**Overview**
- Healthcare communication methods
- General overview of telemedicine
- Real time, store-and-forward and home care
- Current successful areas
  - Teledermatology, telepathology, teleradiology, teleultrasound
- Evaluation of telemedicine
- Web based Telemedicine and EMR systems

**Healthcare Communication**
- **Synchronous communication**
  - Direct conversation, telephone, video conference, page (?)
  - Require full attention of all parties at same time
- **Asynchronous communication**
  - Letter, email, store-and-forward telemedicine
  - Allows flexible, efficient use of expert time

**Communication technologies**
- Phone
- Email
- Instant messaging
- Web based systems inc. EMRs
- Internet video conferencing
  - MS Netmeeting
  - PictureTel/Polycom systems
- ISDN based video conferencing
- Remote control and surgical robotics

**Telemedicine: basic requirements**
- Expert advice available from a distance but not locally
- Problem able to be described sufficiently clearly for a safe medical opinion
- Adequate time for assessment

**Types of Telemedicine**
- Real time video link
- Store-and-Forward telemedicine
- Home healthcare and monitoring
Traditional Video Telemedicine
- Specialized video conferencing equipment e.g. VTEL, PICTURETEL
- Multiple ISDN lines (2, 4, 6 +), each line 64Kbits
- Special imaging attachments for ophthalmoscopy, otoscopy, endoscopy etc.
- Audio attachments include electronic stethoscope

Early Telemedicine Examples

Nebraska Psychiatric Institute
University of Nebraska, College of Medicine, Omaha, Nebraska (US)
In 1959, Cecil Whittson established the first functional telemedicine program. This program focused on psychiatric patient care and medical education. For patient care, telemedicine was used to conduct group therapy. The system was also used to instruct medical students by connecting clinics and classrooms.

Logan Airport Medical Station,
Massachusetts General Hospital
Boston, Massachusetts (US)
In April 1968, MGH established a microwave video link between the hospital and Boston's Logan Airport.
Intended to provide immediate access to a physician without requiring one to be permanently assigned to the airport.
More than 1000 patient examinations were conducted.

Project SHARE
Canada and East Africa
A satellite network was established in January 1986 that allowed for interactive video conferencing between medical facilities in Newfoundland, Canada and Kenya or Uganda.
Connection allowed for:
- formal medical education and lectures
- telemedicine consultations (which included EEGs),
- international medical collaboration and research.
**Home Health Care**
- Increasing use of home care due to rise in chronic diseases and desire to reduce length of hospital stay and costs
- Data communication between hospital and home cheap and simple with Internet/Web
- Automated data collection devices available e.g. for BP, blood glucose, peak respiratory flow rate etc.

**Home Monitoring Projects**
- Cardiac arrhythmia monitoring with "cardio-memo"
- Diabetics: data on glucose control, diet or video discussion
- Asthmatic control with peak flow meter connected to palm PC
- Heart failure patients: control of fluid balance with data from weight, symptoms etc.

**Fax and Telephone:**
**Simple Alternatives**
- Telephone interviews and follow-up
- Mailing x rays, slides, samples, photos
- Faxing ECGs and other investigation results
- Mailing digital images on CDROM

**“Traditional” Telemedicine**
- Real-time transmission of video
- Specialist must be present during consult
- Requires high bandwidth: usually dual ISDN or T1 line
- Good for conferences/teaching
- Expensive and time consuming

**Store-and-Forward Telemedicine**
- Summarize case in text (usually email)
- Take images with digital camera (or still video)
- Send case to specialist center, usually by email
- Specialist reviews case when convenient
  (discussed in more detail later)
**Teleradiology**

- Mainstream application in telemedicine
- Images are acquired with a digital system e.g. a CT scanner or imaged with a high resolution laser scanner
- DICOM format used to exchange images between devices
- Radiologist doesn’t care if image is from the same hospital or other side of the world

**Modern Teleradiology System**

**Teleradiology in remote sites**

- Severe lack of expertise: no radiologist in 137 African countries (source WHO)
- Many remote hospitals have x-ray equipment but only general physicians
- Copying and mailing x-rays is expensive and slow

**Digital radiology (US)**

- Typical high resolution image: CXR
  - 2,048 x 2,560 pixels x 12 bits = 60M bits uncompressed (grayscale)
  - JPEG compression 10-20:1 = +450K
  - Wavelet compression 20-30:1 = +300K
- DICOM standard for x-ray transmission

