Recent Advances in Neurosurgery

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INTRODUCTION

Neurosurgery, a new subspecialty, is constantly evolving and changing over a period of time. In recent times, new insights and requirements in terms of knowledge and practice, sub-specialisation among consultants and use of multidisciplinary teams of neurosurgeons, radiologists, anaesthesiologists, and pathologists are involved to tackle neurological problems. In recent years, newer advanced technologies have expanded and redefined the discipline of neurosurgery.[1]

METHODS

In this article, we have combined our views on important recent advancements and techniques that have surfaced and those of our seniors and colleagues. The hospital where we work is visited by many neurosurgeons and neurologists from different parts of the globe. Our hospital hosts continuous meetings to discuss the recent advances in technologies and methodologies regarding neurosurgery. Many senior doctors give their views and discuss on the pros and cons of them. This article also incorporates the critical analysis of the discussion. Some of the developments described have just become available commercially and some are still under trial.

NEW TECHNOLOGY

A multidisciplinary approach to treatment has made a significant difference in expanding the horizon of neurosurgery. Neurosurgery, even in its crude form, depends upon technologies. Some of the technologies are completely new and others have undergone a lot of reforms to reach their present state. Although revolution has been brought by the use of CT scans, recent advances like intra-operative ultrasonography, stereotactic radio-surgery, use of stem cells, 5-ALA, Deep Brain Stimulation (DBS), can possibly change the face of neurosurgery in future.

1. Intra-operative USG in Neurosurgery

In the past few years, there has been an increased demand for use of neuro-navigational systems in neurological operation theatres and have become one of the necessities for superior resection of neural lesions. Intra operative CT scan and MRI are placed but the feasibility of these tools in resource limited setting is doubtful.[2]

Ultrasonography is a transducer device that uses reflective property for image buildup. The most useful one is with phase array transducer, that uses small acoustic lenses which are rectangular in shape with area of contact being 20 to 25 mm. Use of USG rose to its height in 1990s in other medical specialities but its use in Neurosurgery was in infancy period. But today it is taking pace and is commonly used for localisation of mass lesions,

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DOI: htpp://dx.doi.org/10.3126/mjsbh.v18i2.24352

Submitted on: 2019-05-07 **Accepted on:** 2019-06-17

neuronavigation, burrhole and evacuation with biopsies.[3]

The mass lesion could be localised with the help of vascularity assessment done via colour duplex sonography, B mode with colour mode. After localisation, gradual excision could be done. Generally, total excision becomes very difficult due to the lack of intra operative visibility. However, can be resected further with the help of sonographic evaluation.[3]

Guided biopsies with a diagnostic yield of 85-100% when the most hyperechoic region is chosen for evaluation. USG guided micro neurosurgery represents a handy, reliable and relatively low-risk procedure for the treatment of intracranial brain tumours.[4]

Neuronavigation with the help of USG over the area of intent, the collection of 2D images can be used for forming 3D image volume, which takes around one minute of time. However, in cases of CT and MRI, operation time is much higher.[3]

It is constantly changing and evolving through evaluation about strain imaging that illustrates about the elasticity of brain tissue and gives clue via tissue motion and arterial pulsations.[2] It was found that real-time intra-operative USG helps us to guide the extent of tumour and extent of excision or decompression of tumour and correlates quite well as inferred with postoperative CT or MRI imaging. Hence USG can be useful and cost effective portable alternative as against a very costly and cumbersome alternative.[2]

2. Stereotactic Radiosurgery

A highly precise form of radiation therapy initially developed for the treatment of small brain tumours and functional abnormalities of the brain.

It relies on[9]:

1) Exact location of a lesion must be ascertained with the help of various imaging and localising modalities, which can be used for treatment by this method.

2) It is pertinent that specifics should be generated so as to keep patients immobile during the procedure maintain patient position required for therapy.

3) The major portion of gamma and X-rays must be converged over the lesion to achieve the maximum possible outcome. Highly focused gamma or X rays beams converge on tumour or abnormality.

It can be used in the treatment of various types of brain tumours, AVMs and /or trigeminal neuralgia and tremors. Most of the skull base tumours are intimately associated with critical nervous and vascular structure, therefore multiple attempts at total resection should be avoided as it may cause significant increase in morbidity.[5] Radiosurgery has become an increasingly attractive alternative to microsurgical resection of lesion at skull base. Published case series have described radiosurgical management of these lesions and have shown excellent overall tumour control and extremely low rates of morbidity.[6]

In aggressive tumours like craniopharyngiomas, surgical excision produces high rates of local control but this treatment carries substantial risk of recurrence.[5] It has been postulated that radiosurgery can produce higher tumour control and produce increased survival and/or low rates of morbidity.

