Experiences and Reflections about Selective Amygdalohippocampectomy (AHE)

Summary

Historical view of the development of selective amygdalo-hippocampectomy for the treatment of the intractable temporal limbic seizures. Preservation of neopallial structures and functions.


Keywords: epilepsy, mesiobasal limbic seizures, surgical treatment

Monday, January 4th, 1953 will remain in my memory as a very special day for two reasons. On this date, I started my training in neurosurgery at the University Hospital in Zurich, and also on this, the first day in my chosen specialty. I had the unique opportunity to observe temporal lobe surgery on a young male, who suffered from intractable psychomotor seizures. The continuous ongoing recording of electrocortical activities from the temporal lobe were being attentively observed by Professor Rudolf Hess and his team, who from time to time gave information regarding electrocorticography (ECOG) analysis to the surgeon, Professor Hugo Krayenbuehl, or related instructions to change the position of some of the electrodes. The process of the surgical procedure impressed me, not only from the viewpoint of the installations, which were recording electrocortical activities in real time, but also due to the fact that surgery was being performed under local anesthesia, allowing examination of sensomotoric functions of the patient’s extremities, and occasional exchange of dialogue with the sedated patient, to evaluate his level of consciousness. Depending on the analysis of electro-cortical activities, the neopallial temporal gyri were removed “en block” from the temporal pole, some 4 cm posteriorly and deeper into the white matter to the temporal horn and uncinate gyrus.

Professor H. Krayenbuehl had been performing the standard Penfield anterior two-thirds temporal lobectomy since 1939 [1, 2]. His surgical decisions were based on a combination of clinical features and findings, on electro-corticographic recordings. He had a passionate interest for epilepsy surgery, and at every opportunity referred to the despair epilepsy patients suffer with their seizures, and how urgent the need for diagnostic and therapeutic advancement in this field was.

From 1957-1965 I was involved in stereotactic procedures for the treatment of movement disorders (in particular patients with Parkinson’s disease), and for the treatment of chronic pain in patients with amputated limbs. I used the stereotactic frame designed by Professor Th. Riechert and Professor Fr. Mundinger, Neurosurgical Department, Freiburg in Breisgau, Germany, and the high frequency coagulation apparatus of Professor O. Wyss and Professor R. W. Hunsperger, Institute of Physiology, University of Zurich. In 1959, in a young male with “psychomotor” seizures, EEG showed regular spiked activities in the right anterior temporal region. Professor Krayenbuehl and Professor Hess indicated a stereotactic amygdalotomy. The center of the amygdala was well targeted stereotactically and a series of two coagulations were applied, estimated 3.0 mm in diameter. The postoperative course of the patient was un-
eventful, but seizure activities remained unchanged. In November 1968 I was delegated to visit the neurosurgical department at Hospital Saint Anne, Paris, for four weeks, where Professor J. Talairach and Professor J. Bancaud had been pioneering a new technology in epilepsy surgery. The complex installations for stereoelectroencephalography (SEEG) in their large operating room and the extensive knowledge of the team members in neurolanatomy and in analysis of electrophysiology, impressed me enormously. The intense engagement of the team to define accuracy, in 3 dimensions, the lesional, the initiative and the epileptic zones within the brain of the patient was an overwhelming experience, which, I must admit, was unable to follow in detail. During the following years, the research endeavors of Talairach, Bancaud, Tournou and Szikla culminated in the publication of numerous excellent and unique neurolanatomic and neurovascular stereo-atlas, which are of great value and will continue to find appreciation in the coming decades [3, 4]. To cope with this new technology and assimilate this additional knowledge an appropriate period of time spent in Hospital Saint Anne would have been necessary, however, before a decision could be reached in relation to my stay, and in particular for the acquisition of the expensive equipment, an unexpected and insistent request from the heart surgeon at the University Hospital in Zurich, caused my professional pathway to change entirely. At that period of time, open heart surgery, the occurrence of thromboembolic complications in leptomeningeal arteries of the brain sometimes occurred due to imperfections in the extracorporal blood exchange apparatus of that era. This complication caused great strain on Professor Ake Senning, the heart surgeon. He asked us for assistance, to perform embolectomy, but surgery on such small caliber arteries was beyond our capabilities. As a consequence of his insistence that a neurosurgeon should be trained in microvascular technique, from 1965-1966, I spent 14 months, in the laboratory of cardiovascular surgery at the University Vermont, Burlington, USA, where vascular surgeons J. J. Jacobson and E. I. Suarez, and neurosurgeon R. M. P. Donaghy were pioneering microvascular surgical technique. Before leaving Zurich, I introduced Dr. J. Siegfried to the field of functional neurosurgery and believed to definitely have left the field of epilepsy surgery. Returning to Zurich in January 1967 I was pleased to be informed that the cerebral embolism problems of the brain sometimes occurred due to imperfections in the extracorporal blood exchange. The laboratory and training in microsurgical techniques, however, brought hitherto unimagined dimensions to the neurosurgical procedures. Applying microsurgical techniques, vascular and neoplastic lesions of the CNS could be explored along the cisternal pathways and the lesions eliminated. A “pure lesionectomy” could be achieved without causing damage to normal tissue. Extrinsic lesions in the mesiobasal temporal region such as the skull base meningiomas, chordomas-chondromas, epidermoids and dermoids, as well as intrinsic lesions such as the various types and sizes of gliomas and angiomas within the limbic lobe, could all be explored and removed through an anterior transsylvian cisternal approach without resection and retraction of the mesiobasal temporal lobe. Having the opportunity to perform these procedures, provided me with extensive experience and definitely opened new avenues in neurosurgery.