**Low-cost digital radiology**

- Modern digital cameras provide 2048 * 2048 (4M) pixels or better
- ACR recommendations 2048 * 2048
- Images are generally output in JPEG format or loss-less TIFF files (Soon JPEG2000 we hope)
- Cameras are cheap ($300-$500), portable, robust and relatively easy to use
- The same camera can be used for multiple clinical images types

**Automating Email Telemedicine**

- Text
- Phone + Internet/Satellite
- Compression (Wavelet, Zip)
- Encoding (MIME)
- Encryption (IDEA)
Case and image transmission

- JPEG images 300KB approx.
- Text and images zipped together and encrypted for transmission
- Case can be sent to a personal email account or to a Web server

TeleMedMail: modes of operation

- Peer to peer (via email), 2 modes
  1. Encrypted text with password
  2. Unencrypted (for teaching or internal use)
- Via web server
  - Fully encrypted zip archive
  - Password protected web site
  - EMR database for case management

Sending cases peer to peer as email attachments

- Text
- XML
- HTML page
- Viewers
- Encrypt with IDEA
- Zip Archive
- MIME attachment
- Email
Sending cases to the server system

TMM receiver: Web-based case viewing

The Java viewer for x-rays and other images (displaying Russian X-ray and text)

Telepathology Equipment

**Telepathology**
- Pathologists often send slides to subspecialists for a second opinion
- Sometimes relatively rapid opinions are required e.g. for biopsy results
- Digital cameras are available to attach to microscopes and capture high-quality images
- Selected images can be emailed to a specialist center with other clinical details

Slide courtesy of Prof. Lech Banach
**IPath Server**

- Server for exchange and review of image based case reports especially pathology
- Can take input from the web or from TeleMedMail
- Nice image management tools
- Running in Zurich, Nigeria and Solomon Islands

**Telecardiology**

- ECGs sent by fax or email of image
- CXRs
- Teleultrasound
- Heart sounds?

**Teledermatology**

- Diagnosis mostly: history, visual inspection and biopsy
- Biopsy can be mailed in some cases
- High resolution color images required
- Real time interaction not necessary

**Tele-herpetology**

- Used over several years with video, and now digital still cameras
- Moderate resolution requirements 850x650
- May be accompanied by biopsy
- Web based systems used in some sites including Boston, USA
Teledermatology in a Rural Family Practice
D O’Mahony, L Banach, D H Mahapa et al

Home Heart Failure Care
- Close monitoring of fluid status and treatment in heart failure reduces admissions and improves quality of life
- Use of web based architecture to connect patients at home and their physician/nurse
- Daily monitoring of weight, BP, pulse and symptoms such as breathlessness, oedema
- Advice on diuretic dosage, diet, need for urgent assessment

Columbia University Home Diabetes Care
- Informatics for Diabetes Education and Telemedicine IDEATel
  - Synchronous videoconferencing over standard telephone lines
  - Electronic transmission for fingerstick glucose and blood pressure readings
  - Secure Web-based messaging and clinical data review
  - Access to Web-based educational materials

Telephone and voicemail systems
- Friedman, Boston University, support for hypertension management
- NHS Direct nurse based patient triage
- Voixiva inc. telephone based data collection and reporting for infectious diseases in Peru
- Support for home care for HIV in Capetown, South Africa

Mobile phone tracks heartbeats
Remote care
- The device works by monitoring the microwave transmitted by a mobile.
- Some of the microwaves bounce back to the phone from the heart, lungs of the person using it.

Tele-ultrasound
- Ideal imaging method for many problems in Obstetrics & gynaecology, cardiology, gastroenterology, and renal medicine
- Safe, painless, no radiation
- Low running costs and significant but falling hardware costs
- Good images not always available
Tele-ultrasound
- Moderate operator training requirements but reading images requires expertise
- Relatively low resolution images
- Cardiology and fetal medicine requires motion video
- Equipment can be bulky and expensive for newer imaging techniques

Portable ultrasound machine suitable for echocardiograms

Tele-ultrasound in Fetal Medicine (Mary Dalton, Tufts University, Boston)
- Fetal ultrasound performed in local clinics
- Images reviewed in real time by expert physician
- 4 or 6 ISDN lines (256 or 384 KBS)
- Adequate quality at 256 but movement artifacts in some cases

Evaluation of Telemedicine
- Why use telemedicine?
- Getting past the first grant phase
- Keep it simple and problem driven
- Beware of enthusiasts! (like us...)