Regarding future of stereotactic radiosurgery, the technique is new and evolving with time. It is still under trial and yet to undergo many refinements and changes in substantial ways, so as to receive FDA approval, for treating a patient with metastatic tumours.

3. Stem cells in Neurosurgery

Most likely restorative neurosurgery began three decades ahead in the western world in terms of research and clinical trials. It began with the vision of the possibility of replacing degenerating nerve cells. The final goal of this in neurosurgery is reconstructing neuronal pathways. It can be summarised as replacement, release, and regeneration. That is, dead neurons have to be replaced, the grafts have to be able to release neurotransmitters and circuits have to be rebuilt. As the study progresses, clinical trials may be in effect for the treatment of various conditions like multiple sclerosis, traumatic brain injury, cerebral palsy, Alzheimer's disease, and even spinal degenerative disorders.[7]

Perhaps the most important reason that stem cell development is so appealing to neurosurgeons can be found in the following statement: 'The adult human brain, in contrast to other organs such as skin and liver, lacked the capacity for self-repair and regeneration.' Currently, there is still no set of markers or protein expression profiles that precisely define and fully characterise undifferentiated neural stem cells.[8]

Brain tumours present with a diagnostic dilemma to clinicians, hence it demands an urgent need to develop more effective therapies. One of the modality that has shown promising results could be use of neural stem cells. However, they are constantly under trial for production of immuno-stimulatory cytokines and/or acts as a viral vector. It is pertinent that permanent neurological impairment takes place in cases of traumatic brain injury. In some studies it has been shown that post traumatic neurogenesis tends to occur in hippocampus, subventricular zone and to some extent, at cortical level too.[10]

Though it poses significant advantages over current clinical practice and tends to be more refined from its present crude state, it has multiple concerns like cell survival, immunogenic effects, ethical concerns, stem cell contamination, and others.

4. 5-ALA in Neurosurgery

There is an increasing trend for use of 5 Aminolevulinic Acid (5-ALA) which helps to differentiate tumour borders and healthy brain tissue, which in turn help in removal of tumour. This drug is taken per oral before surgery and when exposed to blue light, it glows as hot pink in colour and tumours can be removed to a greater extent. This is known as fluorescence guided resection (FGR).[11]

Orally administered 5-ALA permits intra operative visualisation of tumour bulk along with surrounding zone of infiltration present in malignant gliomas. Studies have shown that 5-ALA induced fluorescence provides real time information for differentiating normal brain and tumour, which remain independent of neuronavigation and brain shift. High rates of tumour excision can be achieved when this fluorescence technique when used in combination with intra operative monitoring and mapping.[13]

In a systematic review done by Ferraro et al.,[12] it showed that sensitivity of 5-ALA was highest in high grade glioma (85%), and meningioma (81%). Similarly, specificity was high in meningioma (100%), as well as metastasis (84%) and high grade glioma (82%). It also showed that gross total resection was achieved in 69.6% meningiomas and 66.2% in all gliomas, irrespective of their histologic type. This shows that it can also help in achieving better tumour resection.

5. Deep Brain Stimulation

Deep Brain stimulation (DBS) is an outcome of technical and scientific development in the field of Neuroscience and Functional neurosurgery. It is one of the effective surgical treatments for hypokinetic and hyperkinetic movement disorders which are refractory to medications. It has changed the modality of treatment for movement disorders like tremors, Parkinsons disease, dystonia and tend to be beneficial for neuropsychiatric illnesses like depression, epilepsy and obsessive-compulsive disorder.[14]

Though exact mechanism of DBS remains eluded, it is thought that DBS activates neurons and regularises the pathological activity and oscillations within basal ganglia thalamo-cortical network improving sensorimotor processing thus alleviating disease symptom.[14]

Closed loop deep brain stimulation is a new technique which tends to broaden the indications of deep brain stimulation. It analyses multiple electrophysiological and neurochemical afferent information about the function of different parts of brain. The efferent information will be electric stimulus or neural proteins and transmitters, neural grafts pleuripotent stem cells or mesenchymal stem cells and variant of gene therapy.[15]

CONCLUSIONS

Neurosurgery is one of the emerging fields that has benefitted from technological advancements. Recent evolutions in technology like Intra-operative USG, use of 5-ALA, DBS and many others, have significantly improved diagnostic and therapeutic possibilities available to patients. These advancements can be a determining factor towards positive outcome or poor one, relative to patient care. They can act as foundations for safer and more effective treatment of patients, thus improving cost-effectiveness ratio and standard of care.

To cite this article: Paudel SS, Luitel R. Recent Advances in Neurosurgery. MJSBH. 2019;18(2):70-2.

Conflict of Interest: None declared

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