MEDICAL INFORMATICS AND TELEMATICS AT THE THRESHOLD OF THE 21ST CENTURY

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Summary

Medical and health informatics (MHI) is a new and rapidly growing discipline involving the use of information and communication technologies (ICT) so as to improve the acquisition and management of information in the healthcare industry. The role and function of MHI as a profession can be partitioned in many ways – we have chosen to examine what it represents as, in turn, an institution-centred, patient-centred, and community-centred endeavour. Issues of standards, education, and promotion are discussed as they help to define and establish computerized information systems as rapidly-growing cost centres in all sectors of health care. Although relevant as potential modifiers of long-term benefit, the societal implications of the aggressive use of ICTs have deliberately been left for consideration in other portions of the encyclopedia. Our not mentioning them here should not be taken to imply a lack of awareness on the part of the authors that there are downsides to the deployment of systems, including MHI, that are based on technologies as invasive and pervasive as ICT.

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1. Introduction

Medicine is an information and image intensive field. Lots of statistical, diagnostic and radiological data and images are collected from patients in hospitals and medical centres every minute of the day. Medical laboratories are churning out even larger volumes of data and images as research scientists race to probe various kinds of diseases and to find the cures for them. With this deluge of data, information and knowledge from the many branches of medicine, it is not surprising that the importance of computer science and info-communication technologies to medicine are rapidly recognized. Hospital information management and decision-making in patient care depend on reliable, relevant and timely information. Computers can store, process, manipulate and retrieve large amounts of data, information and images rapidly, efficiently and seamlessly. Furthermore, the delivery of healthcare often involves overcoming physical and geographical barriers and hence info-communication technologies help to transmit and share data and information organization-wide or enterprise-wide. Telecommunication links are also needed in many large land-mass or island-rich nations to deliver health services to remote, underserved areas and to provide continuing health education outreach services to health professionals and the communities they serve in outlying areas.

The term 'medical informatics' has its origins in the 1970s from the French who used the expression, 'informatique medicale' to define the application of information techniques and technology in medicine. Since then, the term has been used to cover all areas of informatics applications relating to health and medicine such as dentistry, nursing, public health and pharmacy. Over the years, there have been many formal definitions for 'medical informatics'. As the term implies, *medical informatics* deals with the tools and techniques of computer science and info-communication technology that enhance the understanding, communication, utilization and management of data, information and knowledge in medical and healthcare practice, education and research.

The medical informatics movement started in the early 1960s in the USA, Europe and

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Japan out of the need to process large volumes of hospital data and health insurance claims. Hence, early systems and applications were mainly centred on data and information management. Since then, medical informatics has evolved into a professional and academic discipline and its primary focus has shifted from administrative systems to patient/consumer centric system.

Nota bene: Given the generally descriptive purpose of a chapter like this, no attempt will be made to present medical informatics from anything other than a purely positive point of view. An examination of the significant personal and societal dangers inherent in either accidental or deliberate misuse of digital information, information technology, and/or information systems belongs in a different volume.

2. Brief History

With the large volumes of data that are handled daily by hospitals and clinics throughout the world, it is not difficult to realize that computers are needed to store, process and analyze the data and to communicate the data and the information and knowledge derived from them from one machine to another regardless of whether these machines are within the same building or in different parts of the world. It was the need to use computers for information management that the field of medical informatics was evolved in the 1960s with the deployment of computers in hospitals to deal with administrative applications such as billing and processing insurance claims. One of the earliest hospitals to use computers for administrative processing was the El Camino Hospital in Mountain View, USA which installed the Technicon Medical Information System (TMIS) in 1965. These administration systems were superseded by first-generation Hospital Information Systems (HIS) in the 1970s with early attempts to integrate clinical components into the administrative and financial systems. Some well-known early HIS include the HELP system developed by the Latter-Day Saints (LDS) Hospital in Utah, the DIOGENE system in Geneva and the TETSUMON system at the University of Tokyo, Japan.

