

Neurosurgery in the Past and Future. An Appraisal

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Introduction

The brain is the centre-point of communication between the human being and the universe. It defines consciousness which is an integral part of human evolution, from which arise inventions and discoveries. The study of the human brain has always been challenging. The functions of a large portion of the brain are still poorly understood and unexplored. The limited understanding of the physiology, anatomy, and pathophysiology of the central nervous system has allowed us to develop investigative modalities for diagnosis and to further evolve therapeutic strategies to obtain either control or cure.

Neurosurgery in the 20th Century

Neurological surgery was recognized as a specialty in the beginning of the 20th century. The early neurosurgeon was a clinician-neurologist who would diagnose and localize brain lesions based on clinical history and neurological examination. The clinic-pathological correlation of brain lesions led to the diagnosis of brain tumours, vascular lesions, and spinal disorders.¹ The introduction of ventriculography, pneumoencephalography, and angiography in the second and third decade led to the indirect diagnosis of brain tumours and vascular pathologies.^{1,2} However, the mortality and morbidity of neurosurgical disease was profoundly high due to crude neurosurgical operative techniques and a lack of skilled neuro-anaesthesia.^{1,3} Most frequently, after a hectic day spent diagnosing the site and probable nature of the brain lesion, the neurosurgeons would then operate on the lesion in the most hostile environment, marred by lack of microsurgical instruments and inadequate knowledge regarding control and maintenance of intracranial pressure during surgery.

The advent of the Computed Tomography (CT) scan in the early 1970s helped to delineate brain lesions in a better manner; marginally raising the comfort level of the neurosurgeon.^{1,4-6} The invention of cerebrospinal fluid diversion procedures for hydrocephalus was a significant advance in the management of raised intracranial pressure.^{5,7} The introduction of magnetic resonance imaging (MRI) in the 1990s and invention of the high magnification surgical microscope provided a giant leap forward in the surgical resection of brain tumours.^{4,8,9} This was coupled with progress in neuro-anaesthesia techniques and management of intracranial pressure which helped the neurosurgeon to operate on a relaxed brain;⁵ thereby promoting a safe maximal resection of the brain tumour, as well management of vascular lesions.^{3,5} The enhanced magnification provided by the surgical microscope improved the understanding of micro-surgical anatomy and the confidence of the micro-neurosurgeon.⁹ In the 1950s and 1960s, the discovery of radiation treatment and chemotherapy as an adjuvant therapy for malignant brain tumours, which could not be removed completely, provided a further boost to reduce mortality and morbidity.^{1,4,5,10} Broad spectrum

antibiotics and steroids in the treatment of central nervous system infections have made a significant impact on reducing the fulminant nature of central nervous system infections and the incidence of brain abscesses. In the last 20 years of the 20th century, endovascular procedures have been a good adjunct for treatment of arteriovenous malformations, and a primary modality for treatment of aneurysms, thus avoiding a craniotomy.^{1,5,11}

The 1990s were designated the 'Decade of the Brain' by U.S. President George H. W. Bush as part of a larger effort involving the Library of Congress, the National Institute of Mental Health, and the National Institutes of Health, "to enhance public awareness of the benefits to be derived from brain research".⁴

This interagency initiative was conducted through a variety of activities. These included publications and programs aimed at introducing members of congress, their staffs, and the general public to cutting-edge research on the brain; thus encouraging public dialog on the ethical, philosophical, and humanistic implications of these emerging discoveries.⁴

Challenges and Opportunities for the Neurosurgeon in the 21st Century

The 21st century brings with it multiple challenges and opportunities in view of the explosion in information technology, as well as major advances in molecular biology and genetics. Computers in medicine have revolutionised the investigative modalities, as well as diagnosis and treatment paradigms.⁵ Neuro-imaging, intra-operative neuro-monitoring, neuro-navigation, and neuro-modulation are computer-based applications which are now routinely used in standard neuro-surgical practice. A 64-slice CT scan with 3D imaging capability is used for vascular reconstructions during aneurysm surgery and for detailed anatomicopathological demonstration for brain tumour surgery.^{11,12} Functional neuro-imaging is being studied for epilepsy surgery and certain research protocols.¹³ MRI spectroscopy (metabolic neuro-imaging) is being used to differentiate brain tumours from infections and metastasis.^{5,11,14} Intraoperative MRI imaging is nowadays being used for rendering maximal safe resection of the brain tumours such as gliomas and pituitary adenomas.¹⁵ Neuro-modulation with stem cells for neurological functional restoration is currently being utilized for selected patients with spinal cord injury and certain degenerative neurological diseases.¹⁶ Although the results are modest, they offer some hope for these debilitated patients; who are otherwise wheel chair bound.^{11,16} Rehabilitation will assume a crucial role in improving patient quality of life, since stem cell transplantation and neural regeneration would prevent further cell damage.^{1,5} In fact, one downside of this could be an upsurge in medico-legal cases due to heightened expectations of treatment and the unpredictable natural course of the disease process.