The removal of a lesion and, in addition, selective amygdalo-hippocampectomy in patients with both a lesion and preoperative intractable temporal seizures, proved to be an effective therapy for the seizures. As a consequence of these observations, the question arose as to whether selective amygdalo-hippocampectomy (AHE) through an anterior (proximal) transsylvian cisternal approach should be offered for the treatment of non-lesional (no tumor or angioma) temporal seizures, in place of the standard anterior 2/3 resection of the temporal lobe.

The statement of H. Gastaut [5, 6] in the 1950s, that in most cases the temporal lobe epilepsy originated in the Rhinen-cephalon, was thoroughly discussed and accepted in the Epilepsy Colloquium, Marseille, France, 1954. The presentation of Professor Paulo Niemeyer, Rio, Brazil, was valued greatly, for he had used a transcortical-transventricular approach to perform selective amygdalo-hippocampectomy in 19 patients with temporal lobe seizures and observed, in 50% of patients, cessation of seizures [7, 8]. Discussing and reflecting on this data with Dr. Chr. Bessenilli, epileptologist, trained at St. Anne, Paris, and with Dr. J. Siegfried, neurosurgeon, trained in Montreal Neurological Institute, we came to the conclusion that in patients with typical limbic seizures, the anterior transsylvian cisternal approach and SAHE could be successfully applied, and resection of the normal isocortical temporal structures avoided. Bernoulli and Siegfried conducted the preoperative stereoecephalographic and “reperage” procedures to define accurately the seizure location. Between 1974 and 1976 four patients were operated on using the anterior transsylvian approach for selective amygdalohippocampectomy and parahippocampectomy (AHE). Postoperative computer tomography (CT) proved that the AHE can be accomplished without compromising the isocortical neopallial structures (T1-T4) of the temporal lobe and underlying white matter. All four patients, post-operatively, had no neurological or cognitive deficits and seizures could be controlled. In 1976, Dr. Heinz Gregor Wieser was appointed epileptologist in the Department of Neurology, and introduced transcutaneous application of foramen ovale electrodes for direct recording of electrocortical activities of the mesiobasal temporal areas. He gave the indication for selective AHE in a further 98 patients (1976-1992), and was responsible for the pre- and post-operative investigations and evaluations, and long term follow-up.
studies. Since 1994, working in the Department of Neurosurgery at the University of Arkansas for Medical Sciences (UAMS) in Little Rock, I have had the opportunity to operate on a further 71 patients, who suffered pharma-resistant limbic seizures. After thorough examination of the patients using multi-model neuro-visualization and recording technology WADA and neuropsychological tests the indication for the surgery was given by Dr. Frederick A. Boop, neurosurgeon, UAMS, Dr. V. B. Biton, neurologist at the Epilepsy Center, Baptist Hospital, Little Rock, and Dr. N. Haddad and Dr. B. Shibabuddin, the department of Neurology, UAMS. Following surgery, the patients were evaluated and studied repeatedly at frequent intervals for the first year, and then on a regular basis depending on need. Post-operative seizure outcome was confirmed according to the recommendations of the International League Against Epilepsy (ILAE) and Commission for Neurosurgery for Epilepsy (E). The above-mentioned colleagues were responsible for the pre- and post-operative care of the patients, i.e. regulation of anti-seizure medications, and documentation of studies such as MRI, EEG, neuropsychologic and neuroophthalmologic evaluations.

