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REVIEW ARTICLE

BASIC MEDICAL SCIENCE EDUCATION MUST INCLUDE MEDICAL INFORMATICS

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Abstract : Medical Informatics is the science and art of processing medical information. In this age of "Information Explosion" choosing the useful one is rather difficult, and there lies the scope of electronic database management. However, still many outstanding personnel related to the healthcare sector take pride in being "computer illiterate". The onus of the best use lies on the end-user health care providers only. Another term tele-health encompasses all the e-health and telemedicine services. Computer aided or assisted learning (CAL) is a computer based tutorial method that uses the computer to pose questions, provide remedial information and chart a student through a course. Now the emphasis in medical education, is on problem based learning (PBL) and there CAL could be of utmost help if used judiciously. Basic Medical Education and Research lays the foundation for advancing and applying proper healthcare delivery systems. There is no doubt that deep knowledge of anatomy is mandatory for successful surgery. Also, comprehensive knowledge of physiology is essential for grasping the principles of pathology and pharmacology adequately, to avoid incorrect and inadequate practice of medicine. Similarly, medical informatics is not just a subject to be learnt and forgotten after the first professional MBBS examination. The final aim of every student should not only be to become a good user but also an expert for advancing medical knowledge base through medical informatics. In view of the fast changing world of medical informatics, it is of utmost necessity to formulate a flexible syllabus rather than a rigid one.

Key words : medical informatics; medical education and research; flexible syllabus

INTRODUCTION

Medical Informatics, a novel academic discipline, bridging Medicine and Information Sciences, has already made its presence felt. It may be defined as the art and science of processing medical information, where 'information' is the processed 'data' (1–5). The modern age is called the "age of information" and we are

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becoming apprehensive of "information explosion". Improper access to excessive information leads to nothing but confusion. This is truer in conditions of life and death - which the medical profession has to handle regularly.

Bioinformatics broadly relates to proteomics (informatics of protein structure banks), genomics (informatics of genomes and gene banks) and various newer drug synthesis methods. However, clinical or medical informatics also is a subset of it. Information is derived from the assembly, analysis or summarizing of data into a meaningful form. Data mean any group of operands or factors consisting of numbers (numerical), alphabetic characters or symbols (linguistic), which denote any condition, value or state. Knowledge comprises generalized truths formed from the analysis of available information. Medical or health informatics (dealing with medical information), is a necessary discipline in the tropical countries like India. With the development of excellent satellite telecommunications here, its prospects are brightening. However, this requires essentially a multidisciplinary interaction.

To cite an example, an elderly lady who presents with a fractured forearm due to fall, may have other problems leading to the fall. She might be having increased frequency of urination because of diabetes or urinary tract infection (or benign enlargement of the prostate, in case of a male). While going to the toilet, in the night, due to failing eyesight (which again may have been caused by cataract or drugs), she may overlook an obstacle and fall. The fall may also be due to increased or decreased blood pressure or blood sugar. Moreover, staying alone in the house also could be responsible as there is no one to take her to the toilet. The psychological condition might well be depressed or demented, leading to confusion and unmindfulness. Therefore, the forearm fracture, in an aged lady, has a greater amount of 'history' than the same in a young lady. An overburdened human doctor (not a medical student though!) may not be entirely unjustified if he or she fails to ask or register some of these predisposing factors in the particular example.

The scopes are immense as Medical informatics forms the interface between the subject domain of medicine, and the science and technology of computing. It requires essential inputs from cognitive sciences (including Psychology), information and communication sciences (library and documentation), computer sciences (hardware and software), logic, statistics (including biostatistics and epidemiology), decision sciences, clinical and basic (pre- and para-clinical) medical sciences, health economics and policy making as well as from medical ethics.

Health information systems (HIS)

Health or Hospital information System (HIS) is an integrated system encompassing the departmental systems (like radiology, pathology and pharmacy), as well as the clinical systems (like Intensive Care Unit or ICU). However, a proper definition (6, 7) is yet to evolve. The database includes all sorts of records for each patient, including admission, evaluation, management, transfer, and discharge information, with supporting evidence. Clinical Decision support systems (CDSS, described below) may also be incorporated (8) into it. It is the integration of global needs for all the healthcare users. Finally connecting it to a tele-health (e-health or health related use of electronic information and telemedicine or remote medical consultation) system, people at far places could benefit a lot (9).

