SHORT REVIEW

Computers in surgery

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Abstract
Like most truly epochal revolutions, the computer age crept in on this generation before we could figure out its numerous possible applications. Over the past few years, an increasing appreciation of the usefulness of digital technology has emerged among various professions. How has the advent of the computer impacted the field of surgery? Is it worth embracing for the older practitioners? What does the future portend for our ancient noble profession? This paper reviews current applications of computer technology in the field of surgery and the hopes it hold out to surgeons in developing countries.

Key words: Computers, surgery, applications

Introduction

Periodically, mankind makes a leap forward, resulting in tremendous social changes affecting the very way we live. [1] The computer, originally invented to ease the tedium of mathematical and scientific calculations by *aficionados* (who hitherto had to made do with manual, slide-rules and rudimentary appliances,) has grown to be the epochal leap of our age. The Turing machine, [2] an early precursor of computers, was invented in the 40's to process equations without human directions. Its successor, the Colossus, [3] was used to break complex German naval codes, an act considered by many historians as crucial to the successful execution of the Second World. In a classical replay of necessity being the mother of inventions, the demand for fast, accurate and complex calculations in the early space exploration odysseys, commercial cost cutting demands and military needs all promoted the development of better computers. [4, 5] With improved memory, speed and processing power in an ever more compact casing, the computer has traveled a long memorable road from the mainframe-bound behemoths of yore. It exists in forms of desktops, laptops and palmtops. It is now built as the controlling module in much household, office, business and personal appliances, promoting a more fruitful life our forebears could only have dreamt about and which we only read about as little children in science-fiction and comic books.

Although the inventors of the computer could not have conceptualized the grand scale of its vast influence in human life, practitioners in diverse realms such as arts, humanities, weather- forecasting, deep-sea fishing and industry now increasingly turn to its awesome power. The field of surgery has not been left out and has gone beyond the realms of simple record keeping and word processing. [6] Contrary to expectations, computers are still years behind human capabilities at "thinking", an advanced form of informed reasoning such as doctors use in making diagnoses and formulating treatment. [7] Computer-based diagnosis and treatment is therefore largely confined to remote outstations such as in submarines, space-crafts and for specific interest research groups. [8] Broadly speaking however, surgeons, other healthcare workers, trainees and patients alike have benefited from the influence of computers on society at large and from some notable specific innovations in the field of surgery. Thus, surgical services have not been left out of this new dispensation and sundry bounties of digital tools such as word processing, data analysis, record keeping and the diverse uses of the Internet, which have positively impacted our world. Teaching and research are also increasingly re-engineered by this technology as the global-village concept gradually creeps into the operation room.

Communication and the surgeon

The digital telephone, laptop, palmtop and pager keep the ever-busy surgeon in constant touch with members of the surgical team, clients and the outside

world. Thus he could screen all messages on his pager and return those calls deemed crucial at all times. Internet access and e-mail facilities are available via palmtop computers now and thus, an improved communication network has magnified the scope of social and professional interactions available to the surgeon both on the move and at the office. The palmtop computer is now vastly used by trainee surgeons to download vast literature and books on diverse topics from the internet at minimal cost for ready use at their fingertips. The doctor thus readily consults reference materials by the bedside and needs not wait till he is free from his busy clinical schedule.

In the office

Word-processing has been around for almost 2 decades and has redefined the typical office as was once known. When the computer made its debut in the business place, traditional ways of preparing a document gave way to the digital, recallable formats. Thus, corrected documents did not have to be retyped all over. If this was the office secretary's dream come true, the surgeon, like many bosses worldwide, could almost completely do away with the secretary. Suddenly, you did not have to wait till Monday morning to prepare a paper.

Hospital record-keeping is now more efficient while tracking, updating and retrieval systems have been simplified by space- and time-saving software. Vast records could be written or scanned onto compact discs for permanent storage. Software now exists in use for keeping operation note, complete with picture and voice embedment to wit. With the expanded use of the Internet, such files, with accompanying electrocardiographic records, x-rays, computerized tomography images, magnetic radio-imaging and ultrasonographic printouts could all be compacted into a single digital file. This could be requested for and accessed over long distances by other caregivers through the telephone. Consultations have also taken on additional dimensions where patients may shop for appropriate specialists online and look up relevant information on the Internet before they consult the surgeon. Referrals can also be done online and necessary files downloaded with the referring doctor's permission and patient's approved consent. Through the Internet, the surgeon can now look up the nearest and most appropriate specialist and e-mail his patient's file to the referral hospital, shortening referral time at little cost. [9]

