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Computer Based Medicine: I - The Future

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***Abstract*—**With the rapid growth in business size, today's businesses orient Throughout thirty years local, national and international experience in medicine as a medical student, junior doctor and eventually Consultant and Professor in Anaesthesia, Intensive Care and Pain Management, I note significant generalised dissatisfaction among medical students and doctors regarding their medical education and practice. We repeatedly hear complaints from patients about the dysfunctional health care system they are dealing with and subsequently the poor medical service that they are receiving. Medical students are bombarded with lectures, tutorials, clinical rounds and various exams. Clinicians are weighed down with a never-ending array of competing duties. Patients are extremely unhappy about the long waiting lists, loss of their records and the continuous deterioration of the health care service. This problem has been reported in different countries by several authors [1,2,3].

In a trial to solve this dilemma, a genuine idea has been suggested implementing computer technology in medicine [2,3]. Computers in medicine are a medium of international communication of the revolutionary advances being made in the application of the computer to the fields of bioscience and medicine [4,5]. The awareness about using computers in medicine has recently increased all over the world. In Misr University for Science & Technology (MUST), Egypt, medical students are now given hand-held computers (*Laptop*) with Internet facility making their medical education accessible, convenient and up to date. However, this trial still needs to be validated.

Helping the readers to catch up with the on going fast development in this interesting field, the author has decided to continue reviewing the literature, exploring the state-of-art in computer based medicine and up dating the medical professionals especially the local trainee Doctors in Egypt.

In part I of this review article we will give a general background discussing the potential use of computer technology in the various aspects of the medical field including education, research, clinical practice and the health care service given to patients.

Hope this will help starting changing the culture, promoting the awareness about the importance of implementing information technology (IT) in medicine, which is a field in which such help is needed. An international collaboration is recommended supporting the emerging countries achieving this target.

***Keywords*—**Medical Informatics, telemedicine, e-health systems.

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I. Introduction

IN 1969 the Advanced Research Projects Agency Network (ARPAnet) interconnected only four computers in the US Department of Defence in order that a communication signal could withstand a nuclear war and serve military institutions worldwide. This was the start of what we now call the Internet. By definition, it is an electronic network of computers that includes nearly every University, Government and Research facility in the World. It helps provide reliable and redundant connectivity between disparate computers and systems by using common transport and data protocols [6].

The author thought that it might be important exploring the following related definitions before discussing the details of the current topic.

i. Digital Library *(D-Lib)* is that oxymoronic phrase that attracted dreamers and engineers, visionaries, scientists and technicians. The field of D-Lib has always been poorly-defined, a "discipline" of amorphous borders and crossroads, however it's role in supporting medical teaching, learning and health care development is increasingly important [7].

ii. Webopedia (e-ncyclopaedia) is an online dictionary and search engine for computer and Internet technology definitions [7].

iii. Evidence-Based Medicine (EBM) is all about giving healthcare professionals a more informed way to decide what care to provide a patient and how to provide it. It is simply the right care, and only the right care, for the patient at the right time [8].

iv. Artificial Intelligence (AI) is the study of ideas, which enable computers to do the things that make people seem intelligent. The central goals of Artificial Intelligence are to make computers more useful and to understand the principles, which make intelligence possible [11]. Artificial Intelligence in Medicine (AIM) is AI specialised to medical applications for instance a large database collection of clinical histories of patients [5].

v. Medical Informatics is that scientific field that deals with the storage, retrieval and optimal use of information and data in medicine. It is often called healthcare informatics or biomedical informatics, and forms part of the wider domain of eHealth. The end objective of biomedical informatics is the coalescing of data, knowledge, and the tools necessary to apply that data and knowledge in the decision-making process, at the time and place that a decision needs to be made [3,4,5,6].

vi. Natural Language Processing (NLP) is a range of computer techniques for analysing and representing naturally occurring text (free text) at one or more levels of linguistic analysis (e.g. morphological, syntactic, semantic, pragmatic) for the purpose of achieving human-like language processing for knowledge-intensive applications [14]. In medicine it is known as Medical Language Processing (MLP) [9,10].

vii. State-of-the Art generally is the highest level of development, very up to date, as of a device, technique or scientific field, achieved at a particular time [4,5].

