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Neurosurgery Past, Present and Future–A Saga of Unceasing Effort and Wondrous Achievement

V. Balasubramaniam

SUMMARY

The history of neurosurgery is discussed in two parts the pre-Cushing era and the Cushing-Dandy era. The Cushing-Dandy era is described with the contributions of these two to neurosurgery. The development of neurosurgery and neurodiagnostic methods is traced upto 1972. The modern era of neurosurgery along with all the sophisticated equipments for diagnosis and neurosurgical procedures has brought improvement from many perspectives. The usefulness of modern neurosurgery and the various high cost equipments are analysed from various angles. Advances have taken place with increase in diagnostic accuracy, greater number of condtions diagnosed and also bolder surgery resulting in better quality of life. Judged from all these perspectives modern neurosurgery has justified the high cost and fulfilled the expectations of the scientists who have worked hard towards the improvement. The fear of displacement of clinical neurology is allayed indicating its continuing usefulness.

The future of neurosurgery is described in a limited way as a continuation of growth along the existing lines without allowing for sudden explosions of knowledge. Even at this predeterminated rate the future is bright.

Dedication

The citadel of neurosurgery as it is today is not the work of a few individuals. It is the culmination of the tireless efforts of many people. Some of them are well known and notable, yet for every single notable person there are at least ten whose efforts are not so well known. To all these well-known stalwarts and the unsung heroes, the saints without halos, this talk is dedicated.

The art of medicine is as old as mankind, but in this vast field of healing art, one of the youngest and unquestionably the queen of all specialities is neurosurgery.

The past is always the guide of the present to the future. A study of the history of any subject not only will induce a sense of humility in those who are apt to be proud of their achievements but it will also guide contemporary activity into useful channels for the sake of posterity.

The art and science of healing the sick arose when early man fell a victim to accident or disease. In most cases the parts so affected were easily seen and their repair attempted and achieved, as well as the existing conditions permitted. But, the brain enclosed as it was in the bony skull always remained an enigma. Moreover in the earlier part of the history

*General Amir Chand Oration, National Academy of Medical Sciences, 1991-92

of mankind the heart was always considered supreme and the brain was accorded only a secondary place. So knowledge about diseases of the brain and more so about their treatment did not make any headway. Because of the existence of neatly punched holes in the excavated skulls many would like to believe that these are evidences of earlier neurosurgery. However attractive this may sound, it is very likely that these were done with specific purposes of operating on the brain. However after these doubtful starts neurosurgery did not make an appearance till the latter half of the nineteenth century. The late start of neurosurgery was partly because of the need for solid ground work by giants like Galen, Willis and hosts of anatomists, physiologists and pathologists. This was also because the conventional surgical techñiques that were available for abdominal surgery etc were not adequate for neurosurgery.

The history of neurosurgery can be divided into pre-Cushing era and the Cushing-Dandy era.

PRE-CUSHING ERA

Any attempt to assign chronological priority is always attended with risks of being misunderstood. And anyway it is not always a fruitful exercise where a large time gap exists. The generally accepted view will be presented here. It has been held that Sir William Macwean was the pioneer in neurosurgery. He had operated for many intracranial conditions including a meningioma. Borrowing his lines from Sir Issac Newton, Cushing (in the Macwean memorial Lecture delivered at the University of Glasgow in 1929) says *"We merely stand on the shoulders of our predecessors, and the study contemporary figures of Macwean on one side and of Horsely on the other side are what support the arch of modern neurological surgery."*

To Macwean belongs the distinction of having been the pioneer of craniocerebral surgery. As is well known Macewean was a superb surgeon and made a mark in other branches of surgery like orthopedics, thoracic surgery and otologic surgery. Many however hold that R.J. Godlee was the first to operate on a brain tumor. What is not so well known is that by the time Godlee presented his paper in 1885, Macwean had operated on many patients for 'tumorous' conditions. After Macewean and Godlee the next notable figure was Sir Victor Horsley. Horsley's contributions to neurosurgery were epoch making. He was the first to operate on a spinal tumour. Along with Henry Clarke, Horsley also introduced the Horsley-Clarke stereotactic apparatus for experimental purposes. There were also many early starters in other countries. In Denmark, in 1877 Carl Reinhold Struckmann removed the external portion of what was presumably the hyperostosis of a meningioma.

The reason why Horsley is generally considered as father of early neurosurgery is perhaps because he was entirely devoted to the speciality.

Horsley planted the seeds of neurosurgery but it was in the Cushing-Dandy era that this plant matured.