It may be realized by interfacing a central system to multiple departmental *(e.g.,* Biochemistry, Pathology, Microbiology, Pharmacy and Radiology) and clinical information systems *(e.g.,* intensive or critical care units and nursing units). Middleware in HIS may purvey solutions which integrate data for end users at the front, while hiding the multiplicity of origins of the data at the background. There are various standards (2, 3, 6, 7) that have been (and are being) developed for medical messages communication format. Some of the notable ones include : ASTM (American society for testing and materials), ASC XI2N, DICOM (Digital Image and communication in Medicine, USA), HL7 (Health Level Seven, Inc. USA), IEEE PI 157 (from Institute of Electrical and Electronics Engineers, Inc. USA) MEDIX (Medical data interchange standard), IEEE PI073 MIB (Medical information bus), and NCPDP (National Council for Prescription Drug Programs, USA).

Computer based patient records (CBPR or CPR)

Computer based patient records (CBPR or CPR) involves digitizing all data related to a patient being treated in a hospital (along with modifications and updates) and storing in an easily retrievable or searchable form. The database may include patient admission, transfer, discharge, evaluation and management, as well as, hospital and ambulatory care systems, and at times also CDSS (1, 4, 8). A plethora of nomenclature abounds in literature like EMR/EPR (Electronic medical or patient record) /PMR (Patient medical record) for similar entities. However, present day stress is on *EHR* (Electronic Health Record) *i.e.,* the whole data record of a person in health and disease both.

Clinical or diagnostic decision support systems (CDSS)

Reaching a foolproof diagnosis is never an easy job for a clinician. Often, a simple diagnostic procedure or test is overlooked and the disease eludes diagnosis. Clinical reasoning and decision making are phased. Initially there is a clinical evaluation (history taking and physical examination), followed by precise laboratory investigations. Then integration of clinical findings and test results is done. After that, comparative benefits and risks are weighed among the alternative courses of actions, like drug interactions. Finally, the patient's preferences are taken into account, along with ethical and other considerations like cost of therapy, compliance expectations and a therapeutic plan is developed. Right from the first step (history taking) to the final one, computers can be of immense help to the clinician.

While taking history from a patient, an experienced doctor does an 'iterative hypothesis testing', while a medical student or a fresh graduate learns to do 'comprehensive history taking'. The first method is known as the 'rule of the thumb' or heuristics, which comes from experience and is therefore bound to cause more errors despite saving time. As human brains (and neural networks) work in milliseconds, computers can actually do a comprehensive history taking in a much shorter time.

I have the pleasure of developing some diagnostic decision support systems for medical education and research. A simple example (using the iterative dichotomizer or ID3 decision tree) is provided in www.geocities.com/drsupten. Nevertheless, for computer-assisted diagnostic systems, a human clinician ("man in the loop" for "Intelligence Amplification") must be a necessary component. Moreover, the clinician must understand completely the strengths and limitations of them. Computerized diagnostics and clinical acumen are not mutually exclusive; rather they should reinforce each other for the alleviation of psychosomatic suffering of mankind.

"Expert Systems" (ES) are complex AI (artificial intelligence) programs. Strong AI addresses emulation of human cognition like Natural Language Processing (NLP). Weak AI, on the other hand, deals with "Knowledge Engineering" and is concerned with engineering of systems to perform so called "intelligent" human tasks, like Medical Diagnosis, optimal portfolio selection and battle plan management. The most widely used way of representing domain knowledge in ES is as a set of production rules, which are often coupled with a frame system that defines the objects that occurs in the rules. The frame (expert system shell) format will depend upon the problem domain (its nature and size) and also on the nature of the problem-solving task. Undoubtedly the most difficult task in designing a knowledge-based system is the "knowledge elicitation bottleneck" mainly due to paradox of expertise. It is often said that experts do not know what they know. (The well-known Greek philosopher Socrates called himself clever because he knew that he knew nothing!).

After eliciting the domain knowledge, successfully reformulating it into the system is of utmost importance. One way of doing it is 'scenario analysis' (a structured interview), involving a face-to-face interview with the expert, recorded by video or audio tape for subsequent transcription and analysis. Another common method is 'protocol analysis', observing the expert actually doing the job. Protocols are later made from the records. Unfortunately, information obtained from the protocols may not be sufficient to render sensible rules.

