DEVELOPMENT OF NEUROSURGERY IN THE LAST 50 YEARS

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Although already in ancient times neurosurgical procedures such as trepanations were carried out with great skill no significant progress has been achieved until the end of the 19th century. This was due to the lack of knowledge about the task and the function of the brain regions and also to the lack of investigations and diagnostic possibilities of the nervous system.

The better understanding of the structure and function of the brain and spinal cord and the development of analysis methods for detecting diseases have led to a significant progress of neurosurgery.

With modern imaging techniques of neuroradiology such as computertomography and magnetic resonance imaging and with the introduction of the operating microscope and microsurgical techniques a new age of neurosurgery especially in the last 50 years was created.

This progress led not only to preservation of live but also to preserve important functions of the brain, spinal cord and nerves.

The development of neurosurgery can be divided into three phases:

1. Neurosurgery until the 19th Century

Already in the prehistoric times skull drillings were performed.

Historical findings had shown that these interventions had been performed with great skill and many of patients had survived. These trepanations were performed to treat traumatic brain injuries, in particular depressed fractures but also for the purpose of liberation from evil spirits, such as epileptic seizures and psychiatric diseases.

Since the knowledge of the anatomy and function were missing, no targeted interventions for certain brain diseases were possible.

This situation changed with the progress in neurological sciences and studies of diseases of the nervous system.

2. Neurosurgery from 2nd half of 19th Century until 1960

After essential features of the structure and the function of the nervous system were known, nervous processes could be localized by clinical symptoms and could be treated by surgery.

The birthplace of this pioneer time in neurosurgery was Great Britain.

W. Macewen exised 1879 an intracranial meningeoma in Glasgow, 1884 R. Godlee and A.H. Bennett removed a glioma in Regents Park Hospital London and V. Horsley 1887 an intradural spinal tumour in National Hospital Queen Square London for the first time[12].

In this time a significant progress were diagnostic procedures such as the air filling of the brain, the ventriculography, the ultrasound and especially the availability of cerebral angiography, which was developed by E. Moniz 1920 in Portugal .

These methods gave a gross localization of space – occupying lesions and information about cerebral vascular diseases[12].

However modern Neurosurgery, which is performed nowadays was only possible with availability of modern imaging techniques and microsurgical operative techniques.

In the last quarter of the 19th Century began in Austria to establish neurosurgery as a medical specialist. Anton von Eiselberg, a disciple and successor of Theodor Billroth at the Clinic in Vienna devoted a major part of his energy and work to neurosurgery.

In 1913 he published the first major report about exactly 100 operated cases of brain tumors[5].

During the world warI Anton von Eiselberg created at his clinic in Vienna the first specialized neurosurgical ward for the treatment of war injuries. His work laid the foundation stone for the international importance of Austrian Neurosurgery in the first three decades of the 20th Century.

Leopold Schönbauer was his successor in Vienna and Schönbauer, who went for a short time to Cushing in Baltimore, who operated his first brain tumor in 1910, established contacts with modern trend in Neurosurgery.

His disciple Herbert Kraus became in Austria 1964 the first chairman of the Vienna University Clinic of Neurosurgery, Fritz Heppner 1971 in Graz and Karl Kloss 1972 in Innsbruck[21].

Neurosurgery was established as an independent surgical specialist only for about 50 years, in Austria since 1976.

In this time, in the last 50 years enormous progresses in the field of neurosurgery have occurred.

This ranges from brain tumor surgery, radiosurgery, surgery of brain injuries, functional surgery, cerebral vascular and endovascular surgery to spinal surgery.

3. Modern Neurosurgery from 1960 until now

With the introduction of microsurgical techniques surgery in difficult and functionally important brain areas were possible. R.M.P. Donaghy in Vermont and M.G. Yasargil in Zurich organized 1966 the first international microsurgical Symposium and Yasargil published1969 his first microsurgical book – Microsurgery applied to Neurosurgery [3,30]. Further representatives for microsurgery were in Toronto Ch. Drake and in Germany M. Samii[24].

An accurate preoperative planning of operations became only possible by modern imaging techniques such as CT and MRI since mid of 1970.

In 1972 the first commercial computer tomography for clinical use was installed in London´s Atkinson Morley Hospital, 1974 in Queen Square London and 1976 in University Clinic of Graz where the author had ended his training at that time.

In 1979 Allan M. Cormack and Godfrey Hounsfield got for their work Nobel Prize in Medicine[9].

MR imaging was developed from1973 by Paul C. Lauterbur and Sir Peter Mansfield, they received in 2003 the Nobel Prize[1].