CUSHING-DANDY ERA

It can be said that neurosurgery as a distinct speciality began with Harvey Cushing (1869-1939). Before his days neurosurgery was performed by a few of the boldest but the techniques were not suited for the peculiarities of brain anatomy and physiology, hence it was no wonder that the outcome was unpredictable. A diagnosis of brain tumour was an exercise in clinical neurology but often a sentence of death. It was this that made Foster Kennedy exclaim, *"He who cares for patients suffering from brain tumours must bring to the problem much thought and stout action. There is need also of a formidable optimism as the dice of God are loaded."* Harvey Cushing's contributions to neurosurgery are unrivalled. He not only laid down the various techniques of neurosurgical procedures but also along with Percival Bailey gave out the first comprehensive classification of gliomas. This has been the launching pad for many of the later classifications like Kerhonahan's, Russel and Rubinstein's and others. Many objections have been raised against some of the terms and yet even after six decades no proper substitutes have been found for them like the terms meningioma and medulloblastoma-two of the most debated terms. Every step in a craniotomy was shaped by Cushing. Many of the younger neurosurgeons of today may not be aware that even the standard two later closure of the scalp was handed down from Cushing. He was responsible for introducing the Bovie electric cautery and this was described by him in his Macwean Memorial Lecture (alluded to earlier) of 1927. He described therein how he removed an olfactory meiningioma using this new instrument. Even today most neurosurgeons remove an olfactory groove meningioma in an identical fashion-an evidence of an outstanding and perennial contribution. But Cushing did not stop with laying a solid foundation. He soared to heights unheard of earlier and unlikely to be equalified in the future. By 1931 he was able to report on 2023 verified tumours.

Having been a student of John Halstead, Cushing's meticulous attention to details brought down the mortality of brain tumours. To take one examples prior to the days of cushing the mostality of *acoustic tumours* acoustic tumours was anywhere from 60 to 100%. Cushing brought down the mortality of this tumour steadily. In his earlier years the mortality was 18%, a feast in itself. Later he brought it to 4%-a stupendous achievement. His contributions to pituitary tumours are perhaps the best of his accomplishments.

It is difficult to imagine that there would be anyone equal in stature to Cushing. Yet there was another and what is more he was Cushing's contemporary. Never in the history of neurosurgery was the neurosurgical firmament lit by two suns shining at the same time. This person was Walter E. Dandy (1886-1946). While Cushing hewed and shaped neurosurgery, Dandy reinforced it, elevated it to the highest level imaginable through his innovative techniques and bold approaches into areas considered sacrosanct and dangerous. An obituary in Baltimore Sun wrote about Dandy as follows: *"The imaginative genius to conceive* *of new and startling techniques, courage to try them and skill-superb skill to make them successful."* Dandy was not only a superb surgeon but also a researcher of great standard. His work on hydrocephalus, almost his first, stands unmatched even today. For the first time children with hydrocephalus could have relief and sometimes even cure. He practiced succussfully a series of bold operations like third ventriculostomy, catheterisation of the aqueduct and other procedures like excision of the choroid plexus. He was the first to excise the choroid plexus both by open method and by endoscope-a breathtaking achievement even today. Yet he realized the limitations of his method and did not promise a cure in every case. In his hands many apparently inoperable conditions became capable of solutions like arterio-venous malformations, pineal region turmours, intraventricular tumours and a host of others. His surgical successes are mind-boggling even today. To give one example in 1945 he had done 682 operations of eighth nerve section for Meniere's disease with 0.14% mortality! His observations as to a primary cause for trigeminal neuralgia and his anatomical observations on the entry zone of trigeminal root were greeted with skepticism, but now they have been corroborated by the operating microscope-thus reminding us the adage that cynicism is the reaction of ignorance to merit.

During Cushing-Dandy era surgeons had to operate on the basis of their neurological findings and because of this clinical neurology reached an acme. The only help available was from the plain x-rays, thanks to Roentgen. Anyone who reads Cushing's clinical notes cannot but be impressed by the astuteness of his observations and the exquisitely sharp clinical acumen. And yet this was not sufficient.