Study of the organization of knowledge is known as Epistemology. After acquiring the knowledge, 'epistemological analysis' is conducted to establish the structural properties of expertise.

Ultimately, 'logical analysis' is performed to map the knowledge to a formal structure. At this stage of the design process, the expert's knowledge is reformulated for the system. After the knowledge engineer codes the knowledge explicitly in the knowledge base, the subject expert (clinician) may then critically evaluate the system (repeatedly) until a satisfactory performance level is reached.

ES for medical diagnosis (clinical or diagnostic decision support systems)

For medical diagnosis, there are scopes for ambiguities in inputs, like, history (patient's description of the diseased condition), physical examinations (especially in cases of uncooperative or less intelligent patients), laboratory tests (faulty methods or equipment). Moreover, for treatment, there are chances of drug reactions and specific allergies), patients non-compliance of the therapy due to cost or time or adverse reactions. Because of advent of new modalities of treatment, almost daily, decision making towards a particular treatment regime to be adopted for each individual patient becomes a complex process. More often, a large amount of information has to be processed, much of which is quantifiable. Intuitive thought processes involve rapid unconscious data processing & combines available information by law of average and therefore has a low intra- and inter-person consistency. So, the clinician of today should move towards analytic decision making, which albeit typically slow, is conscious, consistent and clearly spells out the basis of decision.

Connectionist expert systems

The other branch of AI is 'ANN' or artificial neural networks. Because of their interconnections, ANN approach is often called connectionist. *Connectionist ES* are ANN based ES where the ANN generates inferencing rules *e.g., fuzzy-MLP* where linguistic and natural form of inputs are used. Apart from that, 'rough set theory' may be used for encoding knowledge in the weights better and also GAs (genetic algorithms) may be used to optimize the search solutions better. All these methods fall under the purview of "soft computing".

For instance, a trained MLP (4) is used for rule generation in *'If-Then'* form. These rules describe the extent to which a pattern belongs or not to one of the classes in terms of antecedent and consequent clauses. For this, one has to backtrack along maximal weighted paths using the trained net and utilize its input and output activations. After training, the connection weights of an MLP encode among themselves (in a distributed fashion) all the information learned about the input-output mapping. Therefore, any link weight with a large magnitude reflects a strong correlation between the connecting neurons. This property is utilized in evaluating the importance of an input node *(feature)* on an output layer mode *(decision).* For this one needs to compute the path weights from each output node to each input node through the various hidden nodes. Each output-input path that is maximum (through any hidden node) denotes the importance of that input feature for arriving at the corresponding output decision. One or more hidden layers may be considered (if necessary) for evaluating the path weights. An increase in the number of hidden layers simply leads to an increase in the possible variety of paths being generated through the various hidden nodes in the different layers. A heuristic thus allows selection of those *currently active* input neurons contributing *the most* to the final conclusion (among those lying along the maximum weighted paths to the output node *f)* as the clauses of the antecedent part of a rule. Hence, it enables the *currently active* test pattern inputs (current evidence) to influence the generated "knowledge base" (connection weights learned during training) in producing a rule to justify the *current* inference. The complete *If* part of the rule is found by *ANDing* the clauses corresponding to each of the features.

Because of the inherent fuzziness (qualitative nature) of most biomedical data, connectionist expert systems are likely to fare better than their traditional counterparts, as far as diagnosis reaching is concerned.

Spatiotemporal contextual information can be incorporated for automated EEG analysis through syntactic analysis techniques. Here, EEG is represented as a series of elementary patterns called "tokens". After subdividing an EEG tracing into 1-second intervals, a sequence of unique characters may be called a "label". The resulting sequence of "labels" is usually known as a "sentence" which is "parsed" by a definite "grammar". A grammar consists of a set of rules that governs the merging of tokens into higher-order recognizable entities in the input data.

