure technologies are also required. These infrastructure technologies include information security and integrity; seamless multi-modal communications; clinical repositories; and unobtrusive data capture. The strategic goal is to define a path to healthcare information systems flexible enough to accommodate continuous improvement. At the same time, the emerging technologies must support applications aimed at wellness, evidence-based healthcare, and consumer education while enabling reengineering and automation of labor-intensive, paper-based administrative transactions and processes.

These advances are possible only through the development of standards-based, interoperable, yet secure healthcare information technology. Advances in healthcare and general information technology and communications have been emerging to make the goal realistic, increasing by orders of magnitude the ability to process, store, and share digital data. Processor size, disk storage, display resolution, and data transmission speed have all improved. Rapidly falling costs and markedly improved reliability have also been realized.

At the same time, standards have emerged for system interoperability that include object-oriented infrastructures (e.g., Common Object Request Broker Architecture-CORBA) and data access, formatting and exchange standards like Structured Query Language (SQL), Open Database Connectivity (ODBC), Open Knowledgebase Connectivity (OKBC), Hypertext Markup Language (HTML), Extensible Markup Language (XML), and Object Query Language (OQL). Communications standards have matched pace with advances like Hypertext Transport Protocol (HTTP), Healthcare Level 7 (HL/7), and Digital Image Communication (DICOM). In knowledge-based technology, agent communications standards (e.g, Knowledge Query Manipulation Language (KQML) and Knowledge Interchange Format (KIF) are maturing. Agent-based systems built on such standards will manage and share knowledge, using data mining and workflow technology to enhance health care. In addition, Java has made platform-independent software widely available. Overall, these standards have led to a movement from mainframe-based to client/server models and, eventually, to distributed network multimedia information systems.

The types of knowledge that are being captured and disseminated are advancing at an equivalent rate. A complete mapping of all human genes, barely begun 5 years ago, is expected by 2005. The implications for diagnosis and treatment are enormous. Improvements in multimedia, including non-invasive imaging techniques for diagnosis and treatment, are also substantial. Information is becoming much more computer usable through advances in health care vocabularies, including Unified Medical Language System (UMLS), Systematic Nomenclature for Medicine (SNOMED), READ codes, and Galen.

To define and realize the investment strategy, we have been working in a multi-organization team that is focusing on realizing the technologies needed to unobtrusively capture patient data, distill knowledge from that data, and deliver situation-specific knowledge and guidance to clinical teams. Knowledge will be used to enhance an individual’s care, to suggest improvements to best practice, and to provide corroborating evidence for clinical experts who assess the suggested improvements. In the following, we will discuss some results we have already attained in Internet-based multimedia information and process management support for care-giving teams regardless of time, geographic, or organizational separation.

A Unique Partnership for Relevant IT for Healthcare

A unique national healthcare initiative is that of National Institute of Science and Technology’s Advance Technology Program (NIST-ATP), which has funded three initiatives. These initiates are unique in that the federal government’s research and technology development funds must be matched equally, or more, by industry and other matching funds to carry out high-risk technology development that would otherwise not be carried out due to pressures for short term results and low-risk taking. Furthermore, these efforts are expected to result into commercializable technology that could positively impact the national economy and improve US's global competitiveness. The initiative in healthcare is motivated by the fact that the healthcare sector is the largest component of the national economy. Therefore, technologies that reduce the cost, or increase the quality of service and efficiency, as well as improve the competitiveness of healthcare industry, including the IT industry serving the healthcare sector, can have direct impact on the national economy.

Advanced Technology Institute (ATI), a company with a proven track record in consortia leadership, coordinated two programs as joint ventures between NIST-ATP and HOST. The first program, Healthcare Information Infrastructure Technology (HIIT) focused on the virtual healthcare environment by providing the information infrastructure tools needed for dramatic improvement in availability of healthcare information and utilization of healthcare resources. The second program, Healthcare Information Technology Enabling Community Care (HITECC) addressed the challenges related to cost-effective, community-wide, collaborative healthcare by developing and demonstrating simple and secure information technologies for sharing multimedia healthcare information across organizational boundaries. Both programs included facilitated unique collaborations between healthcare organizations, IT companies, and research organizations. As a snapshot, we now discuss two concrete efforts involving healthcare professionals at Medical College of Georgia (MCG) and the Connecticut Healthcare Research and Education Foundation (CHREF), Computer Science researchers at the Large Scale Distributed Information Systems (LSDIS) Lab at University of Georgia, and IT professionals at ATI as well as Infocosm, Inc.—a technology start-up which has licensed technology resulting from HIIT and has commercialized it.

Relevant Web Links

Advanced Technology Institute	http://www.aticorp.org
Healthcare Open Systems and Trials and the HOST White Paper	http://www.hostnet.org http://www.hostnet.org/current_efforts.html#white_paper
Infocosm, Inc. and the EAppS product information	http://www.infocosm.com http://www.infocosm.com/html/csarticle.pdf
Large Scale Distributed Information Systems Lab (including relevant research publications)	http://lsdis.cs.uga.edu
NIST's Advanced Technology Program and its focused program in Information Infrastructure for Healthcare	http://www.atp.nist.gov http://www.atp.nist.gov/www/iihc/iihc_off.htm

IT Case 1: Co-ordination and interoperability involving distributed human and computing resources

Healthcare enterprises consist of many groups and organizations. Many of their activities involve complex work processes that span groups, organizations, and enterprises. These processes involve humans and automated activities that are carried out over, or supported by, heterogeneous hardware and platforms, and involve a variety of software applications and information systems. Management of these processes and their automation is playing an increasingly important role for improving the efficiency of the healthcare enterprises and the healthcare workers as well as the quality (including timeliness) of patient care.

The processes may involve both clinical and administrative processes, large volumes of data and a large number of people, patients and personnel. The care process for one patient will have different types of processes and may interact at points that are not always predetermined. An out-patient clinic visit may involve administrative tasks, such as an administrative assistant obtaining patient information regarding a patient's address, health background and eligibility. There will also be clinical tasks like obtaining blood pressure, temperature, administering a clinical procedure e.g. injection, examination performed by a doctor or nurse, filling a prescription performed by a pharmacist. These processes also include related financial tasks like patient billing that would typically be performed by a different group such as the accounting department. An in-patient hospital visit may involve many more tasks and may create a long-running process that lasts at least as long as the duration of patient hospitalization. These processes are also very dynamic. For example, a care pathway for a patient with disease condition A, may evolve to a more complex work process if another disease condition B is discovered in the course of treatment of A. Because both conditions may have different care pathways they may still have to be treated concurrently. Table 1 gives a summary of the different types of processes, the applications that support them, and their requirements.