DANDY'S VENTRICULOGRAPHY

It fell to the lot of Walter E. Dandy to discover ventriculography. This straightway was able to pick out many tumours which had been elusive earlier. In the words of Horrax, a famous neurosurgeon, *"it brought immediately into operating field atleast a third more brain tumours than could be diagnosed and localised previously by the most refined neurologic method".*

SOME MORE PIONEERS

The Cushing-Dandy era not only marked the beginning of the golden period of neurosurgery but was itself the most brilliant. To borrow the words of Churchill: *"Never in the field of human conflict was so much owed by so many to so few".* Alongwith and after Cushing and Dandy came a galaxy of neurosurgeons who refined and polished the legacy of these pioneers. They included Sir Geoffrey Jefferson (1886-1961), Olivecrona (1891-1980), Norman McOmish Dott (1897-1973) and a host of others. Their skills were formidable and as if to suit this more diagnostic aids came in. They and others too numerous to mention, contributed enormously to the science and art of neurosurgery and worked hard to reduce the mortality following surgery. At this stage one is reminded of a statement attributed to Lord Rutherford : "It is not in the nature of things for any one man to make a sudden, violent discovery; science goes step by step and every man depends on the work of his predecessors. When you hear of a sudden unexpected discovery, a bolt from the blue, as it were you can always be sure that it has grown up by the influence of one man on another, and it is the mutual influence which makes the enormous possibility of scientific advance. Scientists are not dependent on the ideas of a single man, but on the combined wisdom of thousands of men, all thinking of the same problem and each doing his little bit to add to the great structure of knowledge which is gradually being erected"

NEUROSURGERY IN INDIA

At this stage a few words must be said about neurosurgery in India. Before 1950 neurosurgical procedures were done by a few bold and dextrous general surgeons. Dr. Govindaswamy of Bangalore performed leucotomy for psychiatric indications and reported his experience as early as in 1944. Later came some more pioneers. Among them stand out Dr. Narasimha Iyer, Dr. Chintan Nambiar and Dr. C.P. Viswantha Menon. In 1950 neurosurgery was started in India almost simultaneously in two places separated by less than a hundred miles. The two pioneers were Prof. B. Ramamurthy (at Madras) and Prof. Jacob Chandy (at Vellore). After the start given by these two pioneers neurosurgery has grown rapidly and widely all over India and now there are as many as five hundred neurosurgeons.

CT SCAN AND BEYOND

The hard efforts of all the neurosurgeons and the profound skill of all the neurologists reduced the mortality to a considerable extent no doubt. But at times the morbidity following surgery was so severe as to question the wisdom and usefulness of some of the surgical procedures. For example a patient who has an acoustic tumour removed after 6-8 hours of gruelling surgical session might continue to be blind because the optic discs were already atrophic when the diagnosis was made. Angiography and ventriculography diagnosed these tumours only when their mass effect (or space-demanding size) was great.

Such was the state of affairs till 1972 when a great upheaval took place in neurodiagnostics. This was the discovery of Computerised Axial Tomography thanks to the work of Hounsfield and Cormack. Computerised Axial Tomography has become a household word now as CT scan. It is the forerunner of many other scanning techniques using computer technology. The diagnostic accuracy jumped from 60-65% to an astounding 90-95%.

The CT scan was followed by the Magnetic Resonance Imaging (MRI). There is a peculiar quirk of chronology here. The concept of MRI was envisaged as early as 1956 by the Dutch scientist Gorter. Ten years later Bloch and Purcell discovered its application. But only in 1976 (four years after the CT) MRI emerged as a diagnostic tool.

Both MRI and CT had pushed up the diagnostic accuracy to about 99%. Can we ask for more? No longer could neurosurgeons blame the delay in diagnosis and explain away the bad results. And they did not. It is a matter of pride that present-day neurosurgeons rose up to the occasion. Various other types of scanning machines began to appear. All of them were based on computers for the retrieval, deduction and display of the conditions. Some of them are the Single Photon Emission Computerised Tomography (SPECT), Positron Emission Tomography (PET Scan), Digital Substraction Angiography (DSA) etc.

ADJUNCTS TO SURGERY

Almost contemporaneous with these diagnostic paraphernalia many invaluable adjuncts to surgery were introduced. Of these the bipolar diathermy, operating microscope and intraoperative sonography are important. The bipolar diathermy, because of its ability to coagulate only the tissue between the tips of the forceps could be used safely in important areas. The part played by the operating microscope in neurosurgical operations is as significant as that of the CT in diagnosis. Through a small incision deep seated lesions could be easily tackled with absolute safety to overlying or neighbouring areas.