A severe drawback in this approach lies in the amount of heuristics involved in writing the grammar. Also, it is almost impossible for an untrained electroencephalographer (EEGer), to inspect the grammar and make the necessary modifications. Knowledge-based approaches purvey a way of increasing the involvement of the expert (EEGer) in the design process and also allow the utilization of contextual information to a larger degree. These systems apply a body of knowledge ("knowledge-base") to the input data and subsequently derived facts ("data-base"). Typically, the knowledge base comprises IF<premise>THEN<action> type rules which presumably reflect the human expertise. Another advantage of this type of flexible problem solving approach is that the collection of rules may be modified from time to time. Knowledge-based enhancement of EEG signals and parallel processing are being employed to save time and effort, as well as to increase the accuracy of the interpretations.

Rule generation: The trained MLP is used for rule generation in *If-Then* form. These rules describe the extent to which a pattern belongs or not to one of the classes in terms of antecedent and consequent clauses. For this, one has to backtrack along maximal weighted paths using the trained net and utilize its input and output activations. After training, the connection weights of an MLP encode among themselves (in a distributed fashion) all the information learned about the input-output mapping. Therefore, any link weight with a large magnitude reflects a strong correlation between the connecting neurons. This property is utilized in evaluating the importance of an input node (feature) on an output layer mode (decision). For this one needs to compute the path weights from each output node to each input node through the various hidden nodes. Each output-input path that is maximum (through any hidden node) denotes the importance of that input feature for arriving at the corresponding output decision. Note that one or more hidden layers may be considered (if necessary) for evaluating the path weights. An increase in the number of hidden layers simply leads to an increase in the possible variety of paths being generated through the various hidden nodes in the different layers. For the details the interested reader may kindly refer to Sarbadhikari and Pal (4).

Computers in medical training

Computer aided or assisted instruction *(CAI)* is a tutorial method using a computer as a base for managing the student's progress (at the desired pace and time). Computer aided or assisted learning *(CAL)* is a computer based tutorial method that uses the computer to pose questions, provide remedial information and chart a student through a course. Especially now with the emphasis, especially in medical related fields, *on problem based learning (PBL),* these have gained greater significance. In the case of PBL, the approach is top down, rather than bottom up, *i.e.,* instead of starting from Physiology or Biochemistry, one discusses a patient's presenting features and goes backwards to find the physiological and biochemical basis of the disease presented. Here also electronic tutorials can be of great help to the students. Especially in the cases where some invasive procedures have to be used, 'simulators' are far better suited since they do not cause pain or harm to any real person. Cadaver dissection does not give an idea of the functional correctness of the organ structures, while animal physiological studies give a wrong impression of the human organs' anatomy. While studying on patients is commonly done (because of the population explosion in our country there is certainly no dearth of patents!) it may not be ethically sound in all the cases. The other common practice of trying things out on each other (classmate or roommate) is also not without its share of pain, discomfort, and occasionally shyness.

Evidence based medicine (EBM)

For selecting the appropriate alternative regime for a particular patient, there is no definitive method. Data sheets on various medicines purveyed by the pharmaceutical manufacturers are not of much help since they focus on only one particular (generic or brand) drug, while doctors require comparative data on all available treatment modalities. To overcome this problem, Evidence Based Medicine (EBM) compiles data based on systematic review of RCTs (randomized control trials), through 'meta-analysis', involving all available therapies. To cite a concrete example, the comparative effectiveness of various interventions in relieving or reducing pain of osteoarthrosis (OA) can be summarized as: Beneficial and likely to be beneficial. In the first group we get systemic simple analgesics like paracetamol (acetaminophen) for short-term pain relief and improvement in function, systemic NSAIDs (non steroidal anti-inflammatory drugs), which too give short-term pain relief and functional improvement and topical analgesic agents (for short term pain relief). In the second group we find education, dietary advice, empowerment, and support (improved knowledge of the disease and pain relief). Physical support also purveys pain relief and functional benefits. The key points to note are : no good evidence that NSAIDs are superior to paracetamol or to suggest that any one of the various NSAIDs available in the market has greater efficacy in pain reduction in OA. One systematic review of RCT has found that topical agents relieve pain in OA and offer a less toxic alternative to systemic drug therapy. However, there is no evidence to the effect that prescribed local analgesics are superior to cheaper, non-prescription OTC (over the counter) alternatives or local hot/cold packs. On recovery from active inflammation, a program of stepwise simple (isotonic) exercise (like quadriceps exercise or stretching and relaxing the knee joints in knee OA) is often essential.

