Competitive Healthcare Delivery: Involving Medical Technology of Computer Intelligence

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Abstract

Rising cost and increasing expectation from patients (consumers) have caused health care planners to seek ways in improving efficiency, while striking a balance with the quality of services offered. Consequently several successful health-management organizations apply advanced computer technology as the catalyst for a whole new set of parameters for product design, development and operation to achieve excellence in their core business process. In this study, computer technologies refer primarily to technologies used for healthcare delivery services, which are related specifically to aid effective and efficient medical care for patients (the consumers). This study also explores how integrated emerging technologies can play a valuable role in cost-effective medical and health care delivery by means of computer technology.

Keywords: Healthcare engineering, emerging technology, efficiency, cost-effectiveness

1. Introduction

Healthcare services are a universal need, which must be provided throughout a nation, with its delivery catering to the full social spectrum of the population. Generally, the government has limited total resources, and they can hardly meet every need of the population spectrum. Healthcare policy maker, planners and deliverers must thus make effective use of what is available. The ever-rising cost of healthcare is a critical issue for policy makers, healthcare providers, healthcare insurance companies as well as the patient population. The business of health care industry consists of a wide variety of enterprises. Medical products and healthcare services include medical consumables, pharmaceuticals, catering and food, laundry cleaning, waste management and disposal, home-care products, information technology, vehicle fleet management and general research supplies [1].

The health care industry has historically viewed itself as being operationally different from other businesses [2]. Primarily, this thought has developed because healthcare providers believe that, unlike managers in the manufacturing industry, they cannot control or project their production or operational schedules. However, the health care industry is facing an environment where there are pressures to reduce operating costs and increase margins, without threatening production or medical-care quality. Based on an analysis of the total health care system [3], it can be concluded that the supply-management system is one of the primary areas where cost reductions are a predictable outcome. At the same time, as Jarrett points out, the one advantage of reengineering the supply chain is that the cost reductions

would not affect all the components of the medical-care operation. Computer applications for process simulation and workflow redesign can thus be utilized to address these issues.

Clinical services are all about decision making. In this regard, we could refer to the application of decision support system for operational decision-making [4]. The increase in health care cost and inefficiencies are partly due to inadequate and tedious purchasing procedures [5]. With supplies and services representing the second largest expense category in a hospital's operating budget, procurement professionals are under enormous pressure to reduce cost in these areas. To do so, there are two paths available. One is to lower the unit price paid for those goods and services, and the other is to lower the transaction costs.

The theory of information systems (ISs) concentrates on getting the right information at the right time in the right format to the right user. This requires focus on organizational objectives as well as design and dynamics, as much as it requires focus on the procurement of the most appropriate hardware and software [6]. It is to be recognised that healthcare supply chains have evolved from mass to focussed marketing and that, while flexibility is essential, facilities must in the future concentrate on single integrated supply chains. Health care costs are under attack by the public, because healthcare information-management systems are merging and consolidating [7]. Consequently information technology (IT) network can be conceptualized as a set of choices available to organizations or departments within an industry or a company that relate to their business processes. For instance, the day-to-day logistics operation involve activities such as purchasing, production, transportation, warehousing and management. All of this has to operate within a technological environment and industry trends in new technology development and adoption to achieve competitive capabilities. Nowadays competitive environment encompasses the demands made by the market, including (i) the price, characteristics, and features of the product; (ii) the location of customers; (iii) the time requirements of customers; and (iv) the variability in demand. It also includes those trends of usage of advanced computer technologies which shape the global marketplace and the capabilities of designers and managers.

Finally, the trends toward volatility and uncertainty in the economic and competitive production fields, which have given rise to the new applications of advanced computer technology, can be applied in the near future. These observations are probably not new to designers or managers. However, what may not be obvious are the increasingly important benefits associated with computer, communication and information technologies in the process design and development in healthcare industry. Indeed, advancement of information technology (IT) networks provide the organizational mechanisms that support the inter-organizational interactions to reduce product design and business development time (time-to-market), expenses and costs, and improve product quality. The incorporation of these costly technologies into medical applications and healthcare delivery is deemed to make medical diagnosis more (i) timely and reliable, (ii) treatment more efficacious, and (iii) the delivery system more cost-effective.

2. Computer technology and Healthcare industry

The goals of healthcare policy and service administration are to achieve, maintain and enhance the quality of health in the public. Healthcare, like all industries, is recognizing the need to give all decision-makers (doctors, nurses, pharmacists, finance

and billing staff, and managed-care contractors) timely and high-quality information. The overall trend toward managed care and the increasing integration of medical-care systems with pharmacy, billing and other automated medical systems is crashing head-on with critical IT requirements, as the demand is clearly outpacing the supply. While individual citizens may hold primary responsibility for their health status, there is much that the health service providers working in concert with physicians, nurses, other health professionals, and community leaders can do to assist in the process. In this regard, attention could be focused on incorporation and strategic use of new medical technologies to enhance the efficiency of patient-treatment clinical-support units (of pathology, biochemistry, microbiology, radiology, pharmacology), procurement and inventory systems, and administrative services. The delineation and solution of this issue is what healthcare administration and services delivery are all about.