HISTORY OF MICROSURGERY IN BRIEF

Because of the significant role played by the operating microscope in neurosurgery it would be worthwhile to trace briefly the introduction of the operating microscope. The operating microscope was first used by the ophthalmic surgeons. What is surprising is that there was a gap of many decades before it was taken over by the neurosurgeons. To quote Donaghy *"it is not easy to understand why more than half a century elapsed between the introduction of magnification of surgery (in the field of opthamology) and its incorporation into neurosurgery, where the surgeon so often must deal with fine fragile structures at great depths-a situation for which the principle of magnification seems so admirably suited."* Kurze and House used the microscope during surgery of acoustic tumour. But the credit for establishing and popularising the use of the microscope in neurosurgery belongs to R.M.P. Donaghy and later to Robert Rand. Subsequently Gazi Yasargill brought it to the European continent. Today except for the simplest and most superficial of neurosurgical operation, no neurosurgeon would work without the microscope. Intraoperative sonography can be considered as an extension of the conventional B mode ultrasonography. Since the bony skull prevented the use of ultrasound, neurosurgeons got round this, by employing the ultrasound after bone was reflected. This method is extremely useful in reaching small lesions in the so-called eloquent areas or in deep recesses of the brain.

Besides these there are certain ancillaries which while not being indispensable, certainly make the operative procedures earlier. These are laser and cavitron ultrasonic aspirator.

Advances in physics are providing the neurosurgeon with more and more sophisticated forms of laser.

Besides these, a new approach has been evolved by borrowing a technique that was threatening to disappear after a short period of importance. This is the application of stereotactic principles to routine neurosurgical operations. With the manufacture of CT-compatible and even MRI-compatible stereotactic machines along with microdrivers, the diagnostic accuracy of these machines has been linked with the exquisitely pin-point localisation of stereotactic techniques. This has facilitated resection of deep seated tumour without a major craniotomy.

With all these gadgets the modern neurosurgidcal operation theatre would look like the control room of a spaceship.

The present day neurosurgeons are at the turn of the milennium. Those that took up neurosurgery after 1972 do not known what it is to do ventriculography in a patient with severe intracranial tension. Some of the older neurosurgeons will appreciate this.

PRESENT DAY NEUROSURGERY

Have all these advances done any good? Or are they mere gimmicks and gadgetry to befuddle the sick patients and their relatives? More than this, have the results been better than those of Cushing and Dandy? Can neuroscientists justify the enormous expenditure involved in the construction and maintenance of the various equipments. A CT machine costs about Rs. 1.25 crores, an MRI machine about 3-4 crores of rupees. The maintenance of some of these machines (like the MRI) would run upto 40-50 thousand rupees per month. Because of the high costs the various tests also are expensive. A doubt may arise at this stage. Are these tests essential? Are they cost effective? Can the public afford these tests?

There can be no two opinions that these diagnostic procedures are costly. This is particularly so in neurosurgical practice. To take an example of a patient suspected to have a tumour in the pineal region, the patient will need plain X-ray of skull, CT scan, and sometimes an MRI also as one must known its relationship to the brainstem and the extension in various directions to plan the approach. In most cases a vertebral angiogram (transfemoral or DSA) will be needed to know the displacement of the vessels. They will add upto Rs. 8000 at a very conservation estimate.

After this comes the fees for surgeon etc. How many people can afford this will be a question most of us would like to ask.

There is as yet another aspect to this. With increasing litigation in medical practice the concerned surgeon would not thinking long before ordering for these tests in spite of their cost. This is because he is justifiably scared that he may miss a small lesion or that he may be accused of negligence in not having asked for a test.

A big question that will arise is have all these tests improved the matters? This will be discussed from three angles.

1. Increase in Diagnostic Accuracy

Firstly while evaluating all these tests the diagnostic accuracy has to be balanced against the risks involved. In the evolution of these tests one can see that the tests are not only becoming less risky but also less, if not totally non-invasive. Dandy's ventriculography, which ushered in the era of diagnostic procedures, certainly carried a definite risk, at times serious enough to cause a fatality. Neurosurgeons of those era would remember nightmarish memories of patients, who after injection of a few c.c. of air, became decerebrate and unconscious and had to be resuscitated and even operated straight-away. Not all of them ended happily. Today the MRI is completely non-invasive, except when a para magnetic agent is administered. Simultaneous with reduction of risks there has been an increase in diagnostic accuracy. Because the earlier tests were not only invasive but carried a certain amount of risk there was a justifiable reluctance to resort to them until the indications were strong. The various tests, their risk and accuracy are shown in Table 1.