The same decade also saw the early development in medical record systems to automate the entry, storage and retrieval of clinical patient data and information. One of the earliest attempts at developing a medical information system that linked patient and patient care was undertaken at the University of Vermont Medical Center. In 1976, it launched its PRoblem Oriented Medical Information System (PROMIS) which featured one of the earliest medical record system to be documented, the Problem Oriented Medical Record (POMR) developed by Dr Larry Weed. Up till then, medical informatics was not recognized as a professional field in its own right but rather as a service-oriented discipline supporting hospital and medical center operations.

It was not until the late 1970s and early 1980s that formalization of medical informatics as an academic discipline began. This period saw the growth of medical informatics departments in the USA, Europe and Asia (Japan) as well as the formation of professional groups such as the International Medical Informatics Association (IMIA) which evolved from the International Federation for Information Processing (IFIP) Technical Committee 4 in 1979. At around the same time, the European Federation for Medical Informatics (EFMI) was also established to promote regionalization of the field. Today, EFMI is one of IMIA's regional groups which also include IMIA-LAC (IMIA regional group for Latin

America Countries, established in 1980) and APAMI (Asia Pacific Association for Medical Informatics, established in 1994).

With the establishment of medical informatics as an academic discipline and the formation of professional groups to further promote the field by linking academia with industry, developments in medical informatics took off in the 1990s. The decade saw rapid and pervasive adoption of networked, client-server technology in medicine, the growth of internet and PC-based clinical information systems and knowledge bases and efforts to promote scalability and interoperability of patient-centred systems and applications.

3. Institution-centred Informatics

3.1. Hospital Information Systems

Hospital Information Systems (HIS) were one of the earliest developments in medical informatics and were necessitated by the need to process large volumes of data and health insurance claims. Since then, HIS architectures have evolved from predominantly central, monolithic mainframe systems to a component system of networked-based servers that share data and information across an enterprise-wide collection of computers and workstations. In addition to supporting hospital administrative and managerial applications, today's HISs support an increasingly strong Clinical Information System (CIS) component that focuses on patient-centric functions of the HIS. From any CIS workstation, a doctor can query an electronic patient/medical record (EPR or EMR), giving him access to the patient's history, his laboratory test results from the laboratory reporting system, x-ray images or any radiologic scans from the hospital's picture archiving and communication system (PACS), biosignals such as ECG and EEG tracings. Typically, the CIS will also support an Order Entry system from which the doctor can prescribe medication online and should he over prescribe the dosages for a certain drug or should the drugs he prescribes have adverse interactions, the Alert and Reminder system of the CIS will be trigger an alert. In this way, an intelligent CIS can help minimize threats to patient safety and the occurrence of medical errors. More sophisticated CIS also supports access to online medical libraries and knowledge bases to provide decision support in the care and management of patients in terms of practice guidelines and care plans culled from knowledge bases.

3.2. Picture Archiving and Communication Systems

A Picture Archiving and Communication System (PACS) allows a hospital or medical centre to store digital copies of x-ray and other radiological images such as PET (Positron Emission Tomography) and MRI (Magnetic Resonance Imaging) scans and to deliver these images/scans across an enterprise-network to a desktop computer or a workstation. The advantages of a PAC system are apparent. It does away with the need for the hospital to find physical storage spaces for x-ray films and other scan images. Computerized access and retrieval of archived digital images is almost real-time compared with the hassle of archiving, locating and retrieving physical files thus cutting down on time and misplaced films.