Case based reasoning (CBR)

A medical practitioner encountering a new problem is usually reminded of the similar cases seen in the past. New problems are solved by analogy with the old ones and explanations and reasoning are often derived from the prior experiences. This sort of a problem solving, by computer systems is called case based reasoning or CBR. It must have a large case library instead of a set of rules. The indexing system must also be of very high quality. Albeit this is a computer learning paradigm, in the case of medical expert systems, this problem solving approach is often very useful. Here the learning may combine both inductive (several positive and negative examples) or explanation based learning (EBL), where a single example is enough to generalize a solution. For clinical decision making, iterative dichotomizers (ID) or decision tree form of inductive learning and EBL methods may be used by computers.

Such a system must find out: (A) how cases are organized in memory, (B) how are relevant cases retrieved from memory, (C) how can previous cases be adapted to new problems and (D) how cases are originally acquired. For organizing cases in memory, a rich indexing system must be used. For retrieving and matching the best case from a huge database of cases, *preference heuristics* may have to be used. They may be :

1. Goal-directed preference: preferring cases that involve the same goal as current case.
2. Salient-feature preference, preferring cases that match the most important or maximum number of features.
3. Specificity preference : preferring cases that match features exactly rather than generally.
4. Frequence preference : preferring frequently matched cases.
5. Recency preference: preferring recently matched cases.
6. Ease-of-adaptation preference : preferring cases with features that are easily adapted to new situations.

As the best case will also not match the current situation exactly, it has to be adapted. This can be done by mapping new objects into old ones. For this, the case library may have to be augmented with a plan-modification library and another plan-repair module for future reference. Finally, for acquiring original cases, a thorough CBPR is absolutely necessary.

Statistical analyses

Many (practically all) of the statistical methods applied to biomedical research are better done with computers, especially multivariate analyses and higher order calculations. Earlier only the simpler statistics that were calculated by pocket calculators (within a few hours) were used in research. Now, computers can solve complex problems in seconds (which previously would have taken days or months). Interestingly, not only statistical analyses for research findings, but also for day to day applications like CT scan or MRI are done by computers with very high computational power.

Another important area of biostatistics is the *meta-analysis* of various controlled cases to reach a rational conclusion for EBM.

2. Medical informatics in relation to the basic medical sciences

Medical Informatics could be used for :

(a) Research and Teaching of Basic Medical Sciences - Model building, theory development and innovative experimentation. The aim should be building new knowledge from existing ones, structuring and assimilating the knowledge in terms of cause-process-effects. Standardization of the approaches for reaching a decision is also required.

(b) Applied Research - Formal experimentation with proper evaluation.

(c) Engineering applied to basic medical research- Specific tool building and development.

(d) Implementation of applications for basic medical education and research - Operation, maintenance, management, updating of the applications and training for the users.

(e) Planning and policy development - Role of information technology in health care delivery and medical education.

This sort of a 'fused' or 'sandwich' discipline requires expertise from various (apparently unrelated) fields and can, therefore, cater career openings to a multitude. Professionals with backgrounds in many of the diverse disciplines can join the bandwagon and contribute fruitfully, he gross application may be in the field of "Academic medical informatics" - Research and development, *i.e.,* educational support. The eligible candidates are usually health care delivery professionals (students, teachers and practitioners) who have pursued some training in medical informatics.

Some examples of applied importance are given below. Building a proper knowledge base for basic medical sciences and updating it dynamically with the progress in research, albeit seemingly rather mundane, is of utmost importance. Here the necessity for proper training arises. Even for utilizing all the available electronic educational resources, some minimum expertise is called for.

PCCAL Consortium at School of Pharmacy and Pharmacology, Bath University, UK, produces CAL (Computer Aided Learning) courseware to teach pharmaceutical and life science students, marketed in association with CoACS (www.coacs.com/PCCAL). Similarly, www.mdl.cuhk.edu.hk/mdlcal/psilink.html gives links of various useful Internet Resources on Physiology. The other Internet Guru is http://bubl.ac.uk/link from where through the Life Sciences link, going to the Main Subject menu, one can get a multitude of links to Physiology, Pharmacology, Anatomy, Biochemistry, Pathology, Microbiology and others. Finally the greatest of greats Google (www.google.com) can take you anywhere, provided the keywords are very specific, otherwise it will simply come up with millions of useful (and not so useful) materials. Once a student (and teacher) has access to these animated tutorials, not only will the boredom typical of a classroom vanish, but difficult concepts can be grasped very easily.