Graphic-interactive cranial surgery comprises of the planning and practice of cranial surgery using instrumentation that reconstructs digital cranial images into a graphic representation of the head and then allows the surgeon to operate by interacting with this graphic rendering. The operating arm system and the medical videoscope are such examples of frameless cranial stereotaxy.¹⁷⁻¹⁹ This could lead to a video-library demonstrating surgical procedures and techniques which can then be simulated through virtual reality work stations, thus creating a new methodology for training of young consultants in this field.^{11,20} This will then be translated into real time surgery which will be known as robotic surgery. The use of stereotaxy has opened up the field of neurosurgery to robotics. Robots have been in use for the past 19 years in neurosurgery, but largely remain unknown due to limitations in current robotic systems. The commercial medical robots available in neurosurgery, such as NeuroMate and MKM, remain to be completely adopted by the neurosurgical fraternity.²¹ There is a need to develop more integrated systems in which the robots are linked to the imaging and planning software, or directly to the patient anatomy. Robotic biopsy planning facilitates careful preoperative study and optimization of needle trajectory to avoid sulcal vessels, bridging veins, and ventricular penetration.²²

The real challenge for the 21st century neurosurgeon will be to assimilate the tremendous advances in neuroscience that have occurred over the last century and then integrate this into the current practice paradigms.^{5,11} Advances in computer technology should help create large, central databases of neurological ailments which will then provide a reference model for investigation, therapeutics, and further research into the subject.^{1,4,5,11} Intraoperative image guidance systems provide real-time images, which could increase surgical accuracy.

Image guidance navigation in pituitary surgery provides continuous three-dimensional (3D) information regarding anatomical variations of the sphenoid sinus and relationship of tumors to the internal carotid arteries.²³ However, the equipment is expensive and requires specific training for the operating room personnel. Stereotactic radiosurgery for primary and metastatic lesions, as well as arteriovenous malformations, can be performed using linear accelerators and refined systems for visualization and guidance.²⁴ They can allow effective and safe treatment of radioresistant neoplasms. 3D-computed tomographic angiography (CTA) using stereo imaging technology allows viewing of multilayer fusion images for neurosurgical procedures in intracranial aneurysms.²⁵ The brain-machine interfaces (BMI) connect machines to the human brain viz. motor neuroprosthetics involves implanting microelectrodes for restoring motor deficits.²⁶

The advances in molecular biology and genetics should also change the way a brain tumour, or a degenerative neurological disease, would be treated.¹¹ Genetic microarray would be able to diagnose the type of brain tumour and then suggest relevant molecular targeted therapies. Detection of genetic abnormalities *in utero* would help the mother to make an informed decision about the future of her pregnancy. Myelomeningocele has been corrected *in utero*, so-called foetal neurosurgery, although it has been done in an experimental setting. However, its inclusion into routine clinical practice is yet to be accepted worldwide. Infusion of chemotherapeutic agents directly into the tumour bed using nano-technology would be a major advance in this century.¹¹ The applications of nanotechnology in neurosciences include nerve nano-repair, nano-imaging with nano-particles and quantum dots, nano-manipulation of the CNS with surgical nanobots, and nano-neuromodulation with nano-fibres & nano-wires.^{27,28} The nano-carriers comprise of polymeric nanoparticles, solid lipid nanoparticles, liposomes, micelles, and newer systems, e.g. dendrimers, nano-gels, nano-emulsions and nano-suspensions. These can be effectively transported across various blood-brain-barrier models by endocytosis and/or transcytosis. They have demonstrated early preclinical success in management of brain tumors, HIV encephalopathy, Alzheimer's disease, and acute ischemic stroke.²⁹ Moreover, magnetic nanoparticles (MNPs) conjugated with peptides or antibodies allow direct targeting of the tumor cell surface, and potential disruption of active signaling pathways present in tumor cells.³⁰ Newer strategies permit better delivery of MNPs systemically by direct convection-enhanced delivery to the brain. Direct injection of MNPs into recurrent malignant brain tumors for thermotherapy is being currently explored.

Prerequisites for the Modern Neurosurgeon

The modern-day neurosurgeon, the so called '21st century neurosurgeon', will have to integrate the information technology along with the advances in molecular biology and genetics.^{5,31} Surgery is more likely to become minimally invasive until molecular and genetic targeted options provide solutions to major diseases. Clinical neurology will continue to have its own importance in decision making for surgery, however, technology will help refine techniques, achieve precision, and perfection. Neurosurgeons will have to work in conjunction with other specialities including neurologists, psychiatrists, neuro-radiologists, and basic scientists. For example, epilepsy surgery involves close collaboration between neurosurgeons,

epileptologists, neuro-psychologists, and psychiatrists. As such, the neurosurgeon will have to be a leader and a task master. They will have to accept responsibility for actions, both their own and the team's, without any arguments.³¹ They have to be adaptable to suggestions, since treatments for most neurosurgical diseases have become multimodal. They must maintain patience and show perseverance at all times which will help them overcome obstacles in difficult situations. They need to be well versed with computational neurobiology and telemedicine since future consultations and operative surgery will use digital technology. They should have a sound understanding of bioethics and humanity.³¹ They should have a good knowledge of neuro-anatomy and physiology, and a scientific research based inclination to the subject concerned.

Ethical approval

No ethical approval required for this study.

Conflict of interest

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