4. Patient-centred Informatics

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4.1. Electronic Patient / Medical Record

The notion to develop electronic patient or medical records has been around since the time the role of computers to healthcare and medicine was recognized. One of the earliest developments of the EMR was Larry Reed's POMR (Problem Oriented Medical Record) which was implemented on PROMIS (PRoblem Oriented Medical Information System) at the University of Vermont Medical Center in the 1970s. The Problem Oriented Medical Record is so-called because it captures patient data according to the medical problem that is presented. Other strategies of capturing data in a patient record include TOMR (Time-Oriented Medical Record) in which patient data are captured in a chronological sequence and SOMR (Source-Oriented Medical Record) in which data are captured according to their source, e.g. doctor's notes, laboratory test results, nursing notes, radiology reports etc. The introduction of the POMR generated many interests in the development of electronic medical record systems. Some of the early ones included COSTAR (COmputer STored Ambulatory Record) developed by the Massachusetts General Hospital, the HELP system by LDS Hospital in Utah and the TMR (The Medical Record) system by Duke Medical Center.

Several points about electronic patient records are noteworthy.

The advantages of EPRs are as follows:

- legibility (no more deciphering the doctor's scribblings),
- accessibility (in terms of speed, location, multiple access),
- multiple views – several windows could be simultaneously opened on a single screen to view data from different sources,
- reduced data entry by using templates and icons,
- automated checks and alerts for data entry, spelling and prescription errors,
- built-in decision support
- saves physical storage spaces needed for paper records,
- eliminates misplacement / loss of paper records

Over the years, mode of data entry has also been an important issue. Should data entry be done by the clerk, the nurse or the doctor making direct entries on a computer? Entries made by the clerk by transcribing data and notes written by the doctor are expensive and very error-prone. Older generations of doctors are often resistant to the use of computers and making direct electronic entries. Hence, the human-computer interaction and human-computer interface issues (such as use of templates, re-usable data objects, voice and hand-writing input technologies) have been well-researched topics in the development of EPRs.

4.2. Knowledge Management / Decision Support

Medical knowledge is so extensive that it makes sense to use computer tools and algorithms to help the doctor access information where and when it is needed. For years, doctors who are computer-literate have been exploring the use of computers for knowledge management and decision support. One approach, known as "expert systems", attempts to mimic the diagnostic reasoning of clinical experts using artificial intelligence. Mycin,

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developed in the early 1970s, was one of these early expert systems which was designed to diagnose infectious blood diseases and recommend appropriate antibiotic treatment with dosage adjusted for the patient's body weight.

As the term Clinical Decision Support implies, the primary goal of CDS systems is to provide timely, current and evidence-based information to support clinicians in decision-making when treating and caring for their patients. Support can come in a variety of ways such as:

- clinical practice guidelines during clinical encounters
- alerts and reminders
- therapy critiquing and planning
- decision support for online drug prescription with alerts for potential drug interaction events
- data and information retrieval
- image retrieval, recognition and interpretation
- The use of clinical decision support in electronic patient records has been touted as the answer to improving patient care and enhancing patient safety by reducing the risks of medical errors.

5. Community-centred Informatics

5.1. Disease Surveillance

In recent years, there has been a surge in the development of disease surveillance techniques and tools. Two factors are largely responsible: threats from bio-terrorism and from emerging infectious diseases (EIDs). Ever since the terrorist strikes in the USA on 911 (September 11, 2001), the spectre of further terrorism strikes looms in many parts of the world. A major concern of terrorist threats is the possible use of biological weapons and several candidate agents have been implicated such as smallpox, anthrax, ebola and plague. The difficulty of dealing with biological agents of destruction is the incubation time needed to positively identify their presence, by which time, their goal of mass destruction of human lives would have been achieved. In fact, a recent report (August 18, 2006, Issue #207) in the news letter of the USA Agency for Healthcare Research and Quality (AHRQ) highlighted difficulties in diagnosing anthrax in children which will lead to dangerous delays in treatment of this often deadly disease. To forestall this problem, scientists have resorted to the use of informatics to set up networked sentinel systems for the early detection of illness clusters in the community before diagnoses are confirmed and reported to public health agencies. In doing so, a rapid response to a possible attack from a biological agent could be activated so as to reduce morbidity and mortality should the attack really take place. This kind of system which is based on the reporting of syndromes is aptly called syndromic-based surveillance system.