II. Discussion

In a 1970-review article, Schwartz has mentioned the possibility that the computer as an intellectual tool can reshape the present system of health care, fundamentally altering the role of the physician, and profoundly change the nature of medical manpower recruitment and medical education. In other words, the possibility that the health care system by the year 2000 will be basically different from that of today [4].

Three decades later, the dream has come true and the implementations of computer technology in medicine are now moving even quicker than was expected by Schwartz thirty-seven years ago.

In this article we discuss a very important key factor in improving medical practice, the integration of the complicated different aspects of the health care service in one dynamic and flexible process using computer technology.

We believe that any trial in this direction must start from the stage of the undergraduate medical education and then build up gradually until the whole process is completed in a very comprehensive way. The aim of this process is to make sure that the medical service delivered to the patient is safe and based on strong evidence. For example, in improving the system of the pain service, it is not enough to meet or exceed patient needs and expectations, and to improve the way in which the processes of healthcare delivery are organized. It is equally important to ensure that the clinical care being provided through these health care processes is scientifically correct.

This requires a chain of good medical education; research and clinical practice backed up with reliable administration as well as communication system. With the help of state of the art computer technology this chain could be continuously up dated.

The discussion would probably address the importance of AIM in particular to anaesthesia for being a very critical field of medicine where anaesthetists sometimes have to take immediate life saving decisions.

A. Computer Based Medical Education

1. Basic (Undergraduate) Medical Education

We believe that good basic medical education should be systemic, integrated and comparative to help understanding the field of the study. It should allow the medical student to broaden and develop his own skills as well as self-directed learning. The medical student using the problem-based learning method (PBL) can achieve this. Problem-based learning is one of the most important educational developments in medicine in the past 30 years. It is a continuum of approaches rather than one immutable process. PBL can be included on the student's Laptop along with a range of additional computer based learning resources e.g. lectures and clinical sessions [11,12].

Some researchers have evaluated computer-based medical education. A single blind, randomised, controlled study of 166 undergraduate medical students at the University of Leeds, involving an equal duration of an educational intervention of either a structured lecture or a computer-based teaching package. There was no difference in knowledge between the groups at baseline or immediately after teaching. Both groups made significant gains in knowledge after teaching. Students who attended the lecture rated their subjective knowledge and skills at a statistically significant higher level than students who had used the computers did. Students who had used the computer package scored significantly higher on an objective measure of assessment skills. Being a new method of undergraduate medical education, students didn't perceive the computer package as useful as the traditional lecture format, however they found the computer package easy to use and recommended its use to other students [11]. We believe that the results of the above-mentioned study were generally positive supporting the move toward computer-based undergraduate medical education. The level of the medical students' perception to computer based medical education is expected to improve when they are encouraged to use it more in the future.

As a part of a Finnish nation wide project aiming at Information Technology (IT) Culture in Medical Education in Finland, a survey was done in 2001 focusing on the attitudes towards IT and its use among teachers and students at two medical schools. The results of this survey showed a very positive attitude toward the use of IT and also found that computer related technology was widely applied. However, teachers used IT more in their research work than in teaching. The conclusion underlined the importance of educational and psychological knowledge in combination with new technical skill [12].

In some developing countries including Egypt, quite a few Universities e.g., MUST are now started to encourage their students to use their own personal computers facilitating their medical education. Well-controlled randomised comparative studies are still needed to evaluate the benefit of computer-based undergraduate medical education in these Institutes.