As we are aware, Artificial Intelligence (AI) techniques and fuzzy set theory are applicable to the management of healthcare services at large. For instance, Yuan et al [8] developed a pilot fuzzy logic expert-system for kidney patients, to assist physicians in solving multi-criteria kidney allocation problem. This system was evaluated in comparison with two existing allocation algorithms: a priority sorting system, used by the Multiple Organ Retrieval and Exchange program in Ontario (Canada) and a point-scoring system used by the United Network for Organ Sharing in the USA. In their expert system (Internet-based fuzzy logic), information technology was used to coordinate the organ procurement and transplanting process and to allocate donated organs to recipients quickly, fairly and effectively.

Indeed, AI, involving computer simulation of the human thinking and reasoning process [9], can have major role to empower decision support system, to improve the cognitive basis of decision support system, and incorporate the intent of decision-makers as well as the requirements of customers into the decision outcome [10, 11, 12]. Computer technology can also provide means for cost saving, without compromising healthcare service quality. In order to achieve the goal of cost-effect-management, decision-making strategies from various multi-disciplines are to be involved. As shown in figure 1, the diagnosis process of a child (patient) with head injury can be represented by the flow-chat algorithm for further computer programming. Since engineering is practical application of the sciences, the process of clinical decision-making can be possibly derived from the joint decision-making efforts of hospital and economic engineering professionals through computer technology.

Alternatively healthcare system is deemed to be composed of combinations of parts, people, and procedures in system perspective. It is arranged in such a way that these elements can act as a whole towards achieving some common goals or objectives. The word “system” embodies the concept of “wholeness”. This “wholeness” can be used to orient the way in which ones see the problem. A subsystem is any portion of the system that operates at a different level and handles functional variables at a different level. Healthcare management theory requires maintaining an objective view of how each variable interacts or fits into the operational goal or objective-function of the system, as for a systematic approach to project management [13]. When applied wisely to both design and management decision-making, this approach most often leads to a less costly and to a more efficient process. The systems approach may indeed be defined as a logical and disciplined process of problem solving. A mathematical approach to simulation based on control

theory was initiated by Simon [14] and by Vassian [15] for continuous time and discrete time events respectively. Thus applying system dynamics to total quality management (TQM), Khong [16] proposed a human resource management model for possibly computer software simulation.