More recently, health threats from emerging infectious diseases (EIDs) have also sparked international concerns for effective disease surveillance to avert possible global pandemics. The lesson from the SARS episode of spring 2003 is one such example. Just as the SARS problem seems to have been wiped from the face of the earth, another new threat emerges from the H5N1 avian flu. In view of its rapid spread and the prospects of the virus

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jumping from its avian host to human host through mutation, there are worries of a replay of the global disaster caused by the Spanish flu pandemic of 1918 in which millions of people were killed. Such concerns have prompted the international community to develop disease networks to monitor and alert one another of the disease spread. In Singapore, for example, the Defence Science Organization (DSO) together with the Armed Forces Medical Corps has successfully built a system called Medical Large Scale Integrated Search and Analysis System (MELISA) that makes use of intelligent web agents to trawl Internet news feeds on infectious diseases [Walter Lim – APAMI]. Also, visualization tools such as Geographic Information Systems (GIS) are increasingly deployed to render disease hotspots and to map containment efforts. In one such example, mathematical modeling has been used to render a digital ring fence (DRiF) around an outbreak source on a GIS so as to visualize areas of population concentrations within the DRiF for containment efforts. The mathematical modeling helps to estimate the radius of the DRiF which is proportional to the risk of infection (Lun).

5.2. Telehealth / Telemonitoring

The importance of info-communications technology in healthcare has been recognized for a long time. In countries that have large land masses such as Australia, Thailand or Finland, the delivery of healthcare to remote areas which are thinly populated is a challenge. Similarly, island-rich nations such as Indonesia or the Philippines also have problems of providing healthcare services to underserved islands away from the main ones. One way of overcoming the geographical and distance barrier in the delivery of healthcare is to deploy telemedicine. The American Telemedicine Association (http://www.atmeda.org/) defines telemedicine as “the use of medical information exchanged from one site to another via electronic communications to improve patients' health status” and telehealth to encompass a “broader definition of remote healthcare that does not always involve clinical services”. Telemedicine activities can take place over a range of services:

- Simplest level – exchange of health and medical information via the telephone, fax machine or simple email
- Intermediate level – exchange of data and image information on a delayed basis – so-called “store and forward” method
- Highest level – interactive audio-visual consultations between patient and doctor or, doctor and doctor in the presence of the patient, using high resolution monitors, cameras and optional devices such as digital stethoscopes and other digital diagnostic tools. Probably the highest end of telemedicine service is the use of remote telepresent surgery in which a patient can be operated upon by a surgeon at a remote site.

Videoconferencing, transmission of still images, e-health including patient portals, remote monitoring of vital signs, continuing medical education and nursing call centers are all considered part of telemedicine and telehealth.

With increasing penetration of broadband internet into the homes of many countries, telemonitoring has, in recent years, become an exciting telemedicinal application. By connecting medical monitors such as ECG machines, glucometers and spirometers to their home computers, home-bound patients like heart patients, diabetics and asthmatics can now

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be remotely monitored by their care-providers from a distance.

The benefits of telemedicine are many. They include:

- Increasing access to healthcare and health information which in some cases can be life-saving;
- improving healthcare for patients in geographicaly disadvantaged or underserved communities;
- handling emergencies in remote areas such as in planes, on ships and on the battlefront where it may be difficult or impossible to give medical treatment to a patient in time;
- linking doctors with experts to enhance their skills and expand their professional knowledge;
- significantly reducing travel time for doctors and patients;
- minimizing the need to transport elderly or very ill patients thus reducing discomfort and risk of complications;
- reducing professional isolation of doctors and healthcare providers working in remote areas;
- facilitating cross-consultations between doctors so that patients have a higher chance of being treated correctly at the first consultation.
- Perceived disadvantages of telemedicine include:
- depersonalization of the patient-doctor relationship;
- potential clinical risks arising from remote consultation;
- high infrastructural and systems operation costs although these are increasingly being lowered with cost reduction in technology;
- costs in retraining medical personnel and revamping operational systems to adopt telemedicine;
- temptation to commercialize telemedicine without a sound business model.