Let us take a concrete example. An experienced teacher in Physiology may easily visualize how a skeletal muscle contracts and relaxes, what is the mechanism of power stroke, what is the role of calcium and magnesium and so on. However, for a beginner, the three dimensional structure of the muscle fiber and its nerve connections seem to be incomprehensible. But, if the student starts with an animated version of muscle contraction, along with its explanations, the concept is etched powerfully in the long term memory. This sort of benefit accrues for the Korotkoff sounds or the heart sounds (normal and adventitious) as well through animated tutorials. In which stage of erythropoiesis the nucleus is extruded, that is rather difficult to memorize initially, but if one "sees" the process, it becomes rather easy to remember. Competitive antagonism of drugs and some body enzymes can also be visualized through such tutorials and then it is much less boring to keep in mind how do the phenomena occur. All this reminds us of the old Chinese proverb "I hear, I forget; I see, I remember; I do, I know".

For doing, there are various simulators available now in the market. The National Library of Medicine (National Institutes of Health, Bethesda, Maryland) has the Visible Human Project (www.nlm.nih.gov/research/visible/visble_human.html) where 3-dimensional anatomical structures of the whole human body are available system wise. Various other universities throughout the globe also offer various types of simulators for biomedical education and research. The reader is strongly encouraged to do a 'Google' search on any topic of his/her choice with 'tutorial' as a keyword. Innumerable high quality full lectures with animations can be visualized and downloaded (many times free of cost, with due acknowledgements) from the World Wide Web.

3. Necessity as a core subject

For the purpose of research, training and logistic or administrative issues, it may not be possible to integrate and collaborate successfully at an individual level. Therefore, a number of academic units for medical informatics are already well established in many European countries and the USA. India is globally connected to the Internet. The major public Indian networks include Educational & Research Network (ERNET) of the department of Electronics (DOE); Scientific & Industrial Research Network (SIRNET) managed by the Indian National Scientific Documentation Centre (INSDOC) for CSIR and the NICNET set up and managed by the National Informatics Centre (NIC). The Ministry of Human Resource Development has made available the INDEST Consortium for accessing numerous reputed journals online. In India, some courses on Bioinformatics (in Information Technology or Biotechnology, but not MBBS) also offer Medical Informatics as an Elective. NIC and some private organizations often offer short term courses in medical informatics to doctors — but that is certainly not enough!

Now most of the highly esteemed and famous journals are available as an online version, and that too before the hardcopy is available in the market. With ISDN connectivity being provided by the BSNL and VSAT connectivity being provided by ISRO, the telecommunication activities are usefully increasing in all fields including the healthcare delivery sector. With India aiming at launching men in space as part of Vision 2020, properly functioning infrastructure for e-Health is very much essential. Isolated activities in this regard are being carried out in the various centers or schools for biomedical engineering, electrical/electronics/communication engineering and artificial intelligence research units. However, collaboration between all these units is essential.

In India, the Computer Society of India (CSI) has formed a Special Interest Group in Medical Informatics (SIGMI). The Indian Association of Medical Informatics (IAMI) is actively involved in spreading Medical Informatics awareness through its website (www.iamindia.org) and the online *Indian Journal of Medical Informatics.* Also there are other organizations like Medical Computer Society of India (MCSI) and National Institute of Medical Informatics

(NIMI) related to Medical Informatics.

Even manuscript submissions are accepted electronically entirely in many reputed and indexed journals with high Impact Factor and Prestige Factor. (Interestingly, this article too has been submitted and processed electronically only!)