The long-term results with regard to epileptic seizures, neuropsychologic and psychosocial outcome in so-called “non-lesional” patients (n=102), operated in Zurich (1974-1992), are thoroughly analyzed and published by Wieser, et al. [9-13]. The results of long-term outcome in 71 patients operated in Little Rock will be published in the near future.

**Surgical aspects of anterior transsylvian AHE**

Surgery for anterior (proximal) transsylvian selective AHE is a procedure that lasts an average of four hours. All patients awakened immediately from general anesthesia and had unaltered cognitive functions. Verbal memory and mapping was found to be well preserved, also in those patients who had selective AHE of their dominant hemisphere. The surgical mortality was zero, as well as senso-motoric and visual field deficits were observed, with the exception of one patient who experienced a temporary hemisindrome. Two patients, (one in Zurich, another in Little Rock) developed acute subdural hematoma and blood clots in the resection area. After evacuation of the hematomas, the hemisindrome resolved completely. In these two patients ophthalmologic examination revealed superior quadrant anopsia. Eleven patients (6.5%) experienced transient, partial, oculomotor palsies, which resolved completely within a few days or weeks. This was due to dense adherences between the arachnoid membrane over the hemiated anterior parahippocampal areas and the arachnoid sleeve over the oculomotor nerve. Surgical complications included one case of osteomyelitis in Zurich, that led to removal of the bone flap, with secondary reconstructive cranioplasty. Early in this series (1974) two patients died within two years, unfortunately on acquired Creutzfeldt-Jacob disease, which was transmitted from improperly sterilized EEG electrodes, and had no direct relationship to the selective AHE. During the survival time both young patients were seizure free [15].

**Surgical approaches**

Before any conclusive remarks, I would like to summarize the surgical procedures and their modalities, that are current methods of treatment for temporal epilepsy:

1. En-bloc or gradual resection of anterior two-thirds of the temporal lobe (right side approximately 5.0 cm, left side 3.0 cm from the temporal pole posteriorly) which may include or exclude resection of temporal limbic structures [15-22].

2. Selective removal of amygdala-hippocampus and parahippocampus.
   a. Lateral transcortical (T1-T2-T3) or transsulcal approached or partial resection of anterior third of T1 or T2 or both [23-25, 7, 8, 26].
   b. Subtemporal transcortical (T3-4) or transsulcal (collateral sulcus) approaches [27, 28].
   c. Fronto-orbito-zygomatic craniotomy and anterior subtemporal approach [29].
   d. Suboccipital-supracerebellar-transtentorial approach to the mesiobasal temporal areas for selective AHE. This approach is used for the removal of gliomas, AVMs and cavernomas of the posterior parahippocampal gyrus [30, 31].
   e. Pterional craniotomy, anterior transsylvian approach through anterior inferior perinsular sulcus [12, 32, 13].
   f. Pterional craniotomy, anterior transsylvian, trans-amygdala approach [32].