There are also concerns over the practice of telemedicine such as malpractice liability if a telemedicine consultation goes awry and sufficient safeguards for informed patient consent especially over the explanation of the benefits and risks of a telemedicine consultation.

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Biographical Sketches

Professor K C Lun is a pioneer of medical informatics in Asia. Since presenting his first scientific paper at MEDINFO 86 in Washington DC, his accomplishments in the field include hosting the financially successful MEDINFO 89 in Singapore, chairing the Editorial Committee for MEDINFO 92 in Geneva, founding the Asia Pacific Association for Medical Informatics (APAMI) in 1994 and assuming the IMIA Presidency in 2001. In recognition for his contributions to the Organzation, Professor Lun was made an Honorary Fellow of the International Medical Informatics Association in 2004.

For 26 years, Dr Lun served on the Faculty of Medicine of the National University of Singapore (NUS) and held positions as Director of its Medical Informatics Research Programme and Director of the WHO Collaborating Centre for Health Informatics. His pioneering efforts in medical e-learning at NUS won him the *Teaching Excellence Award* in 1998. He is also credited as the creator of *Cyberspace Hospital*, the first virtual hospital on the World Wide Web, launched in 1995. In 2001, he left NUS to join the Nanyang Technological University to help start its School of Biological Sciences, serving as its founding Vice-Dean (Academic) and NTU Dean of Admissions in 2005.

Dr Lun has undertaken consultancies in biostatistics and medical informatics for the World Health Organization (WHO), the International Medical Informatics Association (IMIA), the International Development IDRC, UNDP and several other international agencies. He also serves on the editorial board of the *International Journal of Medical Informatics* and *Methods of Information in Medicine*.

For his contributions to the development of medical informatics nationally and internationally, Dr Lun was awarded the *Singapore Internationale Award* in 2001 and the *Excellence for Singapore Award* in 2002. After a rewarding career in academia spanning over 30 years, Dr Lun retired in October 2006 and set up Gateway Consulting . He still holds an adjunct professorship at the NTU School of Biological Sciences.

Dr. G W Brauer is Associate Professor in the School of Health Information Science, University of Victoria, Victoria, British Columbia, Canada, where he lectures in health informatics, healthcare systems, epidemiology, and the societal impact of information technology.

Following tenure of a New Zealand Medical Research Council Graduate Research Fellowship, that involved spending three years (1976-1978) in the South Pacific as part of an epidemiological research team based at the Wellington Clinical School of Medicine, Mr. Brauer returned to Canada, where he held various positions relevant to medical informatics: the University of British Columbia's Health Systems Division, the British Columbia Cancer Control Agency, and the British Columbia Ministry of Health. In 1988, his experience in informatics, epidemiology and health services research led to his joining the University of Victoria as a

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member of the teaching faculty of the newly established School of Health Information Science.

Dr. Brauer has been active in educational and health services research in provincial (BC Ministry of Health), national (Department of National Defense, Canada), and international (World Health Organization and United Nations University) settings. In the area of medical informatics, Dr. Brauer was recently appointed, by the UNESCO/EOLSS Joint Committee (Paris), to serve as a Member of the International Commission for Development of EOLSS Theme 6.59 on Medical Sciences. The EOLSS is the London-based Encyclopedia of Life Support Systems, and Dr. Brauer is the topic editor responsible for medical informatics as a sub-section of the medical sciences.

Developments in electronic communication and surveillance technologies have recently caused Dr. Brauer to become interested in the potential impact of information technology on educational and democratic processes, especially with regard to the increasing ability of commercial and governmental interests to use such technologies to gain and exert control over consumer behaviour. His current research focuses on information technology and its long term implications for health, including a critical examination of its role in education.

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