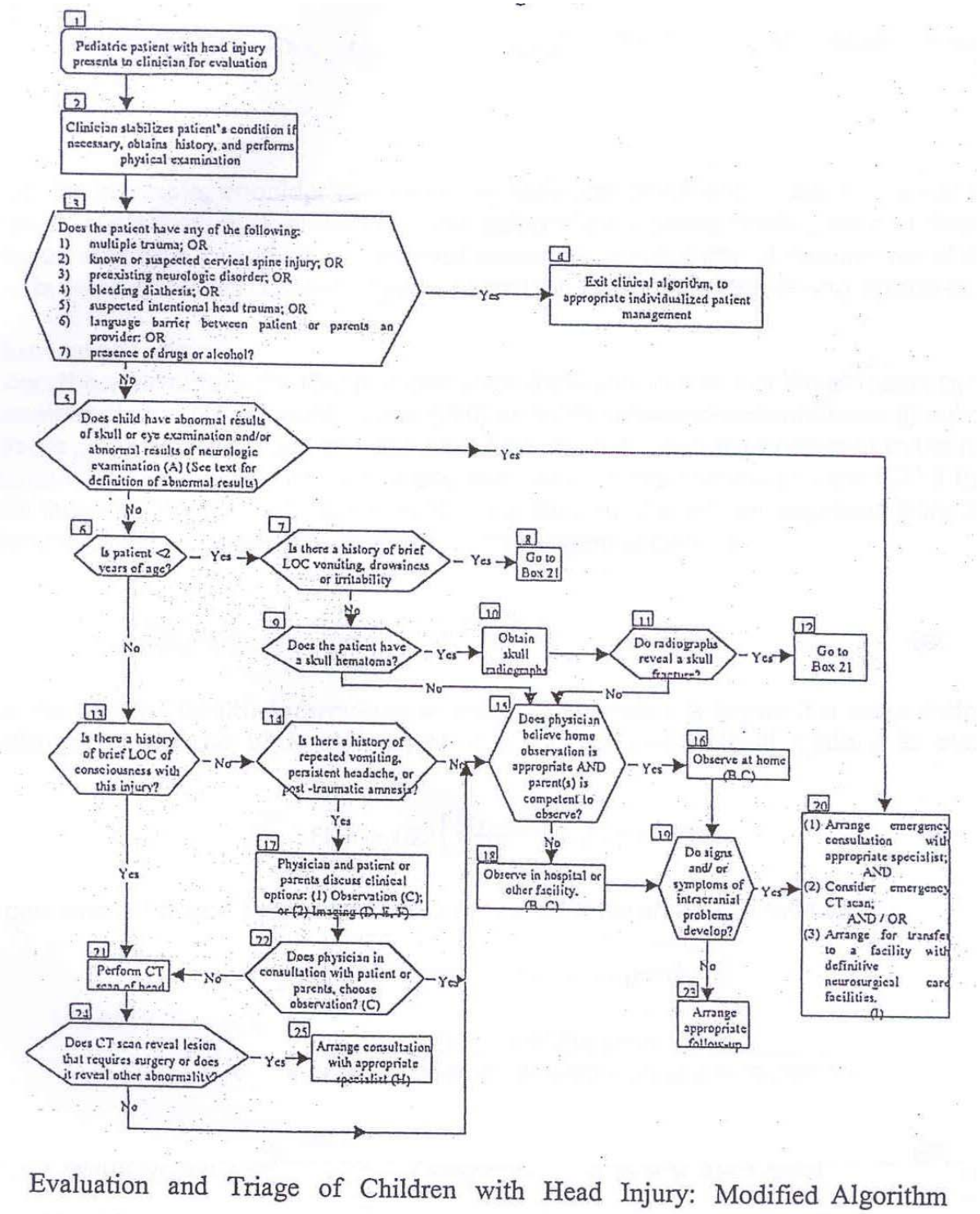


Figure 1: Diagnosis process in system perspective

2.1 Data management system

The IT application in healthcare industry needs solid professionals who can join various platforms and systems together into a seamless whole. In recent years, one of the most significant impacts on product development has been made by the application of data management techniques, which are known as product data management (PDM), engineering data management, product information management, and integrated product data management. The key features within PDM include the following four facets: product structure tree (PST) as the main carrier of data organization and a information expression; work flow and process as the main control means; WAN and LAN as the main workspace and infrastructure; the client/server architecture as the software configuration. These features emphasize that PDM must be involved in the most advanced computer technologies related to both software and hardware, namely: object-oriented technology, object management, multi-layer distributed computing environment, database technology (including RDBMS and OODBMS), network technology, remote communication technology, GUI (graphics user interface) and network user interface independent of hardware, data access interface technology independent of data source, and data embedding technology. With these technologies, the capacities for design process and workflow management can help to better manage product data and design, and allow individual users to interact with organizational information systems in novel ways and at very low cost.

One application for Date management techniques adopted for administration of patients personal records, clinical records and final expense-calculations. The entire computer system allows healthcare service providers to computerise almost every aspect of the daily operations, like patients arrival data, clinical records (such as laboratory report and digitised images) and churns out invoices. It improve efficiency across all internal departments/clinics and enhances customer service with quick call-up of patients' records. With Internet revolution sweeping the globe and Internet technology transforming the world of commerce so rapidly, e-healthcare (entailing effective involvement of IT in healthcare delivery and hospital operations) has become recognized as a new and important strategy in the healthcare arena. Some of its applications are available at: patient-care services online (www.netcare.com.sg), medical record online (www.meetdoc.com), pharmaceutical products online (www.drugstore.com), and blood appeal (donation) through net (www.donorweb.org).

2.2 Info-communication technology and healthcare industry

Healthcare telecommunications encompasses a vast range of equipment and services, namely videoconferencing systems, security systems, call centers and Internet development systems, etc. Internet technology has enabled a new way to deliver healthcare solutions. Basic medical information (such as body temperature, blood pressure, and even ECG) can be measured by the nurse from the remote patient-sites, and this information can be transmitted to the doctor at a major hospital. Under the application services provider (ASP) model, information solutions can be delivered to hospitals from a remote location. For instance, an integrated computerized patient record system means the time required to access radiology film has dropped from a day to a few seconds.

Telemedicine is a system that electronically transports a consulting physician from a medical center to a distant health care facility, where his expertise is

needed (see figure 2). Telemedicine is an interactive audiovisual link that can serve as the means for data exchange, shared radiology review, procedure guidance, and specialty consultation, between physicians or between a physician and other healthcare service providers. With these computer-assisted consultations, the system save on trips, but can still 'see' a doctor. Subsequently, the follow-up medical checks and consultations are equally easy. Indeed, the components of telemedicine combine to marry remote medical consultation with continuing medical education.