3. Stereotactic approaches and a sequence of calculated coagulations in amygdala and hippocampus [33-36, 21].

4. Stereotactic approaches for gamma surgery application to amygdala and hippocampus.

**Advantages and limitations of anterior transsylvan AHE**

The anterior transsylvian approach for selective AHE is advocated, with the aim to perform a “pure lesionectomy”, without injuring the adjacent normal structures of temporal neopallial areas and their connections. In Zurich, I routinely used pterional craniotomy and anterior transsylvian approach for selective AHE. The middle and posterior transsylvian fissure and fossa have never been opened for selective AHE, but are necessary for adequate access to tumors and angiomas of the insular, retrosinsular and subinsular regions.
After opening the anterior sylvian fissure and fossa, the anterior part of the temporal horn is explored through an incision made along anterior-inferior perisular sulcus (15-20 mm length). The amygdala, pes hippocampus, corpus hippocampus, choroidal fissure and choroidal plexus are identified. The amygdala is resected piecemeal, followed by anterior two-thirds resection (2.5-3.0 cm) of the hippocampus and parahippocampus en-bloc. This latter was to meet the requirements of Dr. Heinz Gregor Wieser and Dr. V. Chan-Palay [37], who performed biochemical studies on the resected tissue.

In Little Rock (1995) I modified my surgical strategy for selective AHE. Through a pterional craniotomy, the anterior sylvian fissure, and anterior sylvian fossa are explored. An incision of 10-15 mm length is made lateral to the M1 segment of middle cerebral artery, between polar and anterior temporal arteries, just over the amygdala, which is resected piecemeal, until the crural and adjacent cisterns are identified. The anterior portion of the hippocampus and parahippocampus (2.0 cm in length) is removed en-bloc between the choroidal fissure and collateral sulcus. The posterior parts of the hippocampus and parahippocampus are gradually aspirated as far as the posterior rim of the cerebral peduncle or lateral geniculate body are reached. For surgical details see former publications [32, 13].

The anterior transsylvian-transamygdaloid approach for the selective AHE is a challenging procedure even for an expert microsurgeon, because of the many vital structures that have to be dissected and preserved along the narrow slit of the sylvian fissure and fossa, (such as the veins, arteries and basal nerves) avoiding application of the rigid self retaining retraction system [38-50, 32]. All these structures have remarkable individual variations both in number and size, and in their course, but all were intact, following selective AHE on 173 patients, who were operated on using the anterior transsylvian approach.

However certain limiting factors restrict the above described exploration, and may be a cause hindering complete success of the surgical procedure;

1. From a volumetric standpoint, approximately 70% of the amygdala mass is resected. From a surgical perspective, the superior, lateral, middle and latero-basal parts of the amygdala are completely removed, whereas the areas medial to the optic tract, such as the medio-basal areas with amygdalo-striatal zone, are intentionally not explored [39, 40, 42-45, 51].

2. The anterior two-thirds of the hippocampus and parahippocampus are precisely resected along the tania fimbriae of the choroidal plexus, and along the collateral sulcus. There are, however individual variations pertaining to the connections between the parahippocampus and fusiform gyrus (lateral tempo-occipital): one or two parenchymal bridges interrupt the collateral sulcus, and in some patients there is no rhinal sulcus. The possible surgical consequences of these anatomical deviations are, that lateral parts of the parahippocampal gyrus may remain unresected, or the medial part of the fusiform gyrus may be inadvertently ablated. This latter in particularly can be encountered if the collateral sulcus is very tight. The MR technology demonstrates these variations, but only to a certain degree [52, 53].

3. Following the advice of Dr. Glenda Milner [54], MNI Montreal, I have limited the surgical resection of the posterior parts of hippo-parahippocampus to the level of the lateral geniculate body. Even today it remains for me unclear, how far the boundaries of surgical ablation should extend [55, 56]. Dr. Wieser suggested further removal posteriorly, which was possibly followed by Dr. Yonekawa. Therefore, to learn the results of the series Wieser-Yonekawa would be of great value whether a higher rate of success affecting temporal limbic seizures was accomplished and whether postoperative neuropsychological evaluation revealed changes.