	Processes	Example Applications	Requirements
Hospital Based	Clinical	Charting, Scheduling, Discharge Summaries, Reports	Integration with patient data management software; Management of human and automated activities; Exception handling; Ease of Use; Support for Dynamic Changes; Security; Role-Based Authorization
	Non-Clinical (Administrative and Financial)	Ordering Systems (radiology, pharmacy) Patient Management (billing, accounts receivable, claims filing)	Data Management and Integration; Application Integration; Support for Heterogeneous and Distributed Environments; Security; Support for standards, EDI, HL7; Exception handling
Non-Hospital Based	Laboratory	Laboratory Information Systems	Scalability; Exception handling; Management of complex data types; Transactional Workflows; Integration with other systems; Support for HAD environments
	Pharmaceutical Industry	Clinical Drug Trial Management	Distributed Environment; Scalability; Exception Handling

Table 1: Healthcare Processes and Applications

A process management technology, including the capabilities of workflow management and enterprise application integration, were developed in the METEOR (Managing End-To-End OpeRations) project at the Large Scale Distributed Information Systems Lab (LSDIS-UGA) as part of the HIIT program. METEOR technology is intended to reliably support large-scale complex workflow applications in real-world multi-enterprise heterogeneous computing environments. An important aspect of this project is that the technology and system development effort at the LSDIS lab occurred in close collaboration with its healthcare and industry partners mentioned earlier. The collaborations have involved a detailed study of healthcare workflow application requirements, prototyping of significant healthcare workflow applications with a follow-on trial, and evaluation of METEOR's technology at the partner's location resulting in technology improvement leading to a commercial product called EAppS (Enterprise Application Suite of Platform and Tools) from Infocosm, Inc.

Let us briefly review four very different real-world healthcare workflow applications prototyped or trialed using the METEOR system (many non-healthcare applications have also been developed). These applications vary in scale and requirements ranging from single server, few users and few tasks to multiple distributed web servers, different locations, many users and many tasks. The figures in this section are screen shots from the METEOR Builder Service. For brevity, we will not discuss the specific use of METEOR system and implementation details.

Neonatal Clinical Pathways

A low birth weight infant with underdeveloped organs and systems is at risk for a number of medical problems. To monitor the development of these infants, the infants are processed through various clinical procedures or pathways. Three important clinical procedures performed on a low birth weight infant are obtaining head ultrasounds, performing a metabolic screen, and insuring that the infant receives the proper immunizations prior to being discharged from the neonatal intensive care unit (NICU). Tracking these processes manually for all infants in the NICU is difficult and often results in necessary tests and procedures not being performed in a timely manner. A workflow application was developed for the NICU at the Medical College of Georgia (MCG) to automate the scheduling of procedures at the appropriate times and in order to track test results to insure appropriate medical outcomes. See the adjacent box "*The Role of Information Technology In Supporting Neonatal Clinical Pathways: A Healthcare Perspective*".

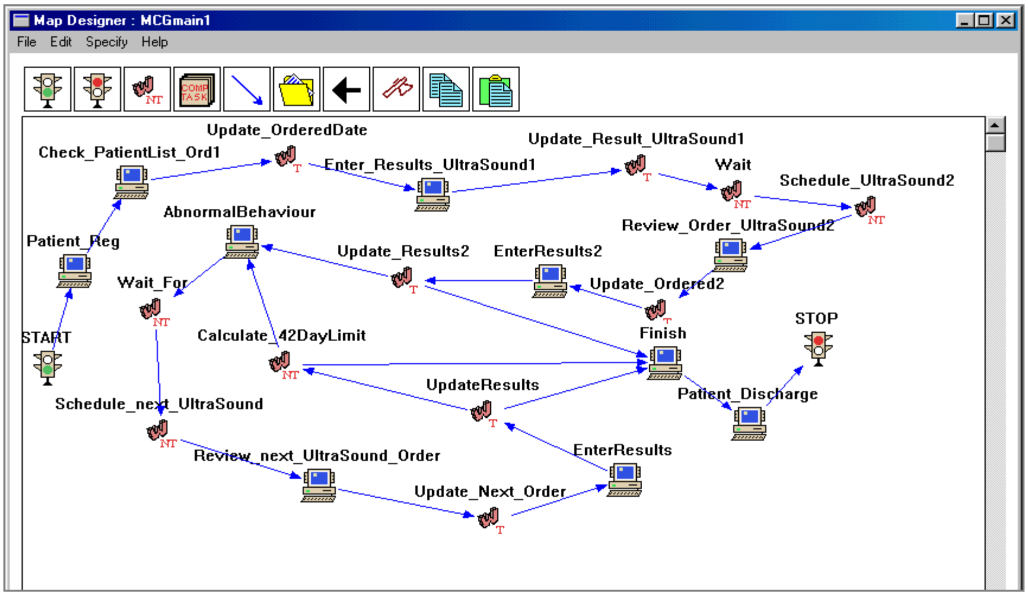

Figure 1: Head UltraSound Pathway

Figure 1 is a graphical representation of the head ultrasound pathway. Here, an initial ultrasound is done when the infant arrives in the NICU; in addition, the head ultrasound is repeated at specified intervals over a period of weeks. The duration depends upon whether or not test results indicate an improvement in the baby's condition. The application issues reminders to the nurse assigned to tracking this data in the NICU for scheduling tests, retrieving test results and updating the patient record. The workflow process for this application involves a single organization, three roles, and a single database.

