FRONTIERS

Surgery of the Mind, Mood, and Conscious State: An Idea in Evolution

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Since the beginning of recorded history, humans have sought a physical means of altering disordered behavior and consciousness. This quest has spawned numerous innovations in neurosurgery and the neurosciences, from the earliest prehistoric attempts at trepanation to the electrocortical and anatomic localization of cerebral function that emerged in the 19th century. At the start of the 20th century, the overwhelming social impact of psychiatric illness intersected with the novel but imperfect understanding of frontal lobe function, establishing a decades-long venture into the modern origin of psychosurgery, the prefrontal lobotomy. The subsequent social and ethical ramifications of the widespread overuse of transorbital lobotomies drove psychosurgery to near extinction. However, as the pharmacologic treatment of psychiatric illness was established, numerous concomitant technical and neuroscientific innovations permitted the incremental development of a new paradigm of treating the disordered mind. In this article, we retrospectively examine these early origins of psychosurgery and then look to the recent past, present, and future for emerging trends in surgery of the psyche. Recent decades have seen a revolution in minimalism, noninvasive imaging, and functional manipulation of the human cerebrum that have created new opportunities and treatment modalities for disorders of the human mind and mood. Early contemporary efforts were directed at focal lesioning of abnormal pathways, but deep-brain stimulation now aims to reversibly alter and modulate those neurologic activities responsible for not only psychiatric disorders, but also to modulate and even to augment consciousness, memory, and other elements of cerebral function. As new tools become available, the social and medical impact of psychosurgery promises to revolutionize not only neurosurgery, but also humans' capability for positively impacting life and society.

INTRODUCTION

Since the beginning of human existence, the desire to modify human behavior and consciousness through indirect or direct physical intervention has been a "holy grail." Throughout history, these efforts have taken many different directions, with the first millennia characterized by largely shamanistic or ritualistic interventions or trepanations with little understanding of the underlying physiology or therapeutic effect. In the past century, an exponential increase in our awareness of the diversity and the prevalence of diseased states of the human mind combined with the increasing technical and technological sophistication of our interactions with the human cerebrum have created an unprecedented opportunity (7). The epidemiology of psychiatric illness and other diseases of the mind and conscious state is staggering—5 of the top 10 causes of disability worldwide are psychiatric and neurobehavioral disorders (96). It is

Key words
- Deep brain stimulation
- Functional neurosurgery
- Neuromodulation
- Prefrontal lobotomy
- Psychosurgery
- Trepanation
- Vagal nerve stimulation

Abbreviations and Acronyms
BRW: Brown-Roberts-Wells
CRW: Cosman-Roberts-Wells
CT: Computed tomography
DBS: Deep-brain stimulation
DTI: Diffusion tensor imaging
MDD: Major depressive disorder
MRI: Magnetic resonance imaging
OCD: Obsessive-compulsive disorder
PET: Positron-emission tomography
PTSD: Posttraumatic stress disorder

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Archival Article Citation: World Neurosurg. (2012) 77, 5-6:662-686.
http://dx.doi.org/10.1016/j.wneu.2013.08.002

*Journal homepage: **www.WORLDNEUROSURGERY.org***

*Available online: **www.sciencedirect.com***

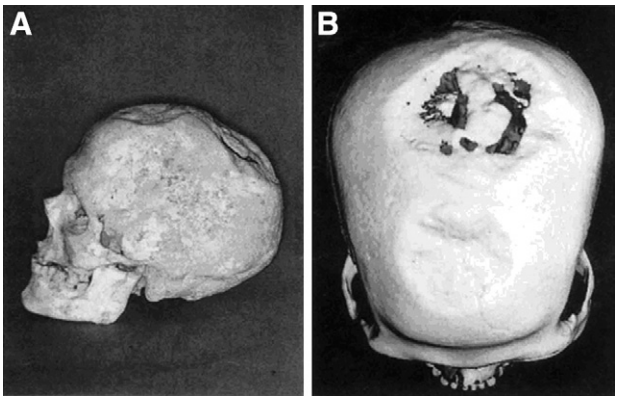

Figure 1. Neolithic trepanation circa 5100 BC (**A**), with evidence of postoperative healing (**B**) (2).