Teaching

Knowledge acquisition in surgery was long considered a long road in suffering. One only needs to recall the tedium of anatomy, physiology and biochemistry of medical school days. Computer power has begun to reduce the odious hours spent in the formalin fumes of medical school dissection-room through the use of virtual reality anatomy packages. [4,10] Surgical texts also come in user-friendly CD-rom, complete with video clips and cross-linking hypertexts. With digital photography, medical illustration has been decentralized from the purview of hospital-based illustration units and is only limited now by the surgeon's imagination. Purchased at prices comparable to their analog progenies, digital cameras are an asset to any practicing surgeon who is serious about recording his techniques and surgical findings. Digital picture cost less than a third of the production cost of traditional ones, with shorter print time and reduced wastage. [11] Great teaching materials can therefore be produced at little cost for PowerPoint projections, an attention-getting teaching tool, and any day. Surgical trainees readily access a lot of data on all aspects of surgery on the web. Interactive sites, online surgical journals and abstracts are freely available from useful search engines such as Medline, PubMed and a host of others. Distance is no more a barrier to knowledge acquisition.

The practice of surgery

The past few years have witnessed the application of computer technology to improving the tools and techniques of surgical practice. The rapidly expanding field of endoscopic surgery had benefited from visual enhancement afforded by stereoscopic rendition of the operation field by computer-generated virtual reality. Furthermore, virtual reality has been incorporated into difficult training circumstances such as neurosurgery and cardiac surgery to provide simulated scenarios, thereby improving cost-effective planning and training. [12] Many surgical applications (akin to the flight simulator's virtual reality for pilots) abound now to teach laparoscopic procedures such as cholecystectomy, appendectomy and fundal plication.

Robotics

A robot is a computer controlled mechanical system with anthropomorphic (human-like) characteristics. [13] In essence, most are extenders of the human arm with vast manipulative capabilities that can utilised to extend and amplify, but not take over, the many functions of the human hands. Robotics has become the most exciting and promising arena where our ancient art couples onto the digital vehicle on the information superhighway. Much touted as the likely successors of the industrial revolution, robots had to wait in the aisles until computers came of age. With vast computing powers at their command, designers have now turned their attention on the potential benefits of robotic technology to surgical practice. Two systems the Zeus® and da Vinci® have been licensed for use by the FDA in the United States of America. [14] There are six main valuable areas in which robotics are of interest to surgery:

Augmentation of the surgeon's arm
Akin to providing the "third arm" for the surgeon, voice-controlled robotics can hold and manipulate endoscopes for the surgeon. A lot of work was done in this regard by companies in collaboration with aerospace industry. [4]

Enhanced dexterity
The robotic hand is more precise, dampening tremors, an unnecessary side effect of ageing among surgeons. They also show superior consistency in procedures where repeated precision is needed as in spinal canal surgery and modeling bone planes for orthopedic prosthetics insertion. Newer, exact-fitting orthopedic prostheses could now be tailor-made from 3-d CAT images of the intact contra-lateral side. The robotic arm does not yet have as great a range of motion as the human arm but further refinement will soon correct this minor problem. [15, 16]

The last few years have witnessed great innovations in the miniaturization of computers. Advanced microchip and battery technologies have stimulated research into the applications of small robots capable of working in remote terrain. Nano-technology, as this new field is called, has many possibilities for surgery. It is envisaged that nano-robots will in the foreseeable future, be programmed to invade specific areas of the body and target diseased tissues, delivering cytotoxic agents to tumor beds and unclogging cerebral vessels of blood clots after a cerebrovascular accident. The possibilities are many and the future is not as far as it may seem. Sometime ago, researchers at a British laboratory demonstrated an ingenious nano-robotic gastrointestinal endoscope which, swallowed as a capsule, sends back pulses of clear pictures as it migrates down the digestive tract for many hours. [17] It has since been successfully used in diagnostic imaging of the small bowel and miniaturised machines will be increasingly available for clinical use within this new decade. [18]

Improved ergonomics
For once, the surgeon does not have to stand all through the duration of the surgery anymore. Rather, he can sit comfortably at a control and, through virtual reality, manipulate the robotic controls remotely to handle instruments and navigate successfully through delicate operations such as coronary bypass, cholecyctectomy and endoscopic hernia repairs[19.] This has vast applicability in telemedicine (vide infra)

Image guided positioning
Stereotaxis has enhanced success and safety of many surgical procedures. Through simulation in training of surgeons as well as in surgical planning, image-guided fine-needle aspiration biopsy and cytology of mammographically detected small breast lumps are more precise and simpler. Endo-vascular ablation of berry aneurysm is demonstrably possible with robotic tracking and guidance.