Progress in Brain Tumor Surgery

Benign Tumors

In the last 50 years the prognosis in benign tumors had improved Preoperativ modern imaging techniques and planning devices such as CT, MRT, Neuronavigation (since 1986) and intraoperative Sonography (since 1985), intraaoperative CT and MRT registrations (since 2002) give a clear picture of intracranial space -occupying lesions and their relation to the different structures of the brain – before and after resection[12].

In recent years image guided techniques especially frameless stereotaxy have become popular subjects in the field of neurosurgery. Frameless navigation helps to overcome the lack of visible landmarks during operations, especially in deep seated lesions.

Since 1997 we have used at the Clinic of Neurosurgery Klagenfurt a new frameless image guided navigation system from Radionics, Boston. A further popular navigation system, which is used in many neurosurgical departments is the system of Brain Lab.

The navigation system is an extreme helpful neurosurgical tool for preoperative planning, precise localisation of the lesions and intraoperative orientation. All these features minimize not only surgical trauma but also postoperative morbidity.

Due to improvements of operativ techniques such as microsurgery (since 1969), endoscopy (since 1985), Cavitron Ultrasonic Surgical Respirator (= CUSA, since 1978) and non invasive methods such as Radiosurgery, Radiotherapy and Chemotherapy, treatment of tumors in difficult regions became possible.

Radiosurgery

In 1951 Lars Leksell, professor of neurosurgery in Lund (Sweden), later at Karolinska Institute in Stockholm, introduced the term radiosurgery to describe his method of multiple Ray beams stereotactically directed toward a common intracranial target[18].

Stereotactic radiosurgery is a radiation technique of high radiation dose focused on a stereotactic intracranial target in a single fraction with high precision.

Radiosurgery was first designed to produce functional lesions in the brain.

As it evolved benign tumors, metastases and vascular malformations in surgically inaccessible and eloquent locations became the mayor target of radiosurgery.

The tools of radiosurgery are Gamma-Knife and Linac –Radiosurgery/ X-Knife.

The principle of gamma unit is,that 201 Co – 60 sources emit gamma rays, which are collimated and focused to one isocenter.

In Linac- systems multiple noncoplanar arcs of X –ray radiation are focused on one spot within the brain (15).

Since 1996 we started at the Clinic of Neurosurgery Klagenfurt with Linac radiosurgery. We use the University of Florida system described by Friedman and Bova in 1989 and the planning software from Radionics, developed in Boston[6].

In neurosurgery the 1990´s were the decade of radiosurgery.

We used radiosurgery especially in benign tumors, metastases, arteriovenous malformations and in Functional Neurosurgery.

Radiosurgery had improved life quality of patients, the tumor control rate is high, there are no side effects, no longer hospital stay and no postoperative morbidity.

Malignant Tumors

In malignant tumors we had in the last decades unfortunately no significant improvements of treatment and progress.

The progress is still poor. Nevertheless, progress in improving overall survival and the preservation of live quality in patients with malignant brain tumors can be achieved by interdisciplinary collaboration and combination of microsurgery, radio- and chemotherapy with temozolamide[11].

B. Progress in Neurotraumatololgy

Due to the improvement of diagnostic methods, such as routine cerebral CT in severe head traumas, continuous measurements of intracranial pressure in intensive care units, modern neuroanaesthological therapies and accurate neurosurgical interventions the prognosis in trauma patients was improved significantly in the last decades.

In neurotraumatology the neurosurgeon is especially concerned with intracranial hematomas, mostly acute epidural and acute subdural hematomas, because they need immediate neurosurgical intervention.

In the last decades we saw in these patients a significant improvement in average mortality and functional outcome.

In the acute epidural hematomas the overal mortality is now 7%, if the hematomas are diagnosed and operated on early.

If the patients were comatose preoperatively the mortality rate is ten times higher than in noncomatose patients – 21,7% versus 1,6%.

Therefore accurate transportation by helicopter and accurate diagnostic investigation is necessary.

In acute subdural hematomas the average mortality is now 44 %, in earlier times we had a mortality of these patients of 80% and more.

C. Progress in Functional Neurosurgery

Parkinson´s disease

A milestone in the therapy of Parkinson´s disease was the introduction of levodopa in in the late 1960s. However motor complications of chronic levodopa therapy are major limitation of this effective therapy. Therefore new conservative and surgical therapeutic strategies were developed.

Stereotactic surgery in morbus Parkinson was successfully used in Europe first by Mundinger and Siegfried in the 1960s. Lesions were made in the ventrolateral part of the thalamic nucleus – thalamotomy and in some parts of the globus pallidus – pallidotomy. These interventions were ablative and non reversible.

Today refined methods are used such as deep brain stimulation (DBS).