4. In Little Rock, I have the opportunity to use surface and deep electrodes intraoperatively to record the electrical activities in the temporal pole, residual amygdala, posterior parts of hippocampus and neopallial cortices. If some “spike” activities are recorded, this is helpful information, but, on the other hand the absence of spike activities during the relatively limited recording time period of 10-20 minutes, can be defined a questionable and unreliable evaluation.

5. There is a reasonable expectation that intraoperative MRI studies with three or more Tesla and 42 MRI or 192 cameras, will more clearly define the operated field and resected areas. At present, interpretation of the volumetric measurements of resected areas on MRI can be misleading, due to the fact that the adjacent parenchyma expands into the resected area, and renders measurements inaccurate.

6. The anterior transsylvian approach for selective AHE has been criticized, the criterion being intentional disconnection of the temporal stem. The term temporal stem gives the impression that this is the only connection of the entire temporal lobe [39, 57]. This term is confusing because it reduces the multidimensional, multidirectional, and multimodal activities of the temporal lobe in the neopallial, archi- and paleopallial areas and the amygdala nucleus to merely one anterior connection (see Fig. 2 and 3 on pp. 723-724, Journal of Neurosurgery, Vol. 90, 1991). The phrase “anterior temporal stem” seemingly, is correct, but has established a precedent for the introduction of terms such as lateral, posterior, or superior stem of the temporal lobe. Terms such as frontal stem, parietal stem and occipital stem, unfortunately, have never been introduced. The creation of ambiguous anatomical terminology will not benefit neurosurgical endeavors. The anterior transsylvian approach for selective AHE preserves the neopallial structures (T1-T4) and underlying white matter, as
well as the anterior loop of the optic radiation, neopallial connections of the anterior commissure, and superior fronto-occipital fiber system. With the transsylvian, transamygdala approach, an attempt is also made to preserve the neopallial connections of the uncinate fascicle.

Discussion

The terminology defining the various types of epilepsy has changed within the past 60 years. Alone the temporal types of seizures are varied such as psychomotor, temporal, rhinecephalic, uncinate, hippocampal, limbic, simple or complex partial seizure type, which reflects neuroscientific advances. Patients with the temporal lobe seizures are separated into two groups, namely “causal — curative” and “palliative”. I am asking myself whether it wouldn’t be better to use the term temporal limbic seizure group (TLS) instead of caudalcurative and the term temporal extra-limbic seizure group (TXLS) instead of palliative. A discussion by experts whether the term “non-lesional” is an appropriate definition, would be beneficial to reevaluate our terminology. Neurovisualization technology, electroencephalographic studies and histopathology identify five distinct groups.

1. Limbic microlesional (sclerosis, gliosis, satellitosis, etc.)
2. Limbic nonlesional (MRI normal, histology normal)
3. Extralimbic nonlesional (MRI normal)
4. Limbic macro-lesional (gliomas, angiomias)
5. Extra-limbic macrolesional (gliomas, angiomias)

In this paper only the groups 1-3 are considered. The cessation of limbic seizures in 69 (73.9%) patients in the first two groups, namely, microlesional (90%) and non-lesional (10%) temporal limbic seizure group, (former causalcurative), is a pleasing result. In twenty three of these patients antiseizure medication was stopped completely. A reduction in or even discontinuation of, antiseizure medication certainly affects various psychological aspects of a patient positively. It is always a great pleasure to witness patients who progress with success in their professional careers, to learn of positive changes in their lives, and to hear the repeatedly remark “to be newborn since operation”. The reissue of the driving license is always celebrated as a triumph by patients and their families. Considering these 73.9% and aura free patients, our joy is suppressed, as we learn that within 15 years this number declines to 27.2%. However, this relapse is well tolerated by the patients and their families because the seizures are stabilized, are less frequent and are milder in severity. A similar positive attitude was observed in the 20% of patients in groups 1 and 2 (microlesional and nonlesional temporal limbic or causal curative), who had a notable and worthwhile reduction in frequency and severity of their seizures. In the remaining 8-10% of patients in groups 1 and 2, the burden of undergoing surgical selective AHE conveyed absolutely no reward. The compensation only for the surgeon was the fact that no single patient in this group experienced an increase in frequency or severity of seizure activity, and psychological and psychosocial condition, remained unchanged.