Elimination of hazards
The surgical team may now be safely removed from hazardous irradiation and caustic chemicals while treating his patients. Robotic arms may safely place therapeutic radioactive rods in body tissues and cavities without exposing the surgeon to any harmful effects

Telemedicine

With an ever increasing speed of the Internet, it is now feasible to bridge distance barriers and perform various tasks remotely controlled robotic tools. This development has commanded much attention from military, navy submarine, nuclear facilities and space exploration programs. Tele-collaboration has been employed in surgery, with robotics enabling surgeons not physically present in the operating room to interactively take part in surgeries. [20]

It is hoped that shortage of specialist manpower experienced in third world countries will be addressed through this aspect of telemedicine. Telemedicine is a fast-expanding application of computers in Medicare. It involves the instantaneous, two-way transmission of digitally encrypted medical data over telephone lines to vast distances across the globe. Thus doctors can hold teleconferences, exchanging text, picture, voice and video data. [21] Cosmonauts aboard the permanently orbiting Spacelab have a full surgical capability backed by a ground team of specialists via telemedicine. [22]

It must be pointed out that these benefits are synergistic and not mutually exclusive. Surgical utilization of these attributes often employ as many of these capabilities as possible.

Other appliances

Computer technology has also found many newer applications in surgery. The use of laser technology is being integrated into intra-operative histopathology for instantaneous interpretation of biopsy specimens without recourse to frozen sections. Although this is still at experimental stages, it would be welcome development for surgeons, especially in the field of oncology. Similarly, newer generations of anesthetic monitors now have integrated programs controlled by computer chips, rendering them programmable and with digital data storage capabilities. Such stored data could be replayed for teaching, post-mortem case-analysis and research. The ECG machine, blood gases monitor, anesthetic gas monitors, temperature probes, pH probes and biochemistry monitors have been adapted to this concept.
Digital x-ray, computerized axial tomography (CAT), magnetic radio-imaging (MRI), ultrasonography scans (USS) and the electro-cardiograph (ECG) all have digital outputs which could be readily accessed from consoles located in the out-patients' unit, doctors' lounge, the wards, operation suite and any part of the hospital networked with this digital interface. Computerization has miniaturised equipment such as the USS, ECG to the extent that they form a part of the surgeon's intraoperative

diagnostic tools. The USS has, for example, been extended to imaginative uses with sterile polythene covers during surgery. Endoscopic retrograde cholangio-pancreatography is gradually being complemented by newer applications such as CT and ultrasonography. [23,24] Similarly, the plastic surgeon computer-sculptures his patient's scanned images, creating an array of possible body image modifications from which the prospective patient can choose[25]. Laser keratoplasty, a new exacting surgery in which ophthalmologists re-mold the cornea to improve vision without the use of external lenses is another application of this novel technology in surgery. [26] The science of optometry has been rendered more exacting through the application of digital technology.

It is envisaged that buildings of the future will be a great departure from the present passive structures of present day constructions. Intelligent buildings wired not only to control their internal environment, but also to respond to peculiar requirements of their users. Thus in an operation theater, a surgeon will carry interactive microchips embedded with his specifications of light intensity and room temperature among many other features. It is envisaged that the increasing use of voice-activated display units will free the hands for other uses and increase resource utilization within the operation suite. [27]

Hospital management

Surgery has also benefited enormously from the computerization of many hitherto traditional hospitals services. Drugs cabinets can now be embedded with microchips networked to the hospital pharmacy, putting a firm control on drug dispensing as each nurse can only access the cabinet and obtain specified amounts of drugs through unique personal-identification codes. The pharmacist is thus in firm control and can track inventory, expiration date and replenishment schedules. Similarly, hospital accounting jobs have been streamlined through the introduction of accounting packages which link all payment points to a central unit and have various levels of authorization and entry points inbuilt for different categories of accounts officers.