2. Advanced (Postgraduate) Medical Education

The question what kind of learning do young doctors have to do when they graduate has always been a hot topic. Two categories of postgraduate education are available for them. The first one is Further Formal Study aiming for post-graduate degree e.g. MSc., MD, and Fellowship or Membership. The second category of learning is Continuing Professional Education (CPE). Due to the nature of the doctors' heavy clinical duties, any type of learning would be mostly workplace-based learning. Computer based learning can

definitely help in this case scenario by supplying rural and remote physicians with their continuing medical educational needs. A wide range of distance learning technologies and methods are now available including audio teleconferencing, slow scan imaging, correspondence study and compressed videoconferencing.

The recent emergence and growth of Internet, World Wide Web (Web) and compact disk read-only-memory (CD-ROM) technologies have introduced new opportunities for providing continuing education to the rural medical practitioner.

Curran et al evaluated the instructional effectiveness of a hybrid computer-mediated courseware delivery system on dermatological office procedure. The study found that a hybrid computer-mediated courseware system was an effective means for increasing knowledge ($p < 0.5$) and improving self-reported competency ($p < 0.5$) in dermatological office procedures, and that participants were very satisfied with the self-paced instruction and use of asynchronous computer conferencing for collaborative information sharing among colleagues [13].

B. Computer Based Clinical Practice

1. Evidence-Based Medicine (EBM)

In our every day clinical practice we usually take clinical decisions on the basis of extrapolated data rather than well-established facts derived from patients. The patient has the right to know the scientific evidence of the treatment he is having and doctors should always be prepared to discuss the different lines of management offered to their patients on a scientific bases. Now the availability of good quantity of well-controlled randomised double blind studies helps making the clinical reasoning of consultants more comprehensible and accessible to trainees. The medicine based on integrated clinical experience along with patient data and the best available research information is evidence-based medicine (EBM). EBM gives the healthcare professionals a more informed approach based on science rather than opinion to decide what care to provide a patient and how to provide it. The problem is delivering the required information at the right time, the right place to the right persons in order to improve the quality and efficiency of the care processes [14,15]. Evidence is gathered through systematic review of the literature, and rules of evidence are applied to critically appraise this original research. Rather than personal opinion or experience, the results of this appraisal are used as the cornerstones of clinical decision-making.

An example for the projects developed to promote EBM is the evidence based medicine information and resource centre in US. Between 1998 and 2001, the New York Academy of Medicine (NYAM) in collaboration with the New York State Chapter of the American College of Physicians (ACP-NY), proposes to establish a centre to help: providing clinicians and librarians with education and training in EBM, informatics resources and the necessary computer competency skills; providing librarians with the required skills to work in partnership with clinicians in accessing and managing medical clinical information; developing and supporting the growing constituency of medical faculty, clinicians and librarians through newsletters, list-serves, and assistance in accessing evidence-based resources; creating and implementing the state-of-art technological centre for supporting EBM practice *[CRISP-Computer Retrieval of Information on Scientific Projects, Abstract Display]*.

Computer-assisted decision support tools for clinicians facilitate integration of individual patient data with the best available research data [16]. For example using the invasive transpulmonary thermodilution cardiac output measurements or the less invasive Pulsion continuos cardiac output (PICCO) technology to help manage critically ill patients in intensive care units (ICU) [17].

2. Medical Informatics (MI) and Electronic Medical Record (EMR)

The term “medical informatics” or “health informatics” is the intersection of information science, computer science and health care. It needs understanding, skills and tools that enable the appropriate use of information to deliver good standard of heath care. Health informatics tools include not only computers but also clinical guide lines, formal medical terminologies, and information and communication systems. Sub domains of (bio) medical or health care informatics include: clinical informatics, nursing informatics, imaging informatics, consumer heath informatics, public heath informatics, dental informatics, clinical research informatics, bioinformatics, veterinary informatics, and pharmaceutical informatics *[US Office of the National Coordination for Health Information Technology (ONCHIT)], [http:www.linuxmednews.org Linux Medical News]*

Medical informatics began to emerge in the US in the 1950s with the rise of the microchip and computers, under the early name “medical computer science. The field has gradually spread involving Europe, Asia and Australia. However, it is very unfortunate to find that this interesting scientific phase still immature in Africa including Egypt.