There is a surprise that in 33 patients (21.2% from group 3 (nonlesional, extralimbic temporal seizures) the selective AHE was effective resulting in complete cessation of seizures. However, within 8 years, mild, but stable, and well controlled seizures occurred. In a further 50% of the patients in group 3 the reduced seizures were tolerated being rare and mild, whereas 30% of patients remained unfortunate, and suffered an unaltered pattern of seizures and their accompanying stress.

Reflecting on the result of surgical outcome, I am constantly asking myself the possible source of the successful and failed incomes. Why could the seizures not be eliminated in a higher percentage of patients, particularly in groups 1 and 2. Should we assume, that the diagnostic investigations are inadequate to achieve an integral analysis, which ultimately leads to defining inappropriate indications for various modalities of surgical treatment? Are the surgical procedures incomplete in tissue resection or are the neurosurgeons inaccurate in their evaluation of the anatomy? It is also striking to note that each approach and method of surgical ablution of gray and white matter from neopallial or limbic areas of the temporal lobe, recount almost the same rate of success, approximately 60-70%. Related studies discussing meta-analysis, and many sophisticated debates among experts with diverse options have been published and documented in journals and several voluminous books [5, 23-25, 15, 34, 16, 17, 58, 59, 20, 60, 61, 36, 1, 2, 22, 26, 62, 4, 63, 10, 11, 64]. I would prefer not to include these in this paper. However, the historical monograph, “Temporal Lobe Epilepsy”, edited by M. Baldwin and Percival Bailey, 1958, with 34 contributions and with extensive discussions of each topic by pioneers of epilepsy research and therapy, is worthy of our attention. The remarks of J. D. Green aroused my attention; “...one may propose a means of progradations of seizures different from classical anatomical pathways”. And “…the study of seizure discharges much be an untrustworthy method of following anatomical pathways”. On page 485 of the same monograph, W. Penfield, great pioneer of epilepsy surgery, drew our attention to his interesting observation: “…surgeons do not remove spikes”. Spikes activity is a clue, and we should accept it as a clue and use it along with all of the other clues that we may have with respect to where the major abnormality in the cortex is located and the focus from which the major part of the discharge is coming”. The comments of Dr. Dell are condensed as follows, “Notwithstanding the fact that the technique of surgical procedures is highly variable in the hands of different authors, the results are rather satisfactory. Percival
Bailey, using a technique which spares most of the rhinencephalic structures, although ablating the temporal tip, claims results as good as those claimed by those authors who routinely perform a total ablation including rhinencephalic structures (Penfield, Paillas, Falconer, Baldwin, etc.) Moreover, Niemeyer, who selectively destroys hippocampus and amygdaloid nucleus, sparing the cortex of the overlying temporal lobe, has obtained approximately similar results. Thus these successful results cannot be interpreted as due to excision of a specific lesion but rather as a result of interruption of a neuronal circuit of selective suppression of epileptogenic structures having a very low convulsive threshold.”

The goal of neurosurgical treatment is always to perform a "pure lesionectomy" and not to harm the adjacent normal tissues and disturb their functions. If the epileptologist could define the exact and certain parts of amygdala or hippocampus or parahippocampus to be removed this can be successfully accomplished. The cooperation and resolve of our partner disciplines in neuroscience are welcomed, and we support their sustained effort to comprehend and formulate objectively the extent of the surgical resection in the mesiobasal temporal limbic structure. There is justifiable reason to believe that further advances in molecular-biology research will lead to accurate definition of therapeutic options for the treatment of patients with temporal limbic seizures.

References

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