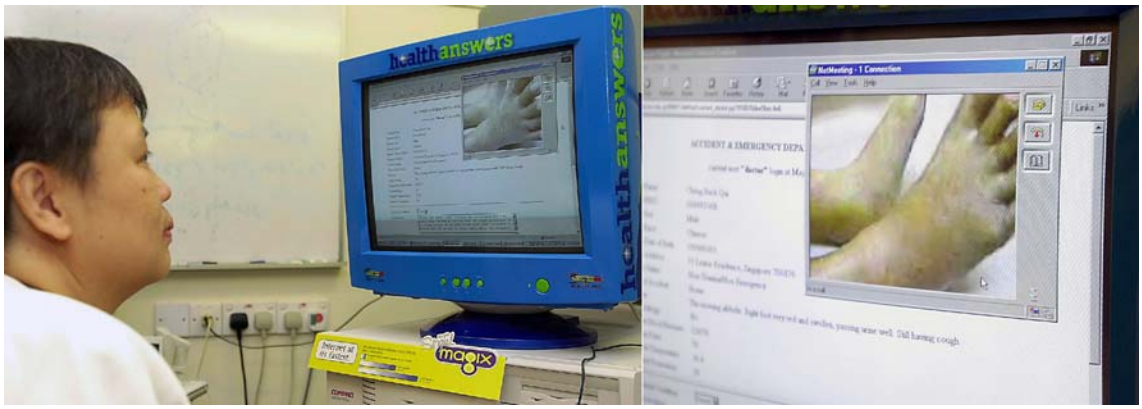


Figure 2: Through telemedicine technology, patient's stricken foot can be viewed (on remote computer monitor) by doctors for diagnosis. (From The Straits Times, Singapore: 8 May 2000)

3. Emerging technology

When medical procedures are involved with new technologies implementations, clinicians will find that they need new types of detailed information for their operations. They will find that the relative importance of various existing skill changes. On the other hand, hidden costs such as application software development, database construction (and even training, attitude modification, management orientation, functional host computer interfacing, inevitable expansion) and a host of others technologies all add to the healthcare costs. Thus pace of the development alone demands a major commitment by high-level management to keep abreast of the current realistic possibilities and affordable healthcare cost. Making a decision about an innovative medical procedure or healthcare delivery system, requires a sound knowledge of such factors as computer technology design, communication and networking, the latest peripherals and benchmarking. According to the importance of technological property, the deployment naturally gives rise to measure the potential benefits associated with the usage of emerging and advanced technology. These benefits generally are circumscribed to three main areas: cost saving, high clinical quality and comfort to patients.

3.1 Computer Tomography technology

Many open surgical procedures can be replaced with minimally invasive procedures, with the advancement in computer technology, as for instance, for the measurement of glucose and to produce a

color-coded picture (digitized images) of myocardial texture to detect myocardial infarcts (see figure 3). Combing theoretical physics, quantum physics, electronic engineering, computing, manufacturing and medicine, the PET (Positron Emission Tomography) scan technology uses a small dosage of a chemical (called radionuclide combined with sugar) which is injected into the patient. The radionuclide emits positrons. A PET scanner will rotate around a patient's head to detect the positron emissions given off by the radionuclide. Because malignant tumors are growing at such a fast rate compared to healthy tissue, the tumor cells will use up more of the sugar, which has the radionuclide attached to it, and hence become amenable to detection.

Computed Tomography (CT) is based on the x-ray principal. As x-rays pass through the body, they are absorbed or attenuated (weakened) at differing levels creating a matrix or profile of x-ray beams of different strength. This x-ray profile is registered on film, thus creating an image. In the case of CT, the film is replaced by a banana shaped detector which measures the x-ray profile. Since the beginning of computed tomography, radiologists have used CT to guide simple interventional procedures such as tissue biopsy. Conventional CT guidance of biopsy and other simple procedures is well established. However, conventional CT can be painstakingly slow since it often requires a new image to be acquired each time the doctor advances the needle or surgical instrument in order to verify the updated position. In many cases, the radiologist repeatedly leaves the scan room each time a new image is acquired, extending the length of the procedure.

The advent of multimodality imaging scanners combining PET and CT has led to a new paradigm in computer digitized imaging that raises new challenges in computer technology, image navigation, and communication. Combined PET and CT scanners provide spatially registered images from the two modalities acquired simultaneously in a single imaging session. The image reconstruction process rescales the native images from different spatial resolution into orthogonal or oblique reformatted planes, in which the data from PET images are color coded and superimposed on corresponding anatomic CT images. The color overlay technique allows the user to visually identify areas of high tracer activity, and determine the underlying anatomic structure.

The application of the integrated technology (PET/CT) was reported in Singapore (see figure 4) for the use of certain cancer diagnosis. (lung, colon, thyroid, esophagus, head and neck and lymphomas) However, wider adoption of multimodality PET/CT imaging techniques in routine clinical applications will depend heavily on the new development of adequate image display as well as on the navigation tools enabling interpreting-physicians to navigate easily and efficiently through multiple dimensions of data.