Health informatics law deals with complex legal principles as they apply to information technology in health-related fields including the privacy, ethical and operational issues.

Computer-based medical records of patients, although an area of active research, are not widely used yet especially in the developing countries. EMR is vital to doctors helping them retrieve the relevant patients’ data for clinical, audit and research purposes. It helps link different departments within the hospital. It consists of different modules, each performing a specific set of function e.g. financial, administrative, and clinical work. Some special software is also available to help integrate the patient’s clinical information helping doctors in predicting the patient’s outcome [3,6]. The different versions of acute physiology and chronic health evaluation (APACHE, I, II&III) scoring system in ICU are an example of this software [18]. Other important automated clinical applications of EMR are outcome studies, quality assurance, resource management, and clinical research [4,5].

C. The State-of-the Art Computer Based Medicine

1. The Use of Medical Language Processing (MLP) Technology

Despite attempting to apply computer technology in medicine since 1970s, these applications are still limited because they require access to clinical data. Because textual information is too varied, such access is possible with coded data only, which is not widely available [9]. Text is difficult to access because it is extremely diverse and the meanings of words vary depending on the context [10]. For instance the outcome of searching for the patients who were diagnosed to have had a stroke within the past ten years would retrieve confusing information because natural language is difficult for computers. In this case the computer would retrieve every text contains the keyword stroke. With the help of MLP the computer would be able to process our natural language to a computer one. Different modifiers (software) are required extracting the individual words and representing the well-defined relations among the words. In the above-mentioned example, a date modifier is required to determine those who had a stroke within a specific period of time [9,10].

2. Computer Aided Learning (CAL)

Computer aided or Machine Learning (ML) is one of the major branches of artificial intelligence in medicine [4,5]. It provides several relatively inexpensive methods for intelligent data collection, storage, and analysis. ML is currently well suited for analysing medical data, especially in medical diagnosis. As an Anaesthetist, I'm especially interested in AI in relation to anaesthetics [19,20,21,22,23,24,25,26,27].

In a trial to help anaesthetists deal efficiently and promptly with anaesthetic crisis, a structured algorithm (based on the mnemonic COVER ABCD-A swift check) would diagnose and correct the problem in 60% of cases and provide a functional diagnosis in virtually all of the remaining 40% [19].

Anaesthesia Simulator-Recorder (ASR) is another computer program that trains and evaluates anaesthetist's management of critical incidents [20]. The program could be downloaded on IBM compatible personal computers, combining a graphic display of the operating room with mouse-driven input and using an integrated set of physiological and pharmacological models to predict patient's responses. It records the simulated patient's vital signs and all management decisions, and produces a printed case summary. Forty-four residents and attending anaesthetists evaluated the program at 7 training centres. They found it easy to use with clear presentation of the case and management options.

ATTENDING is another computer system under development using Artificial Intelligence techniques, designed to critique an anaesthetist's pre-operative plan for anaesthetic management. The system receives the details of the pre-anaesthetic assessment, and discusses the risks and benefits of the suggested anaesthetic approach and explores alternative plans. The ATTENDING system is currently available in a tutorial mode allowing anaesthetist's self-evaluation [28].

Completing anaesthesia records is crucial not only from the clinical point of view but also for medicolegal purposes. The use of a computerised anaesthesia record helps with scanning case records electronically for deviations from specific limits for physiologic variables. Compared with voluntary reporting, the computerised anaesthesia record was found to be more specific and highly sensitive. All participants of the above-mentioned study found that the voluntary reporting had a significantly lower level of compliance than the electronic one and there was also a strong association between intra-operative incidents and in-hospital mortality [29].

The author would like to address that while we are calling to move toward computer-based medicine, it is equally important to mention that direct contact with patients still and will continue to play a pivotal role at all steps of medical education including undergraduate as well as postgraduate levels. Clinical reasoning, communication skills, professional attitudes and empathy can't be taught indirectly. Patient-orientated learning also helps motivation through promoting relevance and providing context. This area of medical education has been investigated in some studies, including effects on the patients themselves, although there are examples of good practice in promoting more active participation [30,31].