2. Increase in Number of Conditions Diagnosed

The second starts from the first. Since these tests can be ordered with absolute safety there has been an apparent increase in the incidence of some problems. As an outstanding example can be given the condition of chronic subdural haematoma. Prior to 1972 the number of chronic subdural haematomas diagnosed was very low. Any person above 50 or 60 years of age or more who developed a hemiplegia or so called 'mental' symptoms was diagnosed to be having a 'cerebrovascular accident' and treated accordingly. This was because cerebrovascular accidents were common at that age and for any other diagnosis an angiography was needed and this could not be asked for with impunity. When the symptoms were persistent and when the attending doctor was alert enough the lucky ones had angiography

Table 1 : Risk Justification and Safety of Modern Imaging Techniques in Neurosurgery

Test	Invasive/non invasive	Safety	Reliability
Air Studies	Invasive	$Risk^{++}$	50-60%
Angiography	Invasive	$Risk^{+}$	60-70%
EEG	Non invasive	Safe	30-40%
CT	Almost completely non invasive	Safe	90-95%
MRI	Almost completely non invasive	Safe	90-95%
DSA	Invasive	$Risk^{+}$	60-70%
PET San	Almost completely non invasive	Safe	80-90%
Ultrasound	Non invasive	Safe	30-40%

done and were cured by drainage of subdural haematoma. Today this impasse can be overcome by a CT scan. Every neurosurgeon can testify to the fact that suddenly chronic subdural haematomas have "increased" in incidence.

Thus CT has revealed that a diagnosis of hemiplegia which in earlier decades meant a cerebrovascular episode, is not always correct. Fortunately the modern surgical ancillaries have carried the improvement further and many of the cases could be treated satisfactorily. One such example is hemiplegia in children which was given the term 'infantile hemiplegia' and nothing more could be done. Not suprisingly many of them turned out to be correctable conditions. Another condition is the prompt evacuation of certain types of intracerebral haematomas.

In the pre-CT scan days the protocol for investigations of a focal seizure required an air study and/or an angiography. In neoplastic conditions which gave rise to such seizures these tests yielded positive results only if there was a mass effect. Consequently, such cases were missed in the early stages. This thing cannot happen today. With CT and MRI the diagnosis of a lesion even 1 cm in diameter is easy. Interestingly even in angiomatous malformations wherein one would expect angriography to have the last word, certain types of small lesions cannot be delineated. Only the CT and MRI can do this. A new term has been carried to describe these. These are known as 'angiographically occult AV malformations.

Yet there is another way CT and MRI have helped. As was already remarked angiography (except in cases of AV malformations) helps because the lesion displaces the various vessels. Tumours in the midline (like the anterior third ventricle, pineal region and foramen magnum) do not show up well in the angiogram. The CT can pickup such lesions. And even here the MRI has an edge over CT particularly in tumours of the clivus. Neoplasms of the brain stem do not produce mass effects early and hence only the CT or MRI can help. When we come to diseases of the spinal cord and spinal canal the MRI has no match. It is no slur on the earlier gneration of neurosurgeons that with all procedures more lesions of spinal cord are diagnosed and diagnosed much earlier.

Increase in diagnostic accuracy and increase in number of conditions detected are the two great benefits of modern neurodiagnostic armamentarium. The third improvement is the effect on the surgical techniques.

Before we discuss this we have to assess the effects of these diagnostic aids on contemporary neurology. Some of the older generations of neuroscientists might have a deep seated feeling that these tests are being ordered on flirmsy clinical findings. There is also (according to some) a more serious fallout from this. It is felt that these tests have already begun to toll the knell of clinical neurology. A vision of the clinical neurology so vigorously nourished by giants like Charot. Jackson, Gordon Holmes and a host of others, being pushed into the background is in the minds of many scientists. According to this nightmare clinical neurological examination will become an academic pastime with no serious therapeutic application. The diagnosis will be given by the computer hooked on to the CT and MRI. To these Cassandras we can say that such a state of affairs will not occur to the extent they envisage. Neither the CT nor the MRI can give the diagnosis. It can list the probabilites. Without knowing the age, sex, state of patient and nature of evolution of the disease none of the tests can arrive at the diagnosis. Unless the whole clinical picture is taken into consideration the result will be disastrous. Many instances can be given of the CT diagnosis being forced to be changed when correlated with clinical findings. Clinical neurology will never be effaced. But it cannot be denied that some of the diseases can be detected a little earlier by these tests than by clinical examination. And that is after all for the good of the patient. Only one example need be given-of tumour of the clivus. There has been a sudden spurt in the number of cases of tumours of clivus being operated by individual surgeons. Is this a true increase in incidence? No. This is because these cases are easily diagnosed by MRI.