Formal Evaluation
- We MUST perform clinical evaluations of informatics and telemedicine interventions
- Include effects on patient outcomes, workflow and sustainability
- Compare with simple alternatives
  - mailing photos or CDROMs,
  - telephone or fax
  - Training more staff to do specialist's work

Legal Issues
- Medical licensing
- Qualifications
- Safety of telemedicine techniques
- Payment
**Teledermatology:**
*Example (Krupinski et al)*

- Still digital camera 832 x 608 pixel, 24 bit color (video cameras less effective)
- 4 dermatologists, 308 cases, (104 had biopsy)
- Each case had history and up to 5 images sent
- Mean review time of 22.6 seconds (3 - 167)

**Results**

**Image quality**
- Good or excellent color: 93%
- Good or excellent sharpness: 83%

**Agreement between readings**
- Photo vs. biopsy: 76%
- Photo vs. direct exam: 84%
- Direct exam vs. biopsy: 89%

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**Evaluation of the Diagnostic Accuracy of Chest X-rays Acquired Using a Digital Camera for Low-Cost Teleradiology**

Agnieszka Szot (former research fellow HST medical informatics program)

**Methods**

- Ninety-one upright postero-anterior chest x-ray images were collected.
- Each image was photographed on a light box with an Olympus C3030 camera on a tripod
- Images were compressed by JPEG and JPEG2000 (wavelet) compression
- Digital images were displayed using the TeleMedMail viewer

**Evaluation study design**

- 93 Chest X rays were assessed by 3 radiologist and 1 pulmonologist
- Images were acquired with a 3 Megapixel digital camera and compressed by 2 algorithms:
  - JPEG at 15:1 ..........................400KB
  - JPEG 2000 at 60:1 ...................120KB
- Each reader assessed the digital images and latter the original films for 8 typical features of TB
- Assessments were compared to a gold standard based on two independent radiologists reading the films

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**Summary**

Radiographs were a viewing box were photographed at a remote hospital in South Africa using a digital camera with a resolution of 1024 x 768 pixels at 24-bit color depth. The resultant images were sized in JPEG format and recorded as small attachments to be read on a PC monitor by radiologists in Glasgow and Cape Town. Twenty-seven images were reviewed, of which 20 were of diagnostic quality (86%). The mean file size was 3.5MB, with a quality control purpose, 100 chest radiographs were photographed at a local hospital and read by a single radiologist and compared with the original films. The diagnostic quality of the digital images was found to be within the acceptable range, with a mean quality Score of 75%. The mean review time for the digital images was 22.6 seconds (3 - 167).
Image features used in the study

<table>
<thead>
<tr>
<th>X-ray feature</th>
<th>Number of occurrences</th>
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<tbody>
<tr>
<td>Infiltration/consolidation</td>
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<tr>
<td>Cavities</td>
<td>13</td>
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<tr>
<td>Pneumothorax</td>
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<tr>
<td>Lymphadenopathy</td>
<td>12</td>
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<tr>
<td>Pleural effusion</td>
<td>20</td>
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<td>15</td>
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<tr>
<td>Scarring</td>
<td>27</td>
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<tr>
<td>Nodule or mass</td>
<td>31</td>
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<tr>
<td>Normal chest x-rays *</td>
<td>22</td>
</tr>
<tr>
<td>TB cases</td>
<td>17</td>
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Comparison of plain and JPEG images per feature

<table>
<thead>
<tr>
<th>Feature</th>
<th>AUC plain</th>
<th>AUC JPEG</th>
<th>Difference</th>
<th>p value</th>
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</thead>
<tbody>
<tr>
<td>Infiltration/consolidation</td>
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<td>0.861</td>
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<tr>
<td>Nodule or mass</td>
<td>0.862</td>
<td>0.855</td>
<td>0.007</td>
<td>0.8667</td>
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</table>