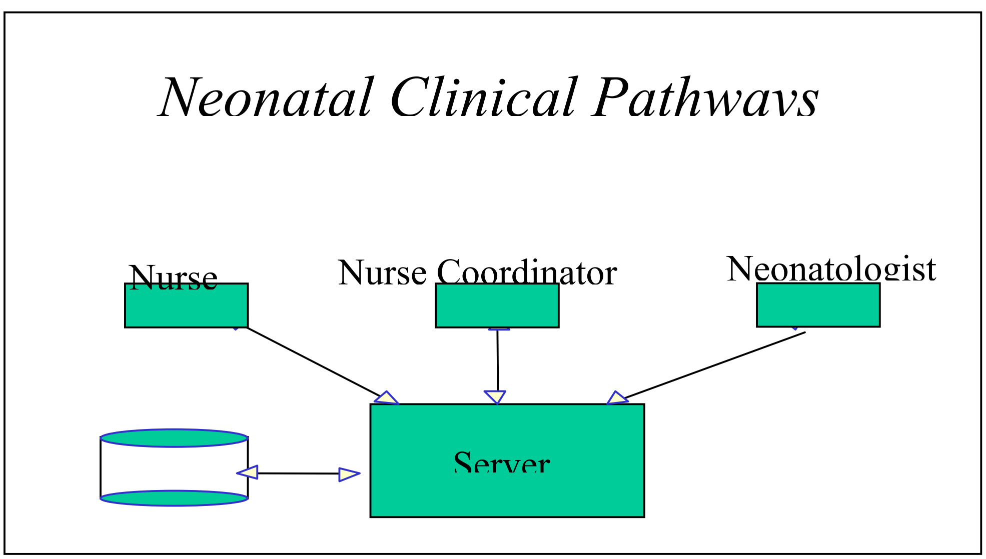

Figure 2 : Implementation for NeoNatal Clinical Pathways

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GeneFlow

GeneFlow was developed specifically for the needs of the Fungal Genome Initiative coordinated by the University of Georgia. This is a multi-institution international consortium of research groups, which is mapping and sequencing the genomes of important fungal organisms. GeneFlow is a workflow application designed to handle genome sequencing data analysis. Raw "shotgun" DNA sequence data consists of short (< 1500characters) overlapping DNA sequences. This data comes from automatic sequencing machines. From this raw data the short overlapping shotgun sequences must be synthesized into larger contiguous sequences of whole chromosomes. The sequence from an entire chromosome may be many millions of characters long. These larger sequences are searched for probable genes and other chromosomal features. Probable genes are then analyzed to determine a probable function, as well as to identify smaller scale features within the gene. These results must then be electronically published. The end result of all this is a completely annotated genome that is made available in public domain.

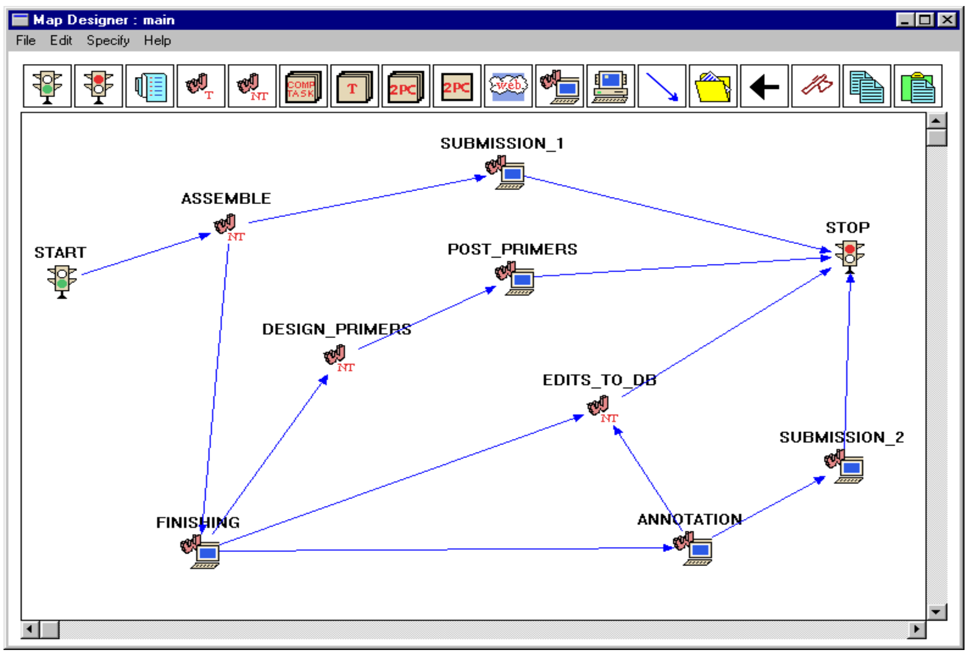

Figure 3 : Workflow Design for GeneFlow

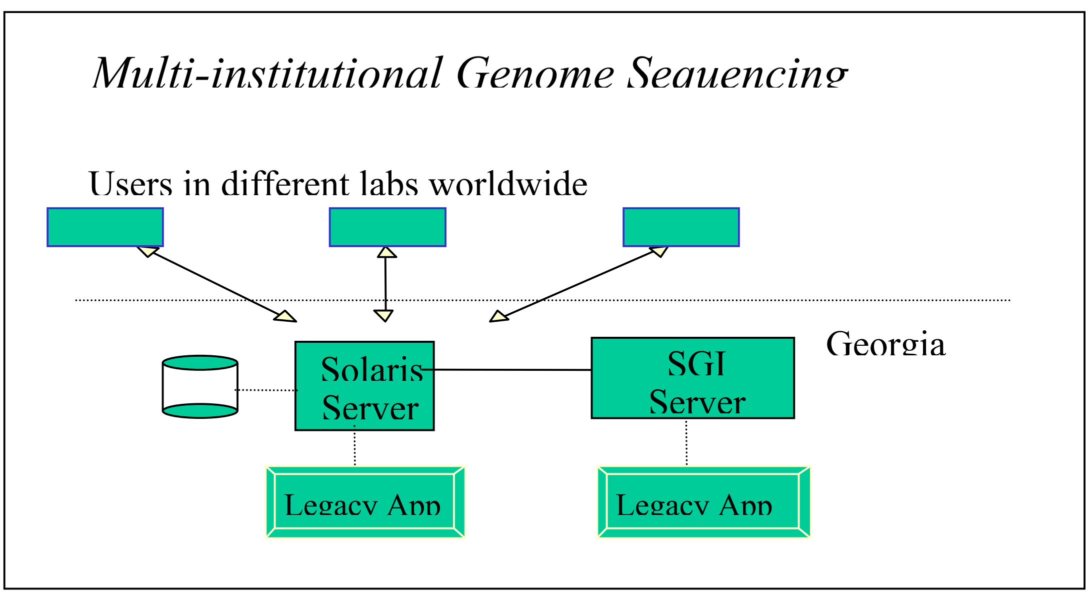

Figure 4: System Architecture for Geneflow

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The METEOR system supported wrapping of genome data analysis applications together in a "genome data assembly line". Multiple and heterogeneous servers (SGI, Solaris), single database, single workflow system, many human and automated tasks, legacy applications, and Web-based access to support geographically distributed users.

Eligibility Referral

The Eligibility Referral Application was to support the process of transferring a patient from one hospital to another. It involves three organizations, two hospitals and an insurance company. The design depicted in Figure 5 shows a consolidated workflow including both the sending and the receiving hospitals that were implemented on different networks of the respective sending and receiving organizations. The workflow starts with the sending hospital trying to determine the right placement for the patient. Once this is done the next few steps include determining the Eligibility information, obtaining the necessary payment information, and also getting the Physicians signature for the specified patient. The final step in the sending hospital's workflow is to send and receive a positive acknowledgement from the receiving hospital that they are indeed accepting the patient. Once this is done the sending hospital can update their database and the receiving hospital takes over from there. The receiving hospital also has its own workflow for processing transferred patients. A workflow instance spans the two hospitals with interaction with the insurance company through EDI transactions.