estimated that the incidence of major depression alone in a single individual's lifetime is between 12%–18%, and with greater than 120 million patients, it represents the greatest cause of disability worldwide (5). The remainder of the top 10 includes alcoholism (fourth), bipolar disorder (sixth), schizophrenia (ninth), and obsessive-compulsive disorder (tenth) (96). In the case of major depression, as many as one third of patients become resistant to treatment (30).

As the enormous prevalence and social cost of psychiatric disease continues to gain recognition, with concomitant improvements in the efficacy and safety of surgical intervention, surgery of the mind and mood promises to become one of the most epidemiologically important fields of neurosurgery. Although "psychosurgery" has many varying connotations and definitions, particularly the narrow category of ablative lobotomies, which drew popular attention and criticism in the middle of the 20th century, in this article it is defined as the full spectrum of neurosurgical treatments for psychiatric illness, including all the various modalities of open, stereotactic, functional, and radiosurgical procedures.

Trepanation

The history of psychosurgery predates the start of recorded history itself. Numerous reports exist of prehistoric examples of trepanation. Although the therapeutic purpose of trepanation is open to speculation, it likely included the treatment of psychiatric illness. The most well-documented example is a skull found in the Neolithic burial site of Ensisheim in Alsace, France, which dates to roughly 5100 BC (**Figure 1**) (2). The skull had two separate areas of trepanation and evidence of subsequent healing, indicating that the lesions were performed intentionally while the individual was still alive, as opposed to an epiphenomenon such as infection or postmortem trauma, and that the individual survived for an extended period of time after the procedure. This example represents not only the earliest form of neurosurgery or psychosurgery but of a surgical procedure of any kind. There is also extensive archeological evidence of trepanation in pre-Columbian Mesoamerica, with the most numerous examples originating in Peru and Bolivia, where the procedure was practiced with considerable skill, as evidenced by the number of skulls with evidence of postoperative healing, as well as the associated archeological trove of tools developed for the purpose (**Figure 2**) (122). Although the majority of these were likely performed for trauma or depressed skull fractures associated with the bludgeoning-type weapons of the day, there is also evidence to suggest that the operation was conducted for other ailments as well, including the shamanistic exorcism of malicious spirits, a possible cultural proxy for mental illness, epilepsy, depressed consciousness, or even the restoration of life itself.

There is also mention of trepanation in the classical writings of Hippocrates and Galen, and evidence suggests it was practiced throughout the early Medieval period. After an apparent lull, trepanation returned to prominence in the Renaissance era, with many references and depictions of the procedure in contemporary medical texts and artwork of the time. One notable example is *The Cure of Folly* or *The Extraction of the Stone of Madness*, a painting by the 15th-century Dutch painter Hieronymus Bosch (**Figure 3**). Although many portions of the painting are pointedly allegorical, it nonetheless depicts the extraction of a "brain stone" as a cure for either stupidity or madness, depending on the interpretation of the term "folly" (111). The idea that madness could be caused by a physical stone in the brain was a common superstition at the time, although it is unclear to what extent trepanation was performed to that purpose. Although there is some more contemporary evidence of the use of trepanation in certain African tribes, with the advent of the later Renaissance understanding of physiology and naturalism, the use of trepanation as a form of metaphysical treatment of psychiatric illness passed from Western medical practice until its reincarnation in the 20th century (130).

THE ABLATIVE ERA OF PSYCHOSURGERY

The Origins of Functional Neuroanatomy

Although classical philosophers such as Aristotle and Descartes were some of the first to postulate that the brain was the center of

Figure 2. Surgical knives (known as *tumi*) used for trepanation among pre-Columbian civilizations of South American, circa 100-1100 AD (courtesy Paleo Direct, Altamonte Springs, FL).