Comparison of plain and JPEG2000 (wavelet compression) images per feature

<table>
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<tr>
<th>Feature</th>
<th>AUC plain</th>
<th>AUC JPEG</th>
<th>Difference</th>
<th>p value</th>
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<td>0.862</td>
<td>0.832</td>
<td>0.030</td>
<td>0.5200</td>
</tr>
</tbody>
</table>

Discussion

- No detectable difference in detection of abnormalities on the 2 digital image formats v.s. the original image (for 91 images)
- For this application it appears that adequate diagnostic quality is provided by the digital camera for the diagnosis of TB and similar conditions
- This is a practical technique applicable in clinics with few resources
- JPEG2000 has great potential to reduce file sizes

Limitations

- The power of the study may be inadequate to detect smaller differences
- More images would strengthen conclusions
- Inadequate dynamic range of the cameras for certain films
  - requires careful choice of exposure
  - Better cameras or scanners
- Better gold standard for some diagnoses
  - e.g. Ct scan result could strengthen conclusions
Lessons from this study

- Few telemedicine studies rigorously assess the quality of diagnoses performed at a distance.
- Appropriate statistics must be used to measure diagnostic performance.
- There are trade-offs between study power and generalizability.
- Do the research findings apply in the environments where the system may be based?

Telemedicine and the Web

- Merging of two systems
- Move to all digital standards
- Ability to transform and enhance data
- Asynchronous telemedicine
- Partners in Health TB network discussed on Wednesday

Medical Information Management

- Telemedicine is a flavor of medical informatics.
- You still require a good electronic medical record.
- Storage and transmission of medical data is important in one building or across the world.
- A branch of medical informatics?

Requirement for EMR

- Delivery of complex clinical management in resource-poor areas.
- Monitor the rapid scale-up of a pilot project from 75 to thousands of patients.
- Support clinical research in one of the largest cohorts of MDR-TB patients.
- Monitor and improve resource allocation for complex and expensive drug management.
- Detection of changes in DST patterns that may indicate amplification of resistance in a group of patients.
Information management for a project to treat drug resistant TB in Peru
- Paper charts in multiple sites
- Laboratory results from Massachusetts faxed to Peru
- Patient lists in multiple databases and “Excel databases”
- Drug requirements assessed from spreadsheet of patients medications
- Extensive use of email

**The PIH-EMR**
- A secure (SSL) web based electronic medical record using a relational database
- Standard technology, open source, open standards
- Designed to be usable over low-speed dialup connections
- Bilingual: English/Spanish
- Views for:
  - Clinical care
  - Drug management
  - Analysis for patient monitoring and research

**Locations of clinics and IT systems**
- PIH/Harvard
- USA
- Server (Harvard)
- Database
- DST results
- Massachusetts State Laboratory
- Sputum samples
- PERU
- San Borja
- Carabayllo
- CLINICS

**Drug sensitivity tests (one patient)**

**Aggregate drug sensitivity test results**

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<tr>
<td>INH</td>
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<td>RIF</td>
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<td>AMK</td>
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**The Challenge:**

**HIV treatment in the developing world**

- 6 million people need ARV treatment today
- Currently about 300,000 receiving treatment
- How do we expand treatment rapidly to achieve the 3x5 goal (3M by 2005)?

**HIV treatment data requirements**

- Patient demographic (registry)
- Patient status
- Clinical status
- Investigations
- Drug regimen
- Drug supplies

**Partners In Health/Zanmi Lasante Project**

- Haiti is the poorest country in the Western hemisphere. The rural central plateau where we work is its most impoverished region.
- Haiti's 6% adult HIV prevalence rate is the highest in the western hemisphere.
- There are very few doctors—especially in rural areas—and only dirt roads, which are often impassable in the rainy season.
- Few towns have telephones. There is no cellphone coverage outside the capital area.
Treating HIV with ARVs

- Careful monitoring of clinical progression, side-effects, and lab results.
- Community Health Workers see patients daily. Doctors see patients monthly.
- Daily administration of three antiretrovirals, and supplementary medicines.
- Stockouts can engender drug-resistance.
- Emergency drug orders can cost many times the price of drugs ordered in advance through international agencies (e.g. IDA)

Rapid Large-Scale Expansion

- Haiti received $66M from the Global Fund to fight AIDS, Tuberculosis, and Malaria, including $13M to be administered by ZL.
  - Scale-up to 5000 or more patients
  - Five sites instead of one, some without laboratories
- Increased requirements:
  - More doctors
  - Larger quantities of medications
  - Additional clinic and laboratory infrastructure
  - Better information systems
  - Effective communications between sites

Electronic Communications

- It is impossible to provide the highest standard of care without an affective means of communication
  - Consults on difficult cases
  - Communicating lab results quickly
  - Locating doctors
  - Scheduling transfers and emergency surgery

Internet link at Thomonde expansion site

These sites use low cost Satellite connections and both generators and solar power systems
Informatics in a Developing Country?