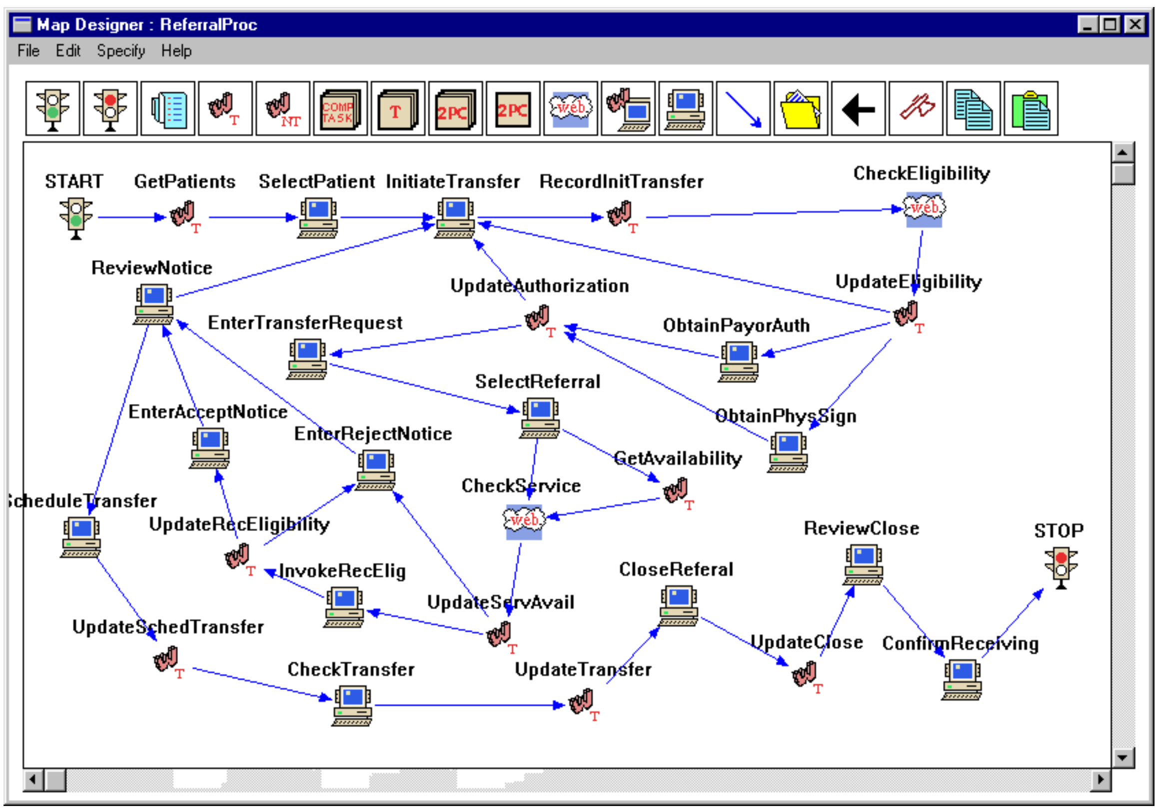

Figure 5: Eligibility Referral Workflow

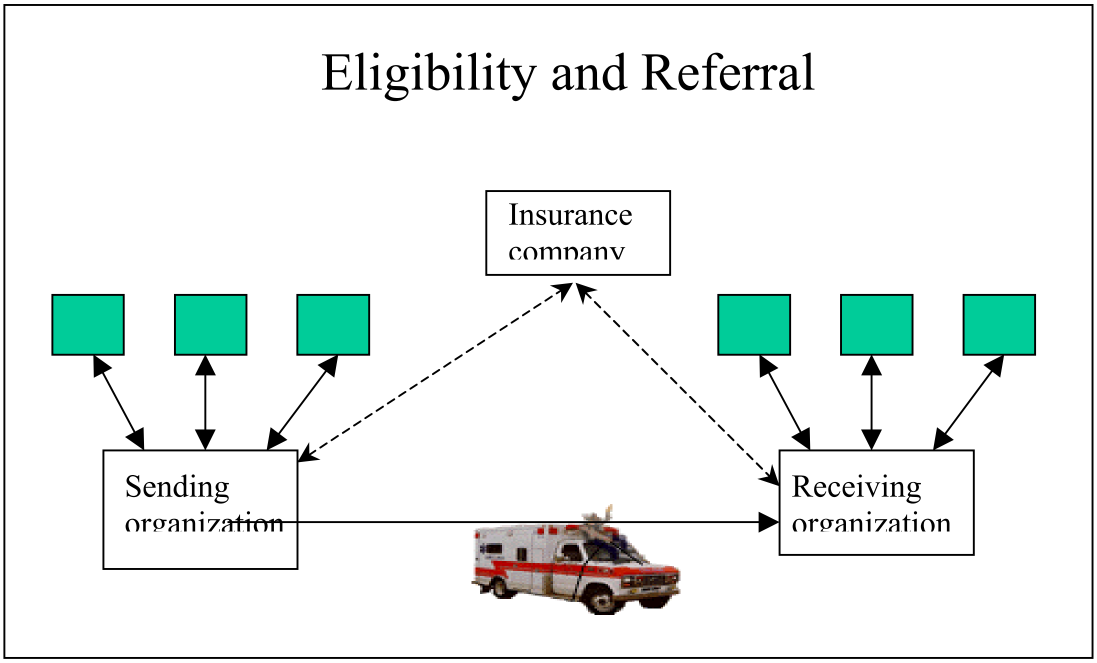

Figure 6: Implementation testbed for Eligibility Referral

This application requires support for distributed and heterogeneous environments, workflow execution and interoperability across multiple installations of the METEOR system, multiple databases and web-servers, and support for heterogeneous tasks such as human, automated and transactional tasks with EDI transactions.

Statewide Immunization Tracking Application:

The Immunization Tracking Application has the most advanced requirements of all four discussed. With managed healthcare coming of age, monitoring and tracking the performance of the different players involved, compulsory performance reporting, immunization tracking, child birth reporting, etc. have become important. In fact, the first item listed under Quality of Care in the Health Plan Employer Data and Information Set (HEDIS) is childhood immunization rate. Healthcare resources have to be used efficiently to lower costs while improving the quality of care provided and the processes in managed healthcare industry need to be computerized and automated.

Figure 7 shows a schematic and the scope of the application we have developed. This includes on-line interactions for the workflow application between CHREF (as the central location), healthcare providers (hospitals, clinics, home healthcare providers) and user organizations (SDOH, schools, Department of Social Services-DSS).
The workflow application can be divided into a clinical subsystem and a tracking subsystem.
The clinical subsystem has been designed to provide the following features:

- Roles for Admit Clerk, Triage Nurse, Nurse Practitioner, and Doctor
- Worklist for streamlining hospital and clinic operations
- Automatic generation of Medical Alerts (e.g. delinquent immunizations), Insurance Eligibility Verification by the Admit Clerk, and
- Generation of contraindications for patients visiting a hospital or clinic to caution medical personnel regarding procedures that may be performed on the patient.