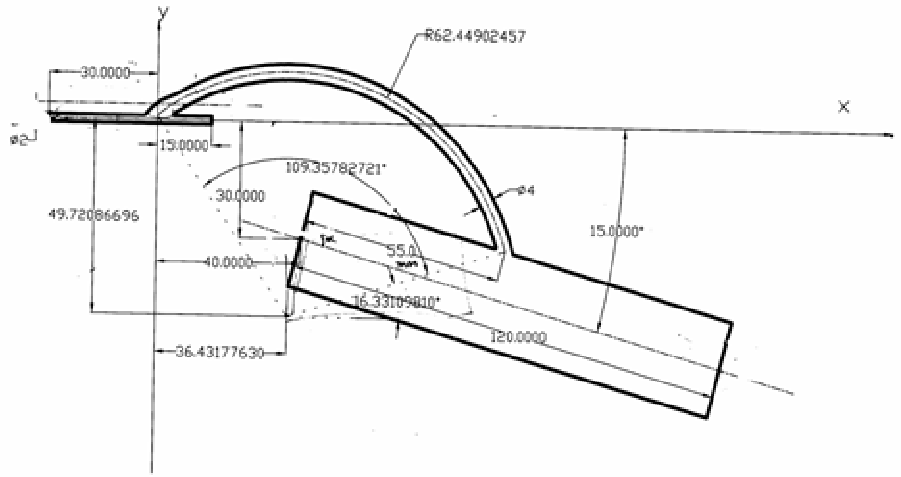


Figure 3a Geometry & dimensions (mm) of the coronary arterial bypass graft system

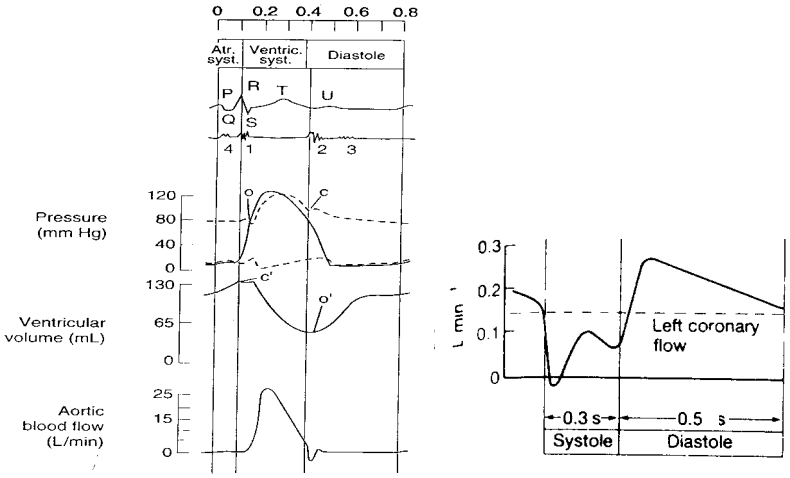


Figure 3b Physiological measurements of flow rates & pressure over a cardiac cycle

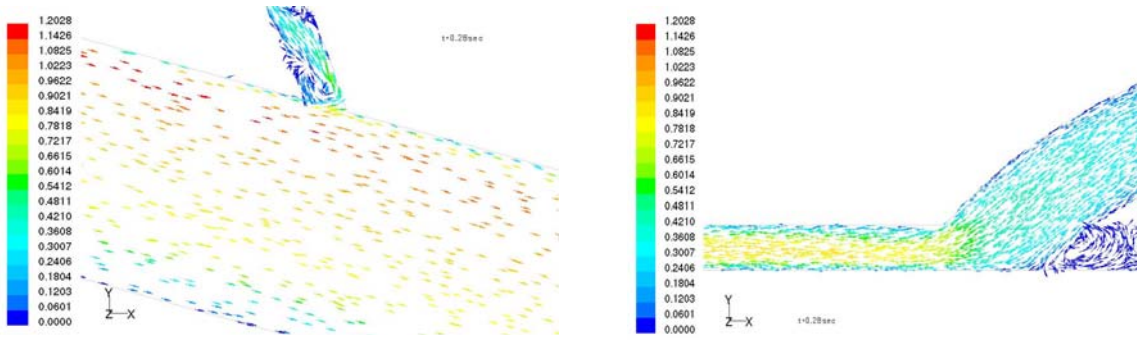


Figure 3c Sample velocity vectors (at t=0.28sec)