3. The Third Perspective-Bolder Surgery, Better Life

The third benefit from these newer tools is in the realm of surgical procedures. With adjuncts like the operating microscope and bipolar diathermy and others, better and/or more radical resections are being done. More difficult procedures are being performed. At the outset it must be pointed out (though it may be obvious) that these to not mean that we are better neurosurgeons than Cushing or Dandy. Even today, any discerning neurosurgeon would know that what Cushing and Dandy had achieved with the few facilities that were available, was indeed astonishing. And if Cushing or Dandy were to live today, what they would have accomplished with bipolar diathermy, microscope etc is beyond our comprehension. This statement is not just made for the sake of praising them. What is meant to be conveyed is that with the modern aids the standards of neurosurgery, judged from any angle has gone up.

As an example the management of craniopharyngioma stands out. Ironically this tumour offered the most formidable challenge even to Cushing who was a master of pituitary tumour surgery. Whereas with pituitary tumours his mortality figures for the last 79 cases was 3.9%, in craniographyngiomas he met his Waterloo. This is what he finally says about these tumours : *"But all in all these cases (cranioparyngiomas) offter the most baffling problem which confronts the neurosurgeon and the fact that the mortality which accompanied radical attempts to extirpate a large solidified tumour must approximate 100% probably accounts for the few reports of these lesions other than by pathologists. Even from the mere standpoint of preservation of vision the problem is a highly complicated and difficult one. Until some method is devised whereby the usually multilocular epithelial lesion can be destroyed or inactivited in situ, the mortality will remain high". This was in 1932.*

Dandy, the master surgeon, says of craniopharyngiomas : *"In proportion of their cystic element, their anterior position and their lack of adherence they are easy of removal. In proportion to the reverse of these factors the tumours are difficult, dangerous and at times impossible for complete extirpation". This was in 1935.*

With bipolar diathermy, operating microscope what is the position today? Certainly much better-let us go through two reports.

Yasargil reports that *"between 1980-1988, fifty nine patients had primary surgery for craniopharyngioma with complete removal of the tumour in each case. There was no operative mortality. One died after 6 months due to non compliance with medication for her diabetes. Two patients (2.5%) had severe morbidity and so far (in 1990) there has been no recurrence."*

Another report by Hoffmann et al in 1992 is as follows: *"Our experience indicates that over 60% of craniopharyngiomas in childhood can be totally resected with minimally significant mortality and morbidity."*

The conclusion is obvious. It cannot be denied that modern neurosurgery has justified the hi-tech diagnostic and operative aids. Yet another example is outstanding. As late as 1968, Matson, the doyen of paediatric neurosurgery while on the subject of brain stem tumours wrote, *"...... should any patient still be alive 18 months after diagnosis, reinvestigation and surgical exploration is indicated, as some other lesion is probably present. Regardless of their history brain stem gliomas must all be classified as malignant tumours since their location in itself renders them inoperable."* While this statement was justified then, the situation is certainly not so bleak now. With CT and MRI we know that there are different types of lesions and those that belong to the focal, cystic or exophytic varieties do carry a fairly good prognosis.

One of the most spectacular achievements of modern neurosurgery is the surgery of skull base tumours. Tumours arising from or involving the skull base usually meant relentless deterioration ending in death. Today a large number of these patients are being operated successfully by many surgeons. The clivus, the bony bridge between the sphenoid and occiput was long considered as absolutely inaccessible and today there are many excellent and innovative appraches to this region. The earlier inaccessibility of this area is exemplified by the title of a book published now in 1992, 'Approaches to the Clivus-Approaches to No Man's Land'.

Another striking innovative technique has resulted from combination of stereotactic surgery and radiotherapy. This is the radiosurgery of Leksell-commonly referred to as the gamma knife. The principle is to focus many beams of radiation (each in itself too mild to injure the brain) to deliver a heavy dose at the desired sites. This is done stereotactically, and since the skull offers no barrier to radiation there is no need for even burr holes. Many conditions like

AV malformation, tumours like acoustic tumours can be treated by this technique. The only disadvantage of this is the huge cost. The treatment charges alone come to round about $15,000 i.e. Rs. 4.5 lakhs.