Health agencies can use the data available to generate reports (for submissions to authorities like the DSS, State Government, etc.), and for determining the health needs of the state. More importantly, immunization tracking involves reminding parents and guardians about shots that are due or overdue and informing field workers about children who have not been receiving their immunizations. These functions are supported by the tracking subsystem. Figure 8 shows an implementation testbed. It included heterogeneous communication infrastructure with heterogeneous servers, multiple Web servers, CORBA-based middleware, and multiple databases managed by different DBMSs.

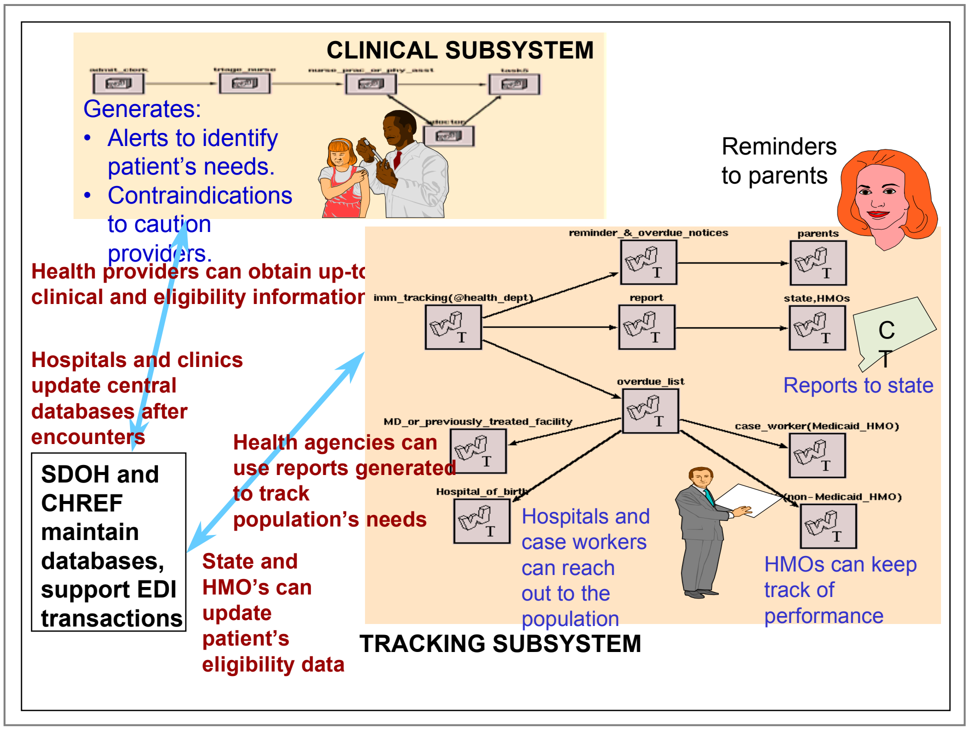

Figure 7: Immunization Tracking Application Schematic

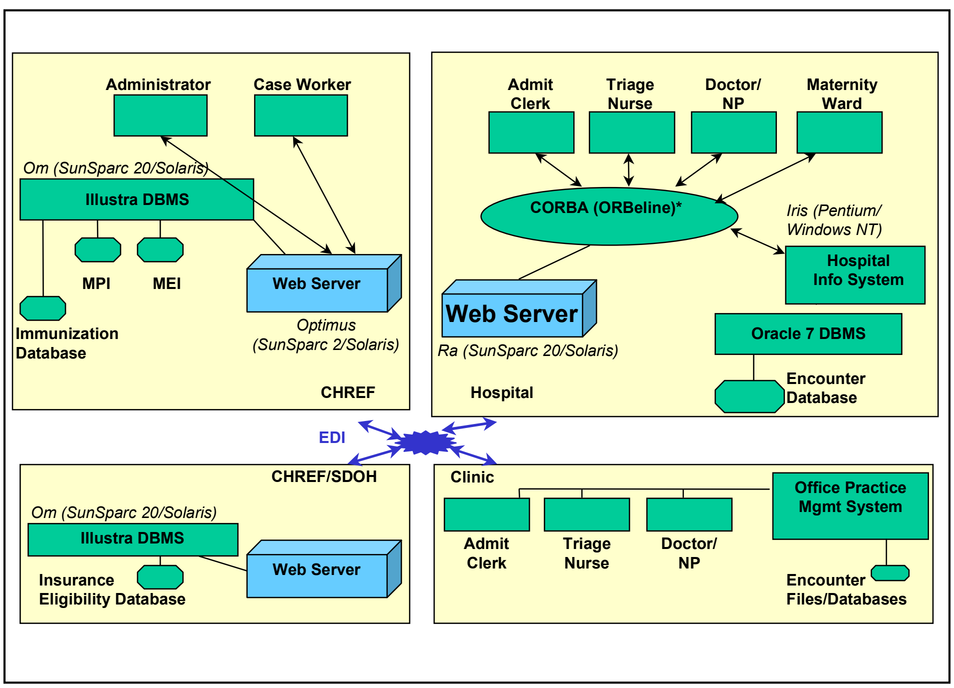

Figure 8: Implementation Testbed for the Immunization Tracking Application

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IT Case II: Teleconsultation Involving Web-based Synchronous and Asynchronous Collaboration

Within the HITECC program, the above team cooperated to develop and trial a system called CaTCH—Collaborative Teleconsulting for HealthCare. Two forms of teleconsulting are possible: synchronous or real-time, where the participants interact at the same time, and asynchronous or store-and-forward, whereby the collaboration occurs at different times. Internet is now a viable medium to conduct such teleconsultation. A number of telemedicine systems have used telecommunications technology for remote consultations. Our focus was to use desktop video and data conferencing technologies, Internet and ISDN-based communications, and a variety of Web and Java-based technologies for integrated support for scheduling and coordination (e.g., Web-based address book and calendar), automatic set up and initiation of videoconferencing, and secure data sharing. Figure 9 shows the capabilities available to each participant in the teleconsultation on his desktop.

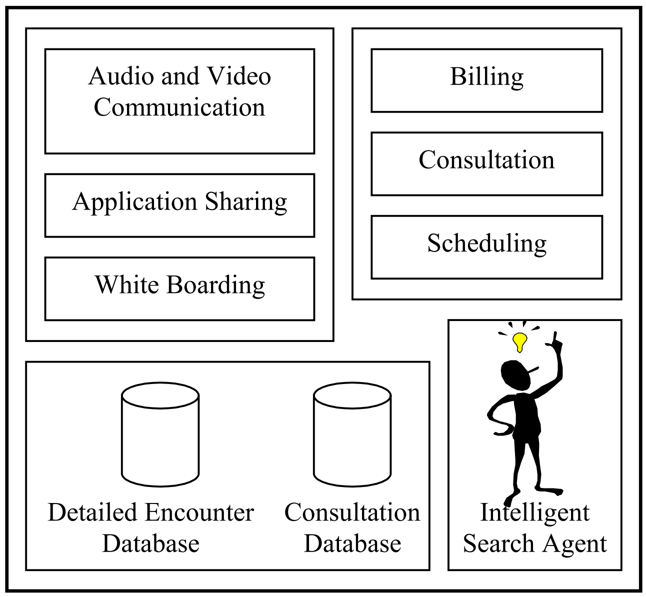

Fig 9: Components available to each collaborating partner

Our experiences have shown that a key difficulty is the mismatch of the healthcare routine with a synchronous form of collaboration. Usually, it is impossible to coordinate the schedule of two or more geographically distributed healthcare workers such as a physician and a consultant for synchronous interaction. Also, the technology complexity and communication bandwidth of the Internet today pose some difficulty in adaptation of this solution in healthcare. Contrarily, healthcare participants feel that asynchronous collaboration is more appealing and usable.