"You guys are crazy!"
- A Clinton Foundation representative, when told of our plan to use an Internet-based system

But the Internet brings practical advantages:
1. One email can avert a 3-5 hour drive, or prevent an unnecessary patient transfer.
2. Doctors unfamiliar with HIV treatment need support and advice.
3. Averting one emergency drug purchase can pay for the satellite infrastructure at a site.
4. Centralized data management drastically simplifies IT needs at more remote sites.

EMR Design

- Secure web-based electronic medical record
- Based on EMR for Multiple-Drug Resistant Tuberculosis in Peru
- RedHat Linux server in Boston
- Oracle 9i Database
- Will be swapped for (free) PostgreSQL
- Apache, Tomcat, OpenSSL

EMR Intake Data

- Demographic and socioeconomic data

Medication check lists

- Medication regimens are selected from a check list which then generates the individual items
- Investigations can also be checked and printed out to accompany the patient
Decision support tools for drug regime entry

Drug combinations

Allergies

CD4 Counts
- CD4s done at labs in two clinic sites
- Results communicated to remote sites by email (paper results follow later)
- Doctors get email alerts when their patients’ CD4 counts are below 350

Offline Application
- The internet may be unavailable for days at a time
  - Lightning season is particularly troublesome
  - It is difficult to get replacements parts
- Java Offline application allows cases to be entered anytime, and uploaded when the internet is available.
  - java.net package simplifies HTTP and SSL
  - javax.crypto package simplifies security
- Easily configurable via XML descriptor files
  - Easy to add new forms to match the web interface
  - Supports data constraints, warnings, and alerts

Drug Management
- Based on WHO paper stock cards
- Inflows and outflows to Cange warehouse entered into EMR
- Flags and warnings when drug stocks fall too low

Drug Needs Analyses
- Calculate future drug needs from physician-entered regimens to predict necessary orders
- Compare calculated needs to actual usage based on stock card values
- Single application for drug management and drug prescribing allows cross checks of data quality
Current status
- It is possible to install a sophisticated network across multiple remote sites in one of the poorest parts of the world, to support the treatment of a complex and prevalent disease.
- Remote Haitian physicians are entering cases and doing online order entry daily.
- This can be a model for similar projects, but we must still do more:
  - Record more follow-up data, and ancillary medications
  - Add more sophisticated decision-support
  - Share the system (Open Source)

ROLE OF TELEMEDICINE

Why Use Telemedicine?
- Because it is the only alternative?
- Because it is better?
- Because it is cheaper?

The Only Alternative
- In remote areas e.g. Antarctica, Andes, Amazon etc.
- On board ships
- On planes (cost of diversion $20-30,000)
- On the battlefield
- In prisons? (US prison population 2 million, half the population of Norway...)

Providing Care in Rural Areas
In the traditional mode of providing care there are two solutions.
1) Either provide more health services to the remote site by full-time or part-time medical staff
2) Transport the patients from the remote site.
   Either option is expensive.

Because it is better
Many times, once the physician and patient see each other, the decisions are made very quickly. But the fact that delays of days or weeks have passed since the first presentation allows for disease progression and many times a more aggressive (and expensive) course of treatment.
Because it is cheaper

Ha Ha!

Video is expensive

Use appropriate technology

Cost effectiveness reviews

A systematic review found that the best evidence for the effectiveness of telemedicine was in some of the studies on:

- Teleradiology (especially neurosurgical)
- Telemental health
- Transmission of echocardiographic images
- Teledermatology
- Home telecare


Future Trends

- Rapidly falling costs of hardware and bandwidth
- Better imaging devices and data compression
- Increasing use of Internet and Web approaches
- “Contracting out” of radiology or dermatology?
- Increasing digitization of medical equipment
- Appropriate technology for developing countries

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iChat AV
Videoconferencing for the rest of us.