Epilepsy & Behavior 70 (2017) 57–60

Contents lists available at ScienceDirect

Epilepsy & Behavior

journal homepage: www.elsevier.com/locate/yebeh

Review

History of surgery for temporal lobe epilepsy

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ARTICLE INFO

Article history:
Received 28 November 2016
Revised 7 February 2017
Accepted 13 February 2017
Available online 12 April 2017

Keywords:
Epilepsy
History
Surgery
Temporal

ABSTRACT

The history of epilepsy and its treatment goes back to ancient times when it included medicinal herbs, lifestyle modifications, and even surgery. Trepanation is considered the oldest surgical procedure for the treatment of epilepsy. The first series of temporal lobectomies for the treatment of drug-resistant epilepsy were reported by Penfield and Flanigin (1950). During the years since then, neuroimaging and other technologies have had remarkable and revolutionary progress. This progress has resulted in tremendous advancements in understanding the underlying causes and pathophysiology of epilepsies. With the help of these technologies and advancements, we may now offer surgery as a safer therapeutic option to more patients who are suffering from drug-resistant temporal lobe epilepsy. However, the degree of improvement in surgery outcome has not been proportionate to the technological progress.

1. Introduction

The history of epilepsy and its treatment dates back at least five millennia [1]. Ancient scholars and physicians contributed significantly to the knowledge about epilepsy and its etiology, manifestations, and treatment. Ancient treatments for epilepsy were usually empirical, reflecting the experiences of the scholars and physicians, theological views, and even superstitions. These treatments included prescribing diets, medicinal herbs, lifestyle modifications, and occasionally surgery [2,3]. Evidence of trepanation (making a burr hole in the skull) was found in the excavated prehistoric human remains from Neolithic times [1,4], and cave paintings suggest that ancient people believed this procedure would cure epilepsy, migraines, and mental disorders [4], though no firm evidence has been discovered to support any medical explanation for trepanation. Evidence for temporal lobe epilepsy (TLE) goes back thousands of years to the pharaohs of ancient Egypt's eighteenth dynasty [5].

The current paper reviews the historical advancement from trepanation for the treatment of epilepsy in ancient times to stereotactic laser thermo-ablation for the treatment of drug-resistant TLE in the modern world.

2. Historical evidence for epilepsy surgery

Trepanation is probably the oldest surgical procedure for which there is reliable archeological evidence [6]. Evidence shows that trepanation was also performed in the classical and Renaissance periods. Hippocrates gave specific directions on the procedure, and Galen further elaborated [1,6]. Ancient Greek and Roman physicians performed trepanation possibly as a treatment for post-traumatic seizures [7], and during the Middle Ages and the Renaissance, physicians performed trepanation as a treatment for various diseases, including epilepsy [1,6]. In the 1600s, Duretus treated a patient with epilepsy by removing broken skull bone that pressed on his brain [7]. By the early 19th century, many case reports of trephining for treatment of epilepsy appear in the literature; the most remarkable of these were the results of Benjamin W. Dudley (1785–1870) from the Transylvania University Medical School in Lexington, Kentucky [8]. He was the first in America to use this technique to treat epilepsy, and he was the first anywhere to publish a series [8].

3. Epilepsy surgery in modern era

Victor Horsley (1857–1916) pioneered the modern surgical treatment of epilepsy [1]. A brain scientist and an English surgeon who lived during the Victorian Era, Horsley was fascinated by discovery of ancient trepanned skulls, especially those that revealed that the operation was performed on living patients [7]. The courageous, optimistic scholar enjoyed presenting novel ideas, even if they were bound to be controversial. In 1886, he performed brain surgery on a young man with severe post-traumatic epilepsy [7]. Horsley removed the scar tissue from the patient's frontal lobe, which resulted in cure of his epilepsy [1,7]. By the end of 1886, Horsley had completed nine successful surgeries for epilepsy and had securely established the efficacy of the procedure [8]. Despite insufficient diagnostic methods to localize the epileptogenic tissue at that time, the results of the surgical treatment of epilepsy were