Figure 10 shows the various system components of asynchronous CaTCH. The key research issues in the asynchronous component of CaTCH are as follows:

- *Data Acquisition*: Leveraging existing technologies to capture medical information pertaining to a patient.
- *Creation of Composite Patient Portfolio*: High-level representation of the patient information.
- *Distributed Data Repository*: Use of intelligent agents to provide specific functions.
- *Agent Based information transfer*: Store CPO and all accompanying patient artifacts.

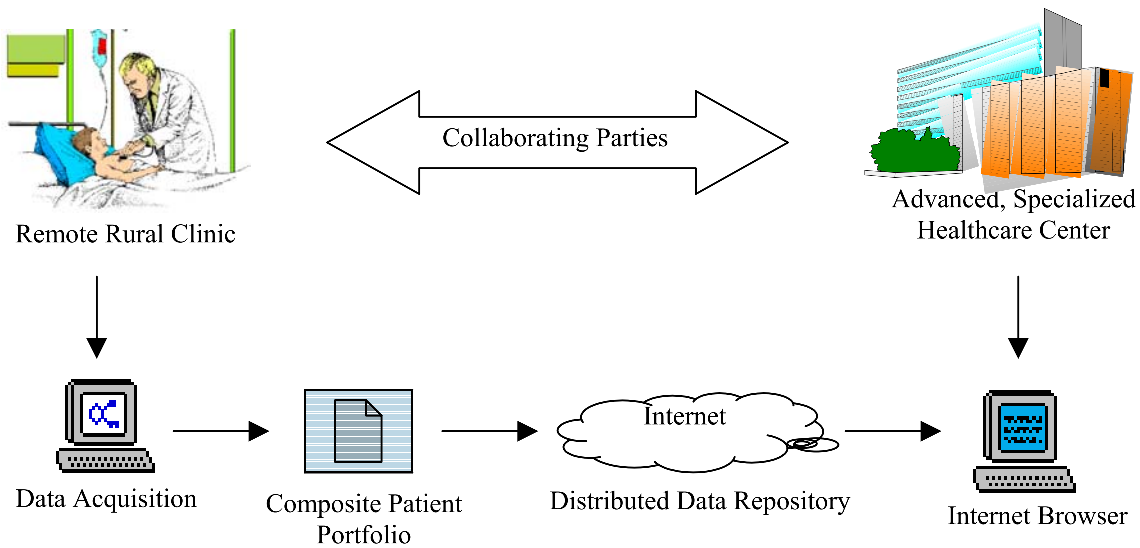

Figure 10: System components in Asynchronous CaTCH.

Two teleconsultation trials were conducted—one involving echocardiograph consultation, the other involving radiology consultation. Figures 11 and 12 show an easy to interface with e-mail metaphor for consultation requestor (typically primary physician), and a browser based consultant interface.

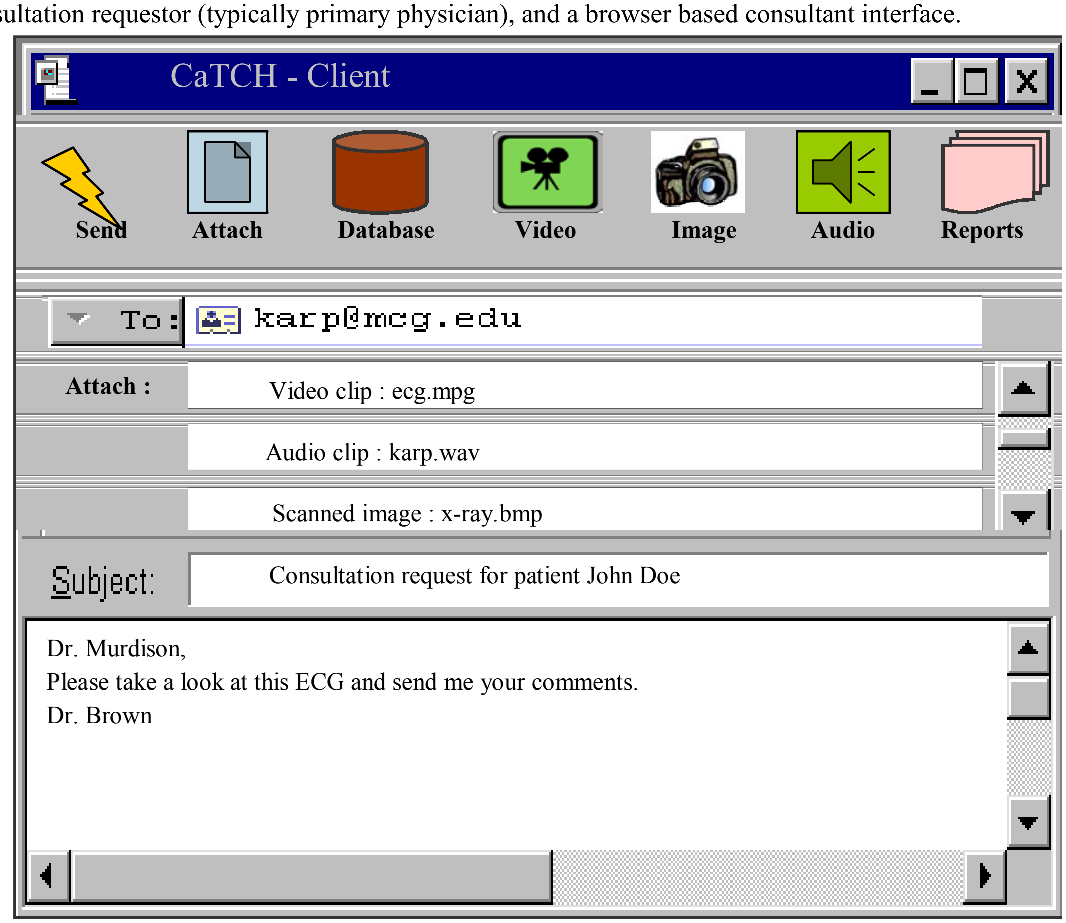

Figure 11: Snapshot of the CaTCH-client interface

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An echocardiology trial was carried out in more detail to compare the interpretation of echocardiograms posted on the Web with interpretations made directly from the traditional analog tape. There was 100% agreement in the overall clinical diagnoses among all physicians, independent of whether they interpreted the original tapes or the MPEG I videos on the web. In addition, using the Web has the potential to provide faster and more cost effective consultation. A healthcare professional's view of the system can be summarized as follows: 1) it allows healthcare to take place in the natural environments of the referring and consulting professional, 2) it provides a mechanism for tracking information in a non-linear, relational manner, and 3) it provides a more cost-effective method for consultation.