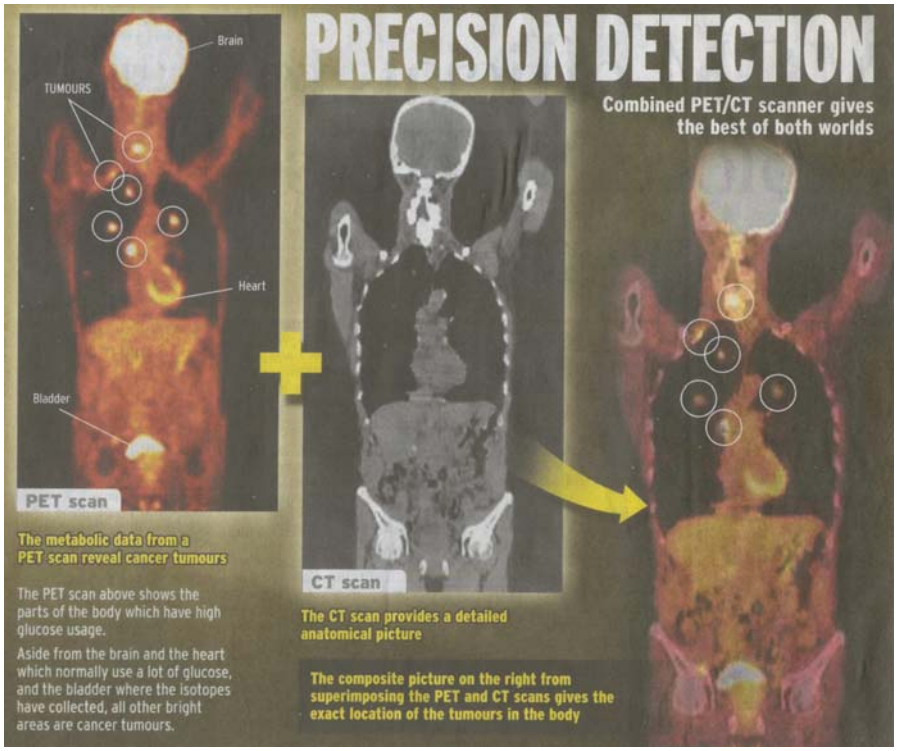


Figure 4: Integrated technology in effective healthcare delivery (From The Straits Times, Singapore: 21 Jul 2003, Singapore on world map for cancer diagnosis)

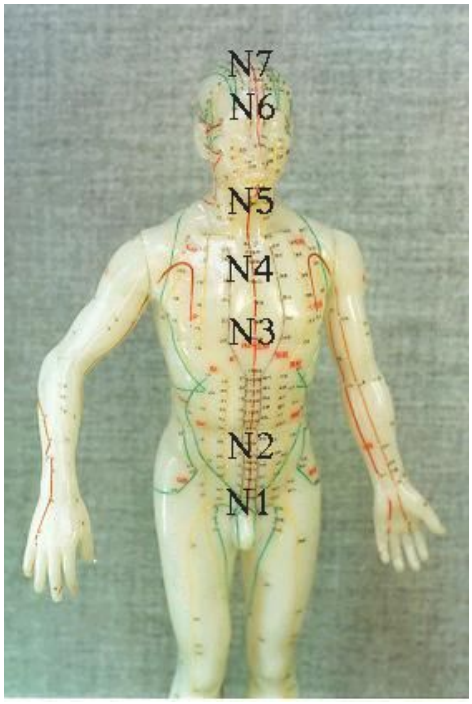
3.2 Holistic health-conditions monitoring

Western biomedical anatomy (what is in the body) and physiology (how the anatomy works) divide the body into many parts. This makes it possible to be very specific about internal biological processes, and is the basis for how a great many biomedical diseases are categorized and named. On the other hand, Holistic Medicine is a healing system that fundamentally believes a human to be more than the sum of their parts. A Holistic Medicine provides a unified framework for diagnosis and treatment that includes every part of the patient's bio-conditions (see figure 5). This means that a holistic healthcare practitioner will be as comfortable with one's emotions as with their tendons and ligaments. Nothing is irrelevant, and everything fits.

"Chinese medicine," often called "Oriental medicine" or "traditional Chinese medicine (TCM)," encompasses a vast array of folk medical practices based on the concept that the body's vital energy circulates through channels (called *meridian*) that have branches connected to bodily organs and functions (see figure 5). Illness is attributed to imbalance or interruption of *chi*. Ancient practices such as acupuncture, Qigong, and the use of various herbs are claimed to restore balance. Acupuncture is a living medicine with a long and complex history of development. Traditional acupuncture, as now practiced, involves the insertion of stainless steel needles into various body areas, to open up the meridians and facilitate the flow of energy to the diseased part of the body. Bioenergetics is a method of studying and understanding the

human personality in terms of the body and its energetic process.

In bioenergetics theory, it is believed that the body and the mind function together, and are functionally identical (meaning what happens in the mind reflects what is happening in the body and vice versa). In bioenergetics engineering, the measurement of the bioenergy characteristics of a patient (representing the degree of healing and function-restoration) can make both the doctor and the patient better understand the treatment and healing process clearly by means of this biofeedback (a process of giving immediate information) to a subject about her/his bodily processes. These processes can be subject to operant conditioning, in the treatment for disturbances of bodily regulation.