The most significant point in present day surgery is the stress on the quality of life. It is not that our pioneers were not interested in this. But then their main concern was to save life at any cost. Later with increasing diagnostic accuracy and greater adjuncts for surgery, mere saving of life was not found sufficient. The stress was also on lowering the morbidity. There was no use in merely winning the battle and losing the war. Heroic attempts just to safe life however crippled the patient after the surgery, but could be accepted if the patients came late in the evolution of the disease; but not now. We saw how the absence of mortability was stressed in the surgery for craniopharyngiomas. Meticulous assessment of the quality of life is kept by various scores. One such is the Karnofsky's scale. To achieve this various steps are taken during surgery to avoid damage to uninvolved parts of the brain or spinal cord. One of the outstanding example of such attitudes that are emerging can be seen in the surgery of acoustic tumours. It was Cushing who brought down the mortality from over 60% to 4%, by his intracapsular excision wherein the capsule was left behind. This was advocated by Cushing to avoid damage to brain stem. At the same time Walter Dandy practised total excision with less mortality and less morbidity. In those days there was no question of saving the VIII never or even the VII nerve. In fact many of the surgeons who followed, concentrated on various methods of overcoming the facial paralysis by nerve grafting etc. From a superficial study it looked as if a facial palsy was a small price to pay for life. But the neurosurgeon of modern era would not rest on his laurels. With help from the enlarging field of otology, methods were evolved not only to remove the tumour completely but to save the facial nerve also. Today most patients need not fear this cosmetic disability. With more progress now attempts are being made to save the VIII nerve also. This has not been achieved completely. Recently a series of 6,982 cases was published where there was an emphasis on the preservation of hearing. To quote Moskowitz and Long, *"... cochlear nerve preservation was accomplished in 23.7% of patients, postoperative hearing preservation in 15.2% of patients, and serviceable or functional hearing in 9.7% of patients."* Surely a great progress from the days of Cushing who wrote: *"In the average case, if the pressure effects of the tumour can be so far overcome by an intracapsular excavation as to permit a subsidence of choked disc and thus to save vision, one may well be content; and should a secondary operation for recurrence ever be necessary it need not be particularly dreaded."*

Hitherto only the neurosurgical procedures have been outlined. It must not be forgotten that equally dynamic developments had taken place in many other branches under the umbrella of neurosurgery. One of them is in the field of radiology wherein a new branch of interventional radiology has come to stay and has taken over the management of some problems like deep seated arteriovenous malformations.

It can be said without fear of contradiction that modern neurosurgery has justified all the amount of interest and time physicists, chemists and computer engineers have spent on this subject. At the same time it should be remembered that if this edifice is big and imposing today it is because it has been built on broad and sturdy foundation laid by the trail blazers.

The Future

Any discussion about the future can be considered only as an extension of the present at the same rate of growth. One can never predict sudden explosive innovations like what happened in 1972 when the CT scan was discovered. The future of neurosurgery will have to concern itself with many of the existing and till now unsolved problems in addition to adding newer methods and techniques.

Of the existing problems that need urgent attention some are

1. Severe head injuries
2. Spinal cord injuries
3. Vascular insufficiency
4. Management of gliomas
5. Congenital abnormalities
6. Neural transplantation

1. Severe Head Injuries

The management of minor head injuries and the evacuation of collections of blood in various compartments of the head have become common place. Today there can be no justification for loss of any life due to an extradural or subdural haematoma. But the patient with severe head injuries is an altogether different problem. Here we are dealing with massively injured brain tissue with a neurochemical explosion. As it is, our present day methods euphemistically called 'supportive and expectant' line of treatment have only enabled us to keep alive by artificial means a person who is deeply comatose and has stopped breathing. Quite properly some have even questioned the usefulness and the need for such aggressive treatment in these cases. If the direction of ongoing research is any indication perhaps the answer might come from neurochemistry. Many efforts are being made to avert the events after a head injury. These happen because of the unlimited formation of free radicals and chaotic movement of ions like calcium. This results in a vicious chain reaction in which more neural tissue is damaged resulting in oedema which produces further damage. Already some trial methods promise a breakthrough. These involve the use of chelating agents, administration of large doses of Vit C, Vit E and certain chemical agents like dimethylsulfoxide (DMSO). The use of methyl prednisolone with heightened anti-inflammatory effect and lessened minerolocorticoid effects promises to be of some use. At the same time we hope that our engineering colleagues will come up with better methods of preventing head injuries atleast in traffic accidents.

2. Spinal Cord Injuries

One of the most dismal chapters in neurosurgery is the management of spinal cord injuries. While we have garnered much information about the mechanisms involved, very little progress has been made in the management or cure of individual cases. Occasional cases of recovery after surgery are mostly anecdotal in nature. In this field again methyl prednisolone offers some hope. In the future, suture of the severed cord with assurance that the neural tissue will grow may come about if our knowledge of neural regrowth improves. But as it is, suture of the cord is useless, even if it is possible unless is regrowth. The place of drugs like naloxone and others is still undecided.

