Evaluation of frame based versus frameless stereotactic biopsy technique in the diagnosis of deep seated brain lesions.

Submitted for partial fulfillment of a master degree in neurosurgery.

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2015

تقييم تقنية جهاز التصويب المجسم والبعد الثالث المبنى على الخزعة الدماغية مقارنة بالجهاز الحديث بدون الخزعة الدماغية فى تشخيص الافات العميقة بالمخ.

رسالة مقدمة من

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توطئة للحصول على درجة الماجستير فى جراحة المخ والاعصاب

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بسم الله الرحمن الرحيم

قَالُوا سُبْحَانَكَ لا عِلْمَ لَنَا إِلا مَا عَلَّمْتَنَا إِنَّكَ أَنْتَ الْعَلِيمُ الْحَكِيمُ

صدق الله العظيم

سورة البقرة آية (٣٢)

Introduction

Stereotactic brain biopsy has been established as an indispensable tool for modern neurosurgeons. This technique provides a relatively straightforward, very accurate, and fairly safe method of obtaining diagnostic tissue, particularly for lesions that are deeply situated or located in eloquent regions of the brain ***(Sawin et al., 2007).***

The neurological deficits that would be caused by approach to and excision of these lesions might be excessive. However a stereotactic approach to biopsy and treatment of some of these deep lesions might avoid such problems ***(Woodworth et al., 2005).***

Following the pioneering work of Horsley and Clarke in 1908 and the first clinical introduction by Spiegel and Wycis in 1947, frame-based stereotactic systems have become one of the most important developments in the history of neurosurgery ***(Rahman et al., 2009).***

Frame-based stereotaxis (FB) is a well-established technique for performing three-dimensional point stereotactic needle procedures such as diagnostic biopsies, lesion aspirations, and brachytherapy instillation. It has proved a safe and effective tool since it was first coupled with computed planar imaging nearly three decades ago ***(Mundinger, 1985).***

Advances in technology and the development of computers and digital techniques in recent years have led to the increasing use of complex systems, with various software algorithms, to process imaging data and facilitate accurate intraoperative localization of intracranial lesions without the use of a stereotactic frame system ***(Germano, et al, 2005).***

The development of frameless stereotaxis (FL) has been rapidly embraced by most neurosurgeons to the extent that it is rapidly supplanting FB techniques in general neurosurgical practice. Some early reports have suggested that FL techniques are as good as or better than the traditional frame- based approach ***(Dorward ,et al .,2009).***

Frameless stereotaxy has demonstrated many advantages over frame-based stereotactic systems. It does not depend on stereotactic frames, has fewer limitations in space and the handling during preoperative imaging and planning is easier. Imaging and planning can be separated from surgery in time and location and sophisticated software allows integrating multimodal image data for treatment planning and neuronavigation ***(Raabe , et al., 2003).***

However, in contrast to the rigid guidance during frame-based stereotaxy, frameless stereotaxy may be hampered by complex hand–eye coordination, drift, and natural tremor. Thus, without lockable targeting devices, frameless systems may not be equally eligible for stereotactic procedures that require precisely reaching a target along a preplanned trajectory, such as brain biopsy (BB) or depth electrode placement (DEP) ***(Ringel , et al., 2009).***

Recent large series seem to indicate similar diagnostic yields and complication rates, but have failed to agree upon factors such as differences in cost and operating room time between the two methods ***(Smith ,et al., 2005).***

This suggests surgeon and institution experience and preference as major contributing factors and makes clear the necessity of continued investigation and reporting of clinical experience with these techniques ***(Shastri ,et al., 2006).***

Aim of the work

This is a review of literature aiming to compare the use of frame based and frameless stereotactic biopsy techniques in the diagnosis of deep seated brain lesions regarding their technical advantage & disadvantage, reliability and safety.

History of stereotaxy

Stereotaxis is a method for locating points within the brain using an external, three-dimensional (3D) frame of reference, in order to perform a neurological procedure in a minimally invasive manner ***(DeAngelis, et al,2002).***

Image-guided stereotactic biopsy for histopathologic diagnosis of cranial lesions has become a standard component of the neurosurgical armamentarium .The word ‘‘stereotactic’’ derives from the Greek word ‘‘stereos’’ for ‘‘three dimensions,’’ and the Latin word ‘‘tactus’’ for ‘‘to touch’’ ***(Germano, et al 2002).***

In 1908, Horsley and Clarke reported the first stereotactic device in the English literature, which was used to access the dentate nucleus in the cerebellum of monkeys . Nearly 40 years later, in 1947, stereotactic techniques were introduced in humans by Spiegel and Wycis, who used their system