DBS is a reversible therapy using small programmable implanted electrodes to block brain signals that cause disabling tremor. Surgery involves insertion of one or more electrodes into the thalamus, pallidum or subthalamic structures using MRI for accuracy. Additional a pacemaker for stimulation will be implanted[23].

Surgery of Epilepsy

Although in recent years pharmacological research has succeeded in developing anticonvulsants of greatly improved efficacy, it is not possible to ensure in all epileptics freedom of seizures or at least a remission of the predisposition to seizures by administration of pharmaca.

This is the starting point for considering surgical treatment of epilepsy. The surgery in epilepsy had made in the last decades great advances.

With increasing knowledge of the anatomy and function of the limbic system and stimulated by reports of Penfield in 1952 surgical intervention in epilepsy especially in temporal lobe epilepsy became more and more interesting and become commonly accepted[19,22,29].

Only in a few neurosurgical centers surgery of epilepsy were performed.

At the Clinic of Neurosurgery Graz my teacher F. Heppner began in 1952 with the operative treatment of patients suffering from focal epilepsy refractory to medication.

In the first 30 years following operation were performed:

6 Hemisperectomies, 50 Hippocampectomies, 6 Fornicotomies, 40 Cingulectomies, 13 Amygdalotomies, in total 115 operations. A part of these operations were performed by stereotactic method[8].

In Hippocampectomies in each case hypersynchronic activity was mapped by means of electrocorticography. To reduce the formation of scar tissue and minimize trauma in some cases CO_2 – laser was used since 1976[13].

In the late 1970s and 1980s we have performed the selective amygdalo-hippocampectomy in microsurgical technique described by Yasargil.

The results were excellent, especially in hippocampectomy, about 80% of the patients were postoperative free of fits or markedly improved.

In recent years the continuous improvements of surgical techniques with intraoperative electropysiological und modern imaging registrations, as well as the presurgical localization of epileptic regions offer good perspectives for patients with focal seizures.

An important target of presurgical evaluation is the delineation of the epileptogenic tissue, which is responsible for the generation of seizures.

Non invasive evaluation include intensive Video-Monitoring and magnetencephalography, in difficult cases invasive evaluation will be applied with subdural or depth recording, PET, MR – spectroscopy and ictal SPECT.

Besides individually tailored resection of epileptic areas transsections like callosotomy or multiple pial transsection are performed.

Other surgical treatments are today vagus nerve stimulation and focal stereotactic radiosurgery[4].

Surgery of Pain

Over the past 4 – 5 decades, techniques and devices for surgery of pain have undergone considerable refinement.

In 1967 direct electrical <u>spinal cord stimulation</u> was performed for the first time.

Shealy used a single electrode placed in the subdural space. Earlier spinal stimulation electrodes required laminectomy under direct vision. Since 1975, electrodes were implanted percutaneously, currently electrodes are placed in the epidural space.

Spinal cord stimulation evolved as a direct clinical application of the gate control theory, which was proposed by Melzack and Wall in 1965[20]. The gate theory postulates a gate in the dorsal horn of the spinal cord that could be closed by activation of large afferent fibers or by activation of inhibitory pathways.

The most common indications for spinal cord stimulation are failed back syndromes,

ischemic pain with peripheral vascular disease, peripheral nerve injuries with neuropathia or neuralgia, postamputation pain including phantom limb and stump pain.

In general, results of spinal cord stimulation are much better in patients with more peripheral distribution of pain[16,17].

In the management of intractable pain in some cases long term intraspinal infusion of opioid drugs is necessary to avoid the side effects of oral opioid medication such as sedation, dizziness or drowsiness.

In the last decades many <u>implantable medication pumps</u> are developed.

The studies had shown that these implantable pumps, which need a less concentration of opioid are efficacious, practical and deemed safe for treatment of non-malignant pain syndromes.

Trigeminal Neuralgia

If conservative treatment of trigeminal neuralgia is ineffective, operative treatment is necessary.

Recent literature and our own experiences had shown, that about half of all patients eventually require an operation for pain relief.

The operative approach to trigeminal neuralgia – thermocoagulation of the Ganglion Gasseri after Sweet (1969) and microvascular decompression of trigeminal nerve after Jannetta (1976) have proven to be highly successful methods of treatment.

A milestone in the treatment of trigeminal neuralgia was the understanding of vascular compression of the nerve as it enters the brain stem, described early in 1934 by Dandy, rediscovered in 1962 by Gardner and fully recognized in1976 by Jannetta[2,7,10].

This microvascular decompression of trigeminal nerve is now widely accepted.

Since 1996 we have operated 286 patients with trigeminal neuralgia by microvascular decompression with a long follow up. In the operation the trigeminal nerve is seen after suboccipital craniotomy and opening of the dura. Through adhesiolysis it is the possible to retract the compressing vessel – in most casas the superior cerebellar artery and implant muscle or gelantine between nerve and vessel.