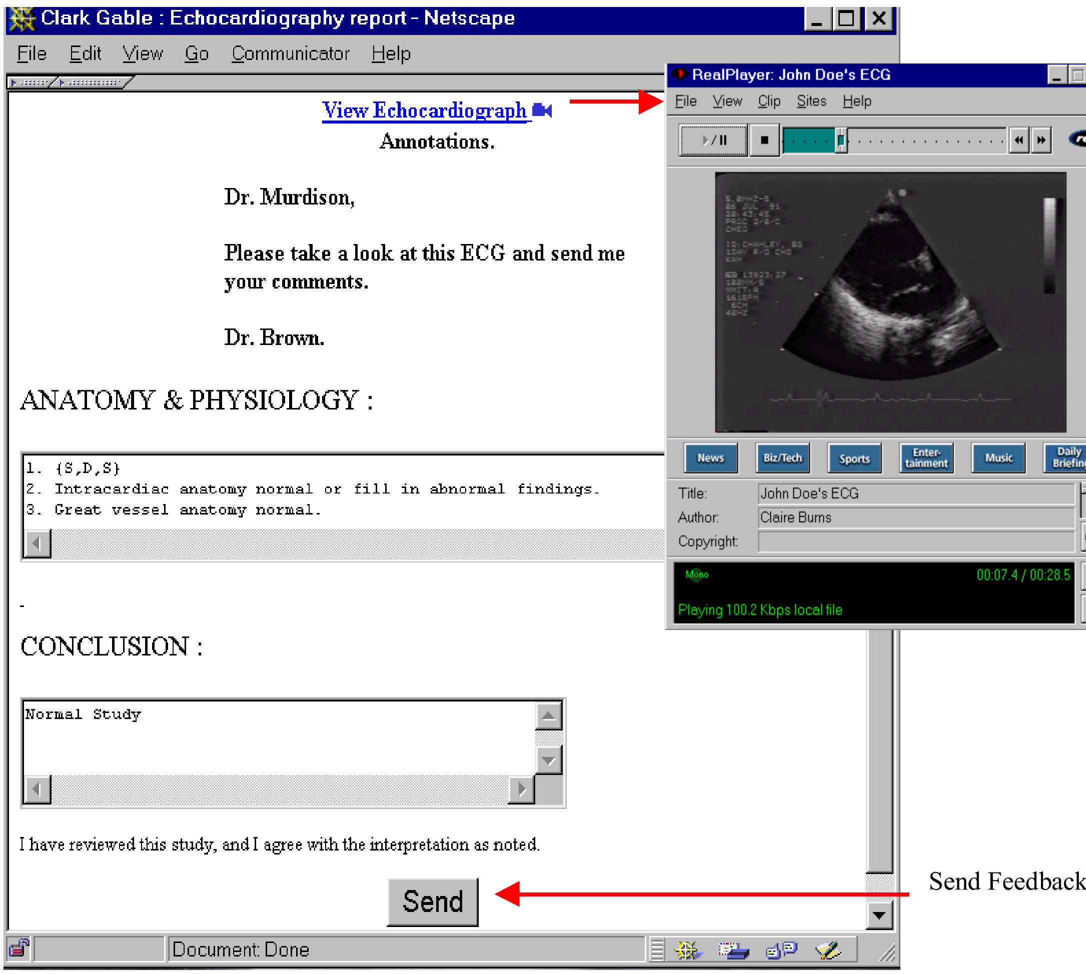

Figure 12: Snapshot of the consultation viewed using a web browser

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"In summary, why we're excited about the CaTCH project because it
#1 -- supports natural environments,
#2 -- supports asynchronous communication that fits the mode of behavior of
most health professionals; and
#3 -- provides a cost effective alternative."
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The Role of Information Technology In Supporting Neonatal Clinical Pathways: A Healthcare Perspective

The neonatal intensive care unit is a complex medical environment consisting of multiple infants with diverse and life-threatening medical conditions. Superimposed on this are the infants' families, and multiple healthcare providers. In some manner, care must be planned, coordinated, and carried out in a collaborative, standardized, and cost-effective fashion. Clinical pathways have evolved to help meet these challenges. To date, these clinical pathways, though useful, have oftentimes become no more than sophisticated checklists; they are linear, non-relational tools. The application of computer technology to support workflow management and collaboration in the neonatal intensive care unit can create a new paradigm of multi disciplinary health care delivery for very sick infants, their families, and healthcare teams.

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In a typical neonatal intensive care environment there may be 20-40 infants, or more, exhibiting a wide spectrum of medical conditions of varying complexities. For example, the intensive care unit may contain infants born pre-term with lung disease and nutritional problems, infants born to mothers who abused drugs and/or alcohol during pregnancy, infants with inherited metabolic disorders, or infants who require extra corporeal membrane oxygenation (ECMO-a "lung machine"). The holistic treatment of an infant mandates that multiple healthcare providers and family members be involved in the process. The ability for so many people to communicate and collaborate under, oftentimes, extraordinary emotional and medical circumstances is a challenging problem. Healthcare providers involved in the care of a specific infant may include several neonatologists, the infant's nurses, medical students, interns, residents, fellows, audiologists, cardiologists, surgeons, respiratory therapists, physical therapists, and others. In addition, the sick neonate must go through many procedures from birth to hospital discharge; examples of procedures are state metabolic screenings, immunizations, circumcision, discharge planning, nutrition consultation, and ultrasound examinations, to list just a few. Each procedure must not only be carried out, but the results tracked, followed-up, and if needed, scheduled. The collaboration and coordination of multiple tasks among multiple healthcare providers and multiple family members is an awesome and cumbersome task, at best.

The concept of clinical pathways has evolved within the last few years in order to better track and coordinate the care of infants. A clinical pathway, sometimes called a critical pathway, is an approach used in neonatology and other medical specialties to deliver standardized care in a quality-controlled and cost-effective manner. It is a multi disciplinary care plan, based on time. The clinical pathway can serve as an important tool to increase communication, collaboration, and learning among all members of the healthcare team, as well as facilitate education and collaboration with the infant's parents or other primary caregivers. Another important function of the clinical pathway is to provide easy access to information needed at shift changes and to write discharge summaries and case reports. A clinical pathway may be viewed as a map of the critical events in a patient's hospitalization, targeting important medical events in this stay, including appropriate interventions to achieve certain results. Critical events may include consultations, tests, activities, treatments, medications, nutrition, discharge planning, and parent teaching. Preliminary data supports the notion that using clinical pathways saves the hospital money and results in shorter hospital stays for patients.