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http://dx.doi.org/10.1016/j.yebeh.2017.02.020
1525-5050/

encouraging and convinced other physicians to pursue the practice [1]. Since the location of the head trauma and therefore localization of the scarred brain tissue was known, especially good results were achieved in surgical treatment of post-traumatic epilepsy during those times [1]. However, with the passage of time many other procedures were tried (e.g., arachnoid cyst removal and carotid artery sympathectomy) with no significant achievements [1].

The subsequent developments in surgical treatment of epilepsy were closely linked with the advancement of the neurosciences [8]. The breakthrough in the diagnosis and treatment of epilepsy happened with the invention of electroencephalography (EEG) in 1928 [1]. Subsequently, the collaborative work of Foerster and Altenburger in Germany, Penfield and Jasper in Montreal, and other scholars increased our understanding of cerebral electrophysiology/function and developed the diagnostic and operative techniques for modern epilepsy surgery [8]. Foerster and Altenburger (1935) employed electrocorticography and also performed surgery under local anesthesia to permit reproduction of the patient's aura by electrical stimulation of the cerebral cortex [8]. In 1937, Penfield and Jasper refined surgical techniques and developed diagnostic and localization techniques that included EEG, cortical stimulation, neuroradiology, and neuropsychology [8]. Corpus callosotomy was introduced in 1940 as a palliative treatment for intractable seizures by Van Wagenen and Herren [9]. Intracranial EEG techniques were also developed in the 1940s and 1950s [8]. In 1948, Juhn Wada found that intracarotid injection of sodium amytal induces a temporary loss of function in the ipsilateral cerebral hemisphere. He suggested that this would be a useful technique for determination of the lateralization of cerebral speech dominance [10].