3. Vascular Insufficiency

In the management of vascular insufficiency, neurosurgeons have been overtaken by the cardiovascular sugeons. Of course the problems are not identical as the effects of hypoxia on the brain are more devastating to the specialised tissue of the brain. While it may be difficult to reverse the effects on tissue already damaged by anoxia, attempts to salvage the penumbra surrounding the dead area may be worthwhile. Again here methods to improve tissue perfusion might help as well as surgical procedures to augment the blood supply. The prophylaxis of this problem will consist in identifying the patients at risk and, to devise methods of reducing these factors. Attempts to revascularise the areas at risk would be useful at this stage. A small beginning has been made towards this.

4. Glioma Management

The management of glioma of the brain is still far from desirable. And this in spite of early diagnosis in at least 99% of cases. It must be said that nowadays radical surgery is practised with greater frequency. The problem now is one can never be sure that the entire tumor has been eradicated at time of surgery. It is necessary to know this as further management depends on as much cytoreduction as much as is feasible. Certain present day laboratory techniques may help to determine this.

The first is the determination of these dimensional size of tumor This is done by making use of the fact that the peripheral benzodiazepine receptors on the mitochondria are found to be increased by 20% in tumor tissues. When the appropriate ligand is used and the brain scanned with a PET scanner the tumor infiltration is seen fairly well. Better than this is to use peripheral benzodiazepine ligands with ferro-magnetic compounds and scan with MRI.

An intra operative estimation of tumor resection would be more useful. Here two avenues are being explored currently. The first is the extension of the conventional MRI into the operating theatre by making it portable and using ferrous magnetic ligands. This will also give rapid images during surgery.

The second is the betaprobe. Here the principle is simple. After the main excisional surgery a positron labelled material (like benzodiaepines, leucine or fluorine—18 fluorodexyuridine) is injected and after sometime (depending on the time of uptake) the betaprobe is placed on different areas in the brain. When there is no uptake complete resection is proved. But unfortunately radical surgery is limited by the fear of producing neurological deficit particularly when the pathology involves the so-called eloquent areas. Radiation therapy, chemotherapy and immunotherapy are still to establish that they are really curative and not merely palliative. It is, at present impossible to predict in what forms a really useful form of therapy will come about.

5. Congenital Abnormalities

One of the unexplored territory is the management of congenital malformations. It is hoped that a cataclysmic breakthough will occur, as currently the picture is far from rosy. Identification of the causative factors and their elimination will be the ideal. Till then the detection of these abnormalities and their management in utero will have to be done. To a great extent the antenatal detection of these abnormalities either by ultrasound or aminocentesis or even blood examination has yielded commendable results. But then the treatment is not so successful. Ventriculoamniotic shunts are yet to be standardised and so also the antenatal repair of dysraphic anomalies.

6. Neural Transplantation

Neural transplant is one of the most exotic fields yet to be explored fully. The term neural transplant envisages a whole brain transplant like a kidney transplant. This is still in the realm of science fiction. At present transplant of small amounts of neural tissue seems to take very well both in the laboratory and at times is clinical practice. When established on a large scale it will be of great use in the management of injuries or replacement of neural tissue damaged by disease or at operation. When a small amount of foetal mesencephalic tissue from a foetus is transplanted the take is good. There are a few case reports of amelioration of Parkinsonism by this method. If these methods are developed perhaps much success will be obtained. There are however some problems in neural transplant not seen in kidney or heart transplant. The area transplanted must make physiological connexions with rest of the brain in addition to anatomical connexions. We do not know how tissue from parietal lobe will connect with tissue in midbrain. In addition, progress made in the preparation of neural growth factor has helped in neural transplantation. But all these problems will be solved one day. And one can never say that even whole brain transplant is not feasible because scientific progress always debunks existing theories and hypotheses.

The status of modern neurosurgery has certainly jusitfied the enormous effort and phenomenal amount of finance that has gone into research. At this same rate there is no doubt that the future of neuro surgery will continue to be equally bright and many of the problems which confront us today may be solved. One need not fear that the invasion of computers and other modern marvels will ultimately displace the physician or the surgeon. Loss of work at one end will always mean increase of work at another end and at a different level. Neurorobotics wherein the entire neurosurgical procedure is done by a robot under a remote control is being practised in some centres. Still the master control is with the living brain of the neurosurgeon. This crest jewel of creation *"the human brain"* will always be in control directly or indirectly.