The operative results are excellent, immediately after operation almost all patients were free of pain, up to 3 years 97%, up to 6 years 95% and after 10 years 92%.

11 patients required additionally thermocoagulation of Ganglion Gasseri[14,25,26].

The principle of percutaneous thermokoagulation is based on the fact, that painconducting non myelinated fibers of trigeminal nerve can be destroyed through an exactly dosed heat effect of 60 – 80 degrees Celsius in the foramen ovale.

Sweet had described this effect in 1969 first.

The long term results in our studies in accordance to the literature have shown, that immediately after operation a high percentage of the patients were pain – free, but there was a high recurrence rate up to 25% and more[28].

D. Progress in cerebrovascular and endovascular surgery

The need to secure unstable intracranial aneurysms was identified by Harvey Cushing in 1923, but the first clipping was performed by Walter Dandy in 1937.

Since then, the progressive evolution of devices, particularly the operating microscope in the late 1960s by Yasargil, has resulted in aneurysm surgery and became a routine procedure.

Traditionally surgical clipping has been the treatment modality of choice for both ruptured and non ruptured cerebral aneurysms since decades[27].

Over the past decade endovascular modalities have become widely used to treat intracranial aneurysms and have displaced open surgical clipping in the background.

One of the most impressive studies on the outcomes of the two treatments for intracranial aneurysms – open surgery or endovascular therapy – was the International Subarachnoid Aneurysm Trial (ISAT), which was presented in 2002. It suggested that the ruptured aneurysm treated endovascularly had a better one year outcome, but an increased risk of delayed rebleeding compared with the aneurysm treated surgically.

The ISAT provided evidence supporting endovascular treatment of first choice.

Since the ISAT study it should be mandatory that all patients should be seen by a neurointerventionalist together with a neurosurgeon to decide whether the aneurysm is suitable for coiling or not[4].

Furthermore the ISAT study pointed out that patients with aneurysmal subarachnoid hemorrhage should treated in centers that offer both – open surgery and endovascular therapy. In conclusion aneurysm therapy changed during the last years. Endovascular therapy is now the method of choice for those aneurysms that are suitable for this technique. In specialized centers, up to 80% of aneurysms could be treated via the endovascular approach.

However, beside all technical improvements in the management of intracranial aneurysms, occlusion of an aneurysm is often not the most difficult part of the therapy. In many cases the subarachnoid hemorrhage determines the outcome of patients.

Primary complications in aneurysm bleeding are intracerebral hemorrhage and acute hydrocephalus, secondary complications are rebleeding, vasospasm, delayed cerebral ischemia, seizures and chronic hydrocephalus.

Vasospasm and delayed ischemia is the most common cause of death and disability following aneurysmal subarachnoid hemorrhage. This complication alone accounts for 14% - 32% of deaths and permanent disability in large studies. Doerfler postulated in

2006 that in future all disciplines should focus now on these remaining problems[4].

E. Progress in Lumbar Disc Surgery

Lumbar discectomy became one of the most frequent operations carried out by neurosurgeons.

In 1922 Adson reported about a laminectomy and removal of a protrusion of a lumbar disc. Dandy reported in 1929 about two cases on which he operated for low back and leg pain. The idea that the disc herniation was neoplastic, was in these times prevalent. Bucy regarded in 1930 a disc problem as a "typical cartilaginous neoplasm".

Mixter and Barr described in 1934 disc herniation as a degenerative disease and the main cause of low back pain and sciatic pain.

Disc herniation operation were performed first by laminectomy, later by laminotomy and since Yasargil and Caspar in the late 1960s and 1970s by microdiscectomy. Microdiscectomy became a standard operation for the treatment of disc herniation.

The microscope stimulated research for less invasive techniques and keyhole operations to treat disc herniation.

In the last decades following procedures were introduced in the disc surgery, some with doubtful success:

Nucleolysis by intradiscal injection of enzymes, manual and automated percutaneous discectomy, endoscopic and laser discectomy, ozone nucleolysis.

Neurosurgery is faced with many new opportunities and challenges, based on advanced technological and molecular approaches to neurosurgical problems.

Advances in technology have allowed the neurosurgeon to locate precisely abnormal tissue in the brain and spinal cord. In addition to advances in neurooncologic neurosurgery, cerebrovascular neurosurgery, functional neurosurgery neurotraumatology and spinal surgery, the future hlds many new research innovations.

In the new millennium the field of molecular neurosurgery can make it possible to introduce genetic material into nerve cells and to redirect protein synthesis to work toward reversing the disease process.

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