Multimedia interaction including Medical Simulation using Virtual Reality or VR (10) is now becoming a powerful tool for education related to medical science and technology. Building a successful simulator also requires proper teamwork. While the medical and bioengineering group can give inputs related to anatomy, physiology, tissue characteristics, combined with the cognitive sciences group (like clinical psychologists) they can give proper idea of clinical skills, and grouping with computer scientists they can give idea about the haptics or tactile feedback information. Similarly the cognitive scientists and computer scientists together can assess the metrics measurement. Therefore if all these three groups combine fruitfully, workable medical simulators can be developed, focusing on specific but small psychomotor clinical and surgical skills. Virtual Reality can be of immense help in such simulated training of students and practitioners, without causing pain or bleeding or tissue damage to the patient and also avoiding the chance of HBV or HIV inoculation during surgery. In some countries abroad, now practical examinations are taken on simulators. This does not cause pain or adverse reaction in any subject, and also demonstrates the examinee's psychomotor skills to a great extent.

Another important aspect is the prescribed or proposed syllabus. In view of the fast changing world of medical informatics, it is of absolutely essential to formulate a flexible syllabus rather than a rigid one. Only this sort of an attitude or mindset can make medical informatics useful to medical students and researchers alike. Otherwise they will have to learn the obsolete techniques which would have no practical application at all and their potential will not be exploited to the full extent.

4. Summary and conclusions

Medical Informatics is nothing but the science and art of processing (bio)medical information (where information is the processed data). In this age of "Information Explosion" choosing the useful one is rather difficult, and that brings in the scope of data management and research. The usefulness of a database can be assessed only by its proper management (building, indexing and updating). However, still many outstanding personnel related to the healthcare sector take pride in being "computer illiterate". The onus of the best use lies on the end-user health care providers only. The importance of clinical informatics is no less. Another term tele-health encompasses all the e-health and telemedicine services.

Reaching a foolproof diagnosis is never an easy job for a clinician. Often, a simple diagnostic procedure or test is overlooked and the disease eludes diagnosis. Clinical reasoning and decision making are phased. Initially there is a clinical evaluation (history taking and physical examination), followed by precise laboratory investigations. Then integration of clinical findings and test results is done. After that, comparative benefits and risks are weighed among the alternative courses of actions, like drug interactions Finally, the patient's preferences are taken into account, along with ethical and other considerations like cost of therapy, compliance expectations and a therapeutic plan is developed. Right from the first step (history taking) to the final one, computers can be of immense help to the clinician. Nevertheless, for computer-assisted diagnostic systems, a human clinician ("man in the loop" for "Intelligence Amplification") must be a necessary component. Moreover, the clinician must understand completely the strengths and limitations of them. Computerized diagnostics and clinical acumen are not mutually exclusive; rather they should reinforce each other for the alleviation of psychosomatic suffering of mankind.

For medical diagnosis, there are scopes for ambiguities in inputs, like, history (patient's description of the diseased condition), physical examinations (especially in cases of uncooperative or less intelligent patients), laboratory tests (faulty methods or equipment). Moreover, for treatment, there are chances of adverse drug reactions & specific allergies, patients' non-compliance of the therapy due to cost or time or adverse reactions. Because of advent of new modalities of treatment, almost daily, decision making towards a particular treatment regime to be adopted for each individual patient becomes a complex process. More often, a large amount of information has to be processed, much of which is quantifiable. Intuitive thought processes involve rapid unconscious data processing and combines available information by law of average and therefore, has a low intra- and inter-person consistency. So, the clinician of today should move towards analytic decision making, which albeit typically slow, is conscious, consistent and clearly spells out the basis of decision. For selecting the appropriate alternative regime for a particular patient, there is no definitive method. Data sheets on various medicines purveyed by the pharmaceutical manufacturers are not of much help since they focus on only one particular (generic or brand) drug, while doctors require comparative data on all available treatment modalities. To overcome this problem, EBM (Evidence Based Medicine) is gradually becoming popular for managing both common and uncommon medical problems. EBM compiles data based on systematic review of RCTs (randomized control trials), involving all available therapies.

Connectionist Expert Systems (CES) are ANN (artificial neural network) based ES where *f* the ANN generates inferencing rules e.g *fuzzy-MLP* where linguistic and natural form of inputs are used. Apart from that, rough set theory may be used for encoding knowledge in the weights better and also GAs (genetic algorithms) may be used to optimize the search solutions better.