Bio-energy characteristics describe the physical-state *X(x)* and mind-state *Y(y)* of the body-mind. In formulating holistic bioenergetics theory, one can make use of Bio-energy functions of multiplicative type as represented by equation (1). The series must be chosen in such a way that it a priori satisfies the boundary conditions of the participant (or patient). Therefore for a bioenergetics spectrum under consideration the bio-energy can be described by

$$w(x,y) = \sum_{m=1}^{r} X(x) \cdot Y(y) \qquad (1)$$

where *m* has been taken as external influenced factors. For a special case of study, for instance, the study of work done (loss of energy), equation (1) becomes

$$w(x,y) = X(x) \cdot Y(y) \qquad (2)$$

The Principle of Minimum Bio-energy refers to that the total bio-energy (*U*) associated with physical and mental field, *V* is always greater than the Bio-energy, *W* affected by external influenceable factors. For holistic health, the total Bio-energy (*V*) of a Bio-system can be dysicted as:

$$V = U\text{-}W \qquad (3)$$

A case study on the loss of bio-energy (due to emitting ‘internal energy to outside of the body) was conducted at Nanyang Technological University. The graphical presentation of experimental measurement of the total Bio-energy through Kirlian Photography techniques is illustrated in figure 6. The pre and post stages of the energy-state was 20-minute interval.

Figure 5: Bioenergy node points (N1 to N7) and acupuncture points. Bioenergetics is a method of studying and understanding the human energy field. In bioenergetics theory, it is believed that the body and the mind function together and are functionally identical (meaning what happens in the mind reflects what is happening in the body and vice versa).

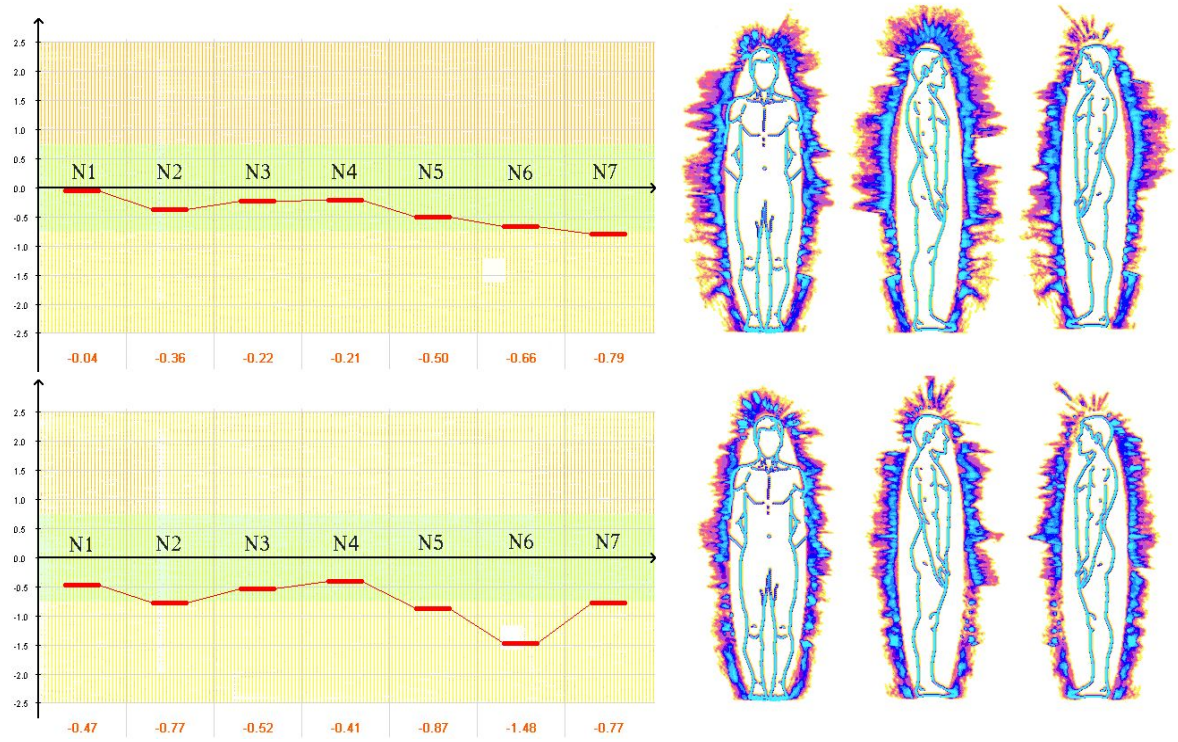


Figure 6: Level before (above) and after (below) Bioenergy discharge-state

4. Issues and challenges for holistic healthcare system

"Holistic" means the belief that something is more than the sum of its parts. For instance Traditional Chinese Medicine (TCM) is the oldest, and the most widely widely-experienced medicine on the planet. Americans are becoming aware of and open to "Holistic" medicine. Patients are increasingly unsatisfied with biomedical treatment options, especially with pharmaceuticals that promise only symptomatic relief while producing even more unwanted symptoms (called side-effects). Holistic Medicine seems to offer something different and potentially more healing. Hence, Holistic Healthcare is a complete system to treat disease and promote well-being using natural methods. It addresses all aspects of health using techniques such as acupuncture, herbology, nutrition, microcurrent-therapy and mind/body methods. It is complementary to conventional allopathic medicine, and supports the bodies own innate ability to heal.