3. Computer Aided Detection (CAD)

Computer-aided detection (CAD) for mammography is a new and developing topic in the field of breast radiology. Despite the best efforts of the radiologists, some breast cancers remain undetected on screening mammograms, which could be a serious medico-legal issue. With the help of CAD, 20% more women were recalled, 20% more cancers were detected, and 20% more time was spent in the screening room than without CAD. Technology will continue to improve over time, and CAD algorithm will improve in their ability to detect masses and to prompt radiologists regarding a finding *[eMedicine-Mammography-computer-Aided Detection: Article by Michael J Uliss]*.

4. Computer Aided Surgery (CAS)

CAS is a term for the research field concerning "advanced surgical techniques, and technology that creates them". In Japan, Professor Takeyoshi Dohi and Professor Masakazu Tsuzuki in the University of Tokyo were the pioneers using this word in their research. "Computer Assisted Surgery" is a more common term in some other counties. This new surgical field has used different experimental as well as clinical techniques including robotics, optics or virtual reality "VR for medicine". To include all these names in one helping researchers exchanging their knowledge, a new single term are needed *[http://homrpage2.nifty.com/cas/whathtm]*.

The human-machine partnership is important because it offers the possibility both of significantly improving the efficiency, safety and cost-effectiveness of exiting clinical procedures and of developing new ones that can not be performed at all otherwise *[http://homrpage2.nifty.com/cas/whathtm]*.

The aims of CAS are to improve patient care by advancing the utilisation of computers during treatment; to evaluate the benefits and risks associated with the integration of advanced digital technologies into surgical practice; to disseminate

clinical and basic research relevant to stereo tactic surgery, minimal access surgery, endoscopic and robotic surgery; to encourage interdisciplinary collaboration between biomedical engineers and physicians in developing new concepts and applications; to educate clinicians about the principles and techniques of CAS and therapeutics and finally to serve the international scientific community as a medium for the transfer of new information relating to theory, research, and practice in biomedical imaging and the surgical specialities *[http://homrpage2.nifty.com/cas/whathtm]*.

Needless to say that CAS is not to replace surgeons with robots because this would simply be unsafe technique. However, it would be very helpful using robots in impossible or monotonic (boring) tasks for humans. It is interesting to mention that a robotic surgery doesn't mean at all "a robot", but a new surgical tool helps in a complex, precise or dangerous tasks for human, or in complemental tasks such as positioning of endoscope.

III. Conclusion

In general the old traditional definition of illiteracy used to be the inability to read and write. The fast development in IT over the last few decades dictated us to change this definition to lack of ability dealing with computer.

As doctors, the future of our practice is expected to be computer based. Currently, a number of computer programs already available demonstrating that the various application of AIM is very useful. This field still rich with many other ideas attracts researchers to discover new applications for computers in medicine aiming at continuously improving all aspects of the health care service.

However, clinical experience gained from direct contact with real patients remains to be vital and irreplaceable in medical education.

Finally, our recommendations are directed mainly to the health care authorities and the medical schools in the developing countries urging them to take immediate step moving toward computer based service. Establishing EBM Information and Resource Centre to help the promotion and use of EBM is increasingly vital meeting the international standard of good health care. Also, AI and Web-based intelligent learning is becoming more effective. AI has made computer more useful and intelligent utilising them in all the fields of human life including health care. Promoting further research in this area and its underlying technologies are crucial.

This requires setting up a standard and a solid applicable plan to be achieved within a certain period of time, catching up with the modern World.

The sporadic individual actions taken already by some medical schools in this direction need to be organised, generalised and scientifically validated.

The author believes that computer based health care is not a luxury but it is an essential service and shouldn't be implemented only in the rich cultures but also in the overseas countries.

Therefore, it is important that the different International health organisations especially the World Health Organisation (WHO), need to work together in helping modernise the health care services for all mankind hoping that this sort of collaboration would give the globalisation a positive meaning.

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