Some of the practical uses of medical informatics could be as follows. An inventory can be maintained, in the PC, where the combined side effects of multiple drug usage can be described. In an elderly patient, there may be simultaneously hypertension (high blood pressure), diabetes mellitus, cardiac insufficiency (heart ailments) and arthritic *(joint)* pain with inflammation. Drugs against all these, in a person with inefficient liver and kidney functions, can multiply the adverse reactions. There may be some history of previous drug reactions as well. More often than not, elderly people tend to buy OTC (over the counter) drugs for self-medication. Even something as seemingly harmless as multi-vitamin pills can give rise to many serious problems in various parts of the body. To make things worse, the nutritional status of aging people is rather low and this very fact can aggravate drug reactions. So, if a user-friendly inventory is supplied, where the person can check in all the possible drug reactions, and stop taking harmful drugs before consulting the physician, this may be life saving. For adjusting the drug doses in accordance with the condition of the individual's body and mind, AI (Artificial Intelligence) programs may be built up to assist the consultant.

Health or Hospital information System (HIS) is an integrated system encompassing the departmental systems (like radiology, pathology and pharmacy), as well as the clinical systems (like Intensive Care Unit or ICU). However, a proper definition is yet to evolve. Computer based patient records (CBPR or CPR) involves digitizing all data related to a patient being treated in a hospital (along with modifications and updates) and storing in an easily retrievable or searchable form.

CDSS (Clinical or Diagnostic Decision Support Systems) are Interactive computer programs, which directly assist physicians and other health professionals with decision making tasks. I have the pleasure of developing some CDSS. Nevertheless, for computer-assisted diagnostic systems, a human clinician ("man in the loop") must be a necessary component.

Computer aided or assisted instruction (CAI) is a tutorial method using a computer as a base for managing the student's progress (at the desired pace and time). Computer aided or assisted learning (CAL) is a computer based tutorial method that uses the computer to pose questions, provide remedial information and chart a student through a course. Now the emphasis, especially in medical related fields, is on problem based learning (PBL) and there CAI could be of utmost help if used judiciously.

'Medical science is advancing very rapidly, especially with the unexpected progress of technology, both related and unrelated to the healthcare delivery field directly.

Not very long back (many of the senior Professors here will recall), Biochemistry was accepted as a part of Physiology. Now the MCI is including Biophysics within Physiology. May be within a few years, Biophysics as a separate subject, will have its own standing in the Medical curriculum. Similarly, you can see that abroad, a person may be Professor in Physiology and Biomedical Engineering; or Biomedical Engineering and Anesthesiology; or even Medicine, Pathology and Pharmacology together. These are the pioneers who have actually advanced our understanding (Arthur C Guyton and William F Ganong are two notable examples).

Why is multidisciplinary interaction at all necessary? Is it just a fancy or buzz word? Certainly not! If we take a look at a novel diagnostic technique (EGG or electrogastrography), the two leading groups (McCallum and Chen; Mintchev and Bowes), have as core faculty one (electrical) engineer (Chen and Mintchev) and either a physiologist (McCallum) or surgeon (Bowes).

Definitely the need has now arisen for a formal training in Medical Informatics to grasp the essential concepts of basic medical sciences (and thereby learn the applied aspects also much faster) in the shortest possible time. While, because of the information explosion, medical knowledge base is expanding very quickly, the time allowed for learning the basic medical sciences is continuously being reduced. The Medical Council of India proposes to offer subjects like Informatics, Genomics, Ethical aspects of biomedical research as audit courses (rather than credit courses where students are given marks which adds to the total) in the beginning of the MBBS Course itself.

Multimedia interaction including Medical Simulation using Virtual Reality is now becoming a powerful tool for education related to medical science and technology.

Basic Medical Education and Research lays the foundation for advancing and applying proper healthcare delivery systems. There is no doubt that an in-depth knowledge of anatomy is mandatory for successful surgery. Also, an incomplete knowledge of physiology will not be conducive for grasping the principles of pathology and pharmacology adequately, leading to incorrect and inadequate practice of medicine. Similarly, medical informatics is not just a subject to be learnt and forgotten after the first professional MBBS examination. The final aim of every student should not only be to become a good user but also an expert for advancing medical knowledge base through medical informatics.

We cannot afford to bury our head in the sand and presume ourselves not to be seen by others. Unless the competent authorities attach due importance and immediately introduce medical informatics as an essential component of basic medical education, we would soon be becoming isolated (ostracized!) and looked down upon in this global village.

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