4. History of epilepsy surgery for temporal lobe epilepsy

The collaborative work of a team led by Penfield and Jasper in the 1930s helped to define the significant role of neurophysiological studies in epilepsy surgery. As a result, the importance of removing the mesial temporal structures in patients with TLE became established [11]. The first series of temporal lobectomies for the treatment of drug-resistant epilepsy were reported by Penfield and Flanigin [12]. They selected their patients for surgery based on the seizure pattern, and EEG, pneumographic, and roentgenologic evidence. Their practice was curative for 53% of their patients, and an additional 25% of their patients experienced a worthwhile (≥50%) improvement in seizure frequency [12]. Subsequently, Bailey and Gibbs promoted identifying TLE (formerly called "psychomotor epilepsy") by EEG and treating it by temporal lobe resective surgery [13]. These authors did not discuss any details of the postoperative complications, particularly memory, language, and other cognitive dysfunctions, in their patients. In the 1950s and 1960s, the success of temporal lobectomy (the most common type of epilepsy surgery) was similar to the original report by Penfield and Flanigin [14,15]. In 1953, neurosurgeon William Scoville performed a bilateral mesial temporal lobe resection on a patient (H. M.) who suffered from drug-resistant epilepsy. After the surgery, seizures were controlled, but the operation had a devastating consequence: a severe compromise of H.M.'s memory function [16]. By the mid-1950s, some other scholars had made observations on memory impairment after temporal lobectomy for drug-resistant epilepsy [17]. As of the mid-1960s, the changes in cognitive and verbal functions following temporal lobectomy aroused considerable interest in the literature [18]. Some investigators noticed that an auditory verbal learning deficit may appear after removal of the dominant temporal lobe [18]. Intracarotid sodium amylobarbitone test (Wada test) was used by some investigators for the purpose of determination of cerebral dominance for speech [19], as suggested by Wada in 1948 [10], but it did not become a popular practice to preoperatively investigate cerebral hemisphere dominance for speech and memory until the 1980s [20,21]. Prognostic implications of neuropsychological test performance for surgical treatment of epilepsy were appreciated in the 1970s [22]. Nowadays, neuropsychology plays a prominent role in presurgical evaluation of patients with drug-resistant TLE. Neuropsychology, including the Wada test, is advantageous in documenting dysfunction associated with a lateralized temporal lobe seizure onset. In addition, neuropsychological test results have some predicative value with regard to postoperative outcome [23]. By the end of 1978, the Montreal Neurological Institute's experience with cortical resection for drug-resistant TLE had grown to 1102 patients. They showed that 70% of those with 2 or more years of adequate follow-up data (median period 11 years) experienced a complete cessation or nearly complete reduction of seizures [24]. Computed tomography (CT) imaging and video-EEG monitoring systems had been invented and became available by this time [24]. Video-EEG monitoring systems revolutionized our understanding of seizure semiology and its correlation with ictal EEG changes. Development of the magnetic resonance imaging (MRI) technology also occurred throughout the 1970s and 1980s [25]. Since then, significant developments have been achieved in diagnostic technologies in the neurosciences, especially for the purpose of epilepsy surgery. These developments included single photon emission computed tomography (SPECT), positron emission tomography (PET), and magnetoencephalography (MEG) in the 1970s and 1980s, functional magnetic resonance imaging (fMRI) in the 1990s, and, most recently, multimodal neuroimaging techniques [26,27]. These advancements have significantly increased our knowledge about epilepsy. These technologies have revealed etiological brain lesions in a large number of patients with epilepsy, widened the indications for surgical treatment of drug-resistant epilepsies, and improved our understanding of the pathogenesis of epilepsy [27]. For example, MRI is significantly more sensitive in identifying the etiological brain lesions compared with CT scanning [28]; therefore, with the help of MRI we can offer surgery to many more patients who suffer from drug-resistant TLE. Introduction of MRI has revolutionized the practice of epilepsy surgery. Whereas historically, invasive EEG recordings were necessary for many epilepsy surgeries, indications for such invasive studies have dramatically changed since the introduction of MRI, which uncovers structural etiological brain lesions in a high percentage of patients with drug-resistant TLE [29]. In addition, with the help of these advancements (e.g., PET scan or intracranial EEG monitoring), epilepsy surgery in patients with nonlesional TLE has become an acceptable practice [30,31]. Therefore, now we can offer surgery to even more patients who suffer from drug-resistant TLE; surgery is now a common practice for these patients compared with the situation 70 years ago [12]. Likewise, with the help of advancements in the past decades we can now offer surgery in more complicated cases, such as those with an epileptogenic area close to eloquent cortex (e.g., with the help of intracranial EEG and brain mapping) [32]. However, this increase in knowledge has not lead to significantly higher rates of seizure freedom among patients with drug-resistant TLE who undergo anterior temporal lobectomy. In the 1980s, complete freedom from seizures for at least two years or more after anterior temporal lobectomy in patients with drug-resistant TLE was expected for 40 to 70% of patients; 60 to 90% of patients experienced a marked reduction or complete elimination of seizures following temporal lobectomy [33]. In 1993, Engel collected data on 3579 patients who underwent temporal lobectomy and reported that 68% were seizure-free and 24% were improved [34]. These figures did not differ significantly from the original report in 1950 by Penfield and Flanigin [12] (Fig. 1). We should mention that in the earlier era, surgeries for drug-resistant TLE were not common, and there was no known standardized post-surgery seizure outcome classification prior to Engle's classification in 1993 [35]; therefore, a head-to-head comparison of the results published in the 1950s with those from recent series is not practical.

Currently, multiple invasive treatment options are available for patients who suffer from drug-resistant TLE, including:

1. Anterior temporal lobectomy: This technique remains the gold standard in the treatment of drug-resistant TLE. Surgery of mesial TLE associated with hippocampal sclerosis achieves long-term seizure