The manner in which clinical pathways are presently implemented in most neonatal intensive care units is labor intensive and open to criticism. Clinical pathways were originally designed to be used by primary and associate nurses; presently, the role of clinical nurse specialist has been expanded to include a role as neonatal nurse case manager. This person may be assigned the duty of policeman in assuring that tasks are completed and goals are met. However, communication between the nurse and other members of the healthcare team is inconsistent. At their very best, critical pathways oftentimes become linear checklists.

Critical pathways have recently been formulated for many diseases and conditions associated with infants housed in a neonatal intensive care unit. Some critical pathways include those for hyaline membrane disease, ECMO, pediatric parental nutrition, discharge planning, cranial ultrasound, mother-baby coupling, and developmental assessment.

The application of computerized workflow management and collaboration to neonatal clinical pathways may be hypothesized to offer many unique advantages. One major attribute afforded by the

A portion of this article appears as the lead article in the special issue on Healthcare IT of Silicon India, October 1999. Summary can be found at: http://www.siliconindia.com/magazine/Oct99it.html

application of this technology is the ability to track relational and interrelational aspects of patient management in a non-linear manner. Presently, clinical pathways most usually involve checklists, which must be filled out manually. These checklists are linear tools trying to cope with non-linear medical processes. Healthcare providers have limited ability to manually relate activity in one part of the workflow to outcomes in another part. The ability to elucidate these non-linear relational components usually resides in the mind of specific health professionals in the intensive care nursery. With the many diverse activities, treatments, and tasks associated with each individual infant, with the many infants in the environment, and with the multitude of healthcare providers and family members, the integration and coordination of care is an imposing goal. Applying computerized technology to this scenario may help to attain this goal. A second critical component brought to clinical pathways by computerized technology is accountability. In a computerized workflow system it becomes easier to identify the responsible individual needed to implement a critical action. This individual can then be tracked, reminded, outcomes assessed, and follow-up, if needed, prompted. A consistent lack of action by the responsible individual can be identified and electronic notifications sent up the administrative command. A third unique opportunity brought to neonatal clinical pathways by computerized workflow technologies is the ability to re-organize information in the record automatically to fit the requirements and format of mandated reports and summaries. A fourth, but no less important, opportunity this type of technology brings to patient care is standardization of care among health professionals within a hospital or between hospitals. This is critical for the sick newborn, since the infant may begin life at a primary level hospital in a rural area, then be transported to a tertiary care center for treatment, and then be re-transported to a secondary level hospital for intermediate treatment, prior to being brought home. The ability of primary, secondary, and tertiary care centers to have information about the type and quality of care at other institutions might increase the chances of a positive medical outcome for the infant.

Technology needed to integrate computerized workflow management and collaboration into the neonatal intensive care environment should be user-friendly, fit into the daily routine of healthcare providers, and require minimal additional funding. Most neonatal intensive care units presently contain personal computers, with staff familiar with databases, e-mail, and the use of the World Wide Web. Additional technology may include wireless functionality and retinal imaging. Wireless technology would permit data for each infant to be kept at the bedside or be brought to the bedside during rounds. The neonatal intensive care unit is an ideal environment for wireless technology, because infants are usually within a limited distance from each other, either in one, two, or multiple room clusters. There are presently many inexpensive wireless technologies available for such environments. Retinal imaging may provide the attending physician or other health professional instant, secure visual access to the information for each specific patient, during medical rounding. Finally, a next generation of computerized workflow management might include artificial intelligence. The data available for each infant might be used for suggesting and prioritizing treatment options. This functionality needs to be viewed as supportive rather than directive. Suggesting the five most reasonable courses of action for a patient based on all the data available may facilitate the delivery of more effective and more standardized types of healthcare.

There are barriers to the implementation of workflow technology into the care of the neonate. First, although this technology may be cost-effective down the road, the hospital must be willing to allot the initial financial and manpower resources needed to implement and sustain the technology. Implementing new technologies during the present period of downsizing in healthcare is a challenge. Tracking a health professional's accountability and insuring that each part of a care plan is carried out in a timely, effective, and cost-efficient manner may be perceived as "big-brotherism" by healthcare providers. There are also medical-legal, security, and ethical issues that must be addressed when applying computer technology to care delivery. For example, how are variances in treatment, which are mandated by the needs of a specific infant and the professional judgement of a specific health professional, integrated into the system?

A simple example of a specific scenario that demonstrates the vision for how technology can and should support clinical pathways is the requirement for obtaining a cranial ultrasound on an infant. Tracking the date on which the ultrasound should be ordered, tracking if it were ordered, if it were normal or abnormal, and if and when ultrasounds should be repeated could all be automated. In this scenario, when tasks are not accomplished, e-mail reminders are automatically delivered to the responsible party. If corrective actions are needed, then they are suggested by the technology. If tasks continue to be ignored, e-mail is automatically delivered to supervisors. If abnormal results are obtained, these are flagged and persons responsible for corrective actions are notified.

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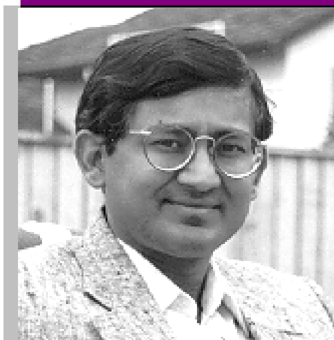
Technology has become so user-friendly and cost effective in the last few years that the time has come to explore ways of integrating computer technology for collaborating and coordinating infant care in the neonatal intensive care unit. This technology can create a new paradigm for healthcare delivery, which stresses relational aspects of treatment and "on-the-fly" integration and communication, and coordination. The effectiveness and impact of this new paradigm must be evaluated. Items that should be included in such an analysis are 1) patient outcomes, 2) length of hospital stay, 3) cost to patient, 4) cost to hospital, 5) family satisfaction, 6) care giver satisfaction, 7) health professional turnover, 8) health professional satisfaction, 9) health professional recruitment, and 10) health professional's knowledge of the patient. Both quantitative and qualitative tools should be used to measure outcomes. Qualitative research in this area should include ethnographic and naturalistic inquiry, with the use of interviews, open-ended instruments, and focus groups.

Authors' Bio



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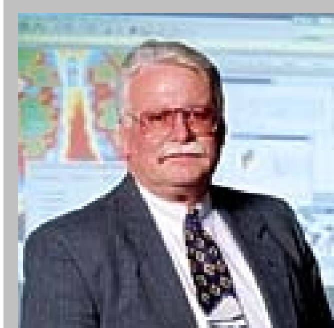

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