Research

Most research planning, data collation and analysis is now computer based. Laboratory tools and their data output equipment have been re-engineered into digital formats enabling easy data collection formats. Thus research equipment can be programmed to record directly onto pre-set computers. The data could be analysed using computer software like Epi-Info, SPSS and Jandit. With such simplified but powerful statistical packages, surgeons have advanced research techniques into novel concepts. Surgical prognostications are now increasingly based on newer

intervention models derived from computer-aided scenarios.

Literature search, access to online journal articles, electronic ordering of medical literature is now commonplace with the use of international services such as WebMD, PubMed, Medline and other medical search engines. Collaborative research efforts are much easier with improved e-mail communications and aspiring medical researchers now take advantage of the inexpensive, peer-reviewed electronic journals in many fields of surgery.

And the downside?

Robots do not yet make judgments required of a surgeon in an operation field. Rather, they are being fashioned as human extenders.

The computer age has brought along its own baggage of problems and unresolved issues. The explosion of information in this digital age could be overwhelming to the best organized of men. It has been said that more medical information has been published in the past 20 years than in the previous 200! Medical knowledge doubles every 6-8 years and the challenge to the surgeon therefore is to sift the grains from the chaff and maximize the accruing benefits form his chosen applications of computer technology. [28] For example, merely registering for an e-mail address opens ones to unsolicited mail (junk mail) from advertisers who get hold of one's e-mail address through the Internet.

Computer fraud is assuming a noticeable dimension even as it is acknowledged that 19th century penal codes had nothing that could successfully prosecute cyber-crime. A global cooperative effort is required to keep this ugly trend to a minimum. It is common knowledge that any item sent on the Internet is never 100% safe from prying eyes. Who then pays for breach of patients' confidentiality on the Internet? Hackers abound who derive sheer pleasure from breaking (via the Internet) into password-secured domains and plundering digital files stored on computers. This real threat, coupled with the ever present danger of rapidly spreading computer viruses necessitates the need for frequent backup of stored data. A monthly backup has been recommended for offices with rapid data turnover rates. Such backup could be in printed hardcopy, floppy diskettes, zip drives, compact disks or, nowadays, uploaded unto free Internet storage spaces.

Users of materials obtained from the Internet and proprietary items must be aware of the stringent copyright laws governing their uses. Knowledge is a universal commodity but copyrighted materials could only be used for teaching, references and research. If in doubt, it is best to seek permission from source or ask for a legal opinion. The converse of this pertains to surgeons who may device useful materials and wish to upload such onto the Internet. It is advisable to obtain a patent in respect of such document and put

a copyright mark on it.

As the populace becomes more familiar with the many uses of the Internet, knowledgeable patients will frequent the surgeon's office with searching questions we must be prepared to answer truthfully. Lawsuits may increase from an informed population and it is therefore advisable for the practicing surgeon to keep abreast of the rapidly changing trends in surgical fields. What are the legal implications of on-line referrals, treatment via telemedicine, surgical decisions following video-conferencing? In robot-assisted remote surgery and telemedicine, is the consulted or remote doctor bound by the licensing regulations of the patient's country? Is he medico-legally liable in a malpractice suit? International legal bodies have to iron out an appropriate legal framework to address these issues without compromising benefits to deserving patients. Online medical help websites are always quick to put a caveat on any information provided, denying culpability in case of any untoward consequences. Surgical consequences clearly go beyond these simple statements of denial.

The third-world is not yet reaping the maximal benefits from the many advantages computer technology has brought into the surgical arena. [29] Cost constraints, erratic power supply, poor paychecks that cannot purchase needed updates and subscriptions, wrong government priorities and poor telephone services are among some of the perceived causes of this lapse. [30] Surgeons in our sub-region are therefore advised to keep abreast of the trends in computer technology and its application to their field. It is not a fad that will go away; rather, it will only grow with time. Computer education should be an integral part of medical school curricula and all faculty members should invest judiciously in cost-effective applications to enhance their productivity in the office, theater and all aspects of patients' care. All medical schools should take advantage of the numerous available aids and grants to provide Internet facilities for their faculty and student communities. It is also our duty as a vanguard group to influence public leaders towards judicious investments in this technology that may yet bridge the poverty gap between the western world and ours. Computer technology is an epochal opportunity for bridging the great technological divide between the advanced nations and our struggling third world communities. We should embrace it.

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