With finance and cost-effectiveness in mind, the holistic healthcare delivery system can be extended and represented in figure 7. It shall be a multi-disciplinary approach (vision) that involves engineering in hospital, clinical and economic fields. This multi-disciplinary vision has taken on a new dimension in developing the science of healthcare delivery in this era of biomedical technology. In developing the Affordable Healthcare Service Model **(AHSM)**, each of the disciplines (and intellectual capitals) of hospital engineering, clinical engineering and economic engineering have their respective value and role, which need to be further technologised. (refer figure 7) Further, each discipline has the perogative to develop its domain with respective to **AHSM**.

In the **AHSM,** one are concerned with advancing the aims of affordable healthcare delivery or service, by building educational, scientific, social and cultural relationships of

the stakeholders in the scientific community. The proposed **AHSM** is intended to stimulate a process of reflection on how intellectual capital (knowledge), clinical-service and biomedical technology and management science could be integrated into development strategies. Balanced development can only be ensured by making professional and cultural factors integral part of the strategy.

5. Concluding remarks

For years, hospital and healthcare IT systems were being used for administrative purposes such as scheduling and billing. In info-communication technology, an entire generation of changes can be wrought in a few short years. With the advancement computer and emerging technologies, the healthcare professions are finally able to use technology in the area where it matters most, namely to improve the quality and safety of patient care.

To achieve low healthcare cost, non-core services should be evaluated and contracted out to external parties if they can do the work more efficiently. With increased pressure to cut costs, in many western countries, public hospitals have been front-runners in outsourcing their non-medical services such as maintenance, housekeeping, catering and landscaping. Similarly, health-care facilities have outsourced areas which they felt could be handled better by other experts. With the current outsourcing-trend, the proposed Affordable Healthcare Service Model **(AHSM)** seems to be feasible framework for both developed and developing countries.

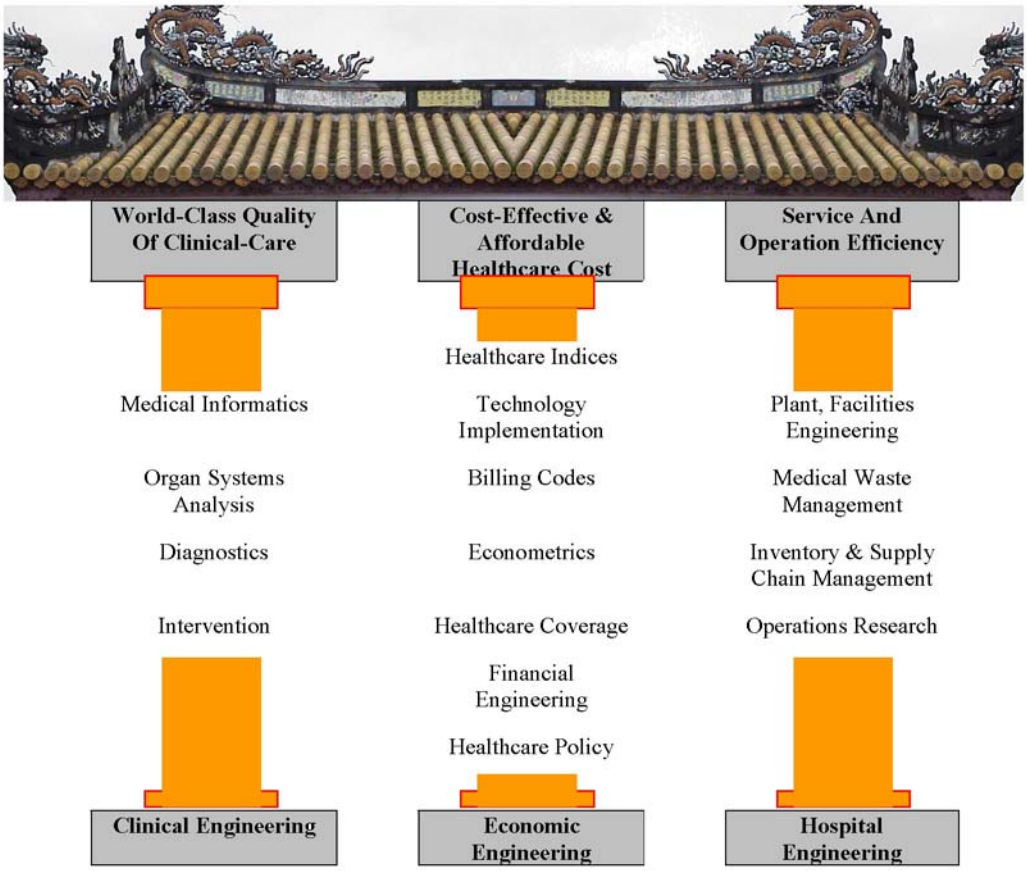


Figure 7: Framework of holistic healthcare system and management for affordable healthcare cost, the Affordable Healthcare Service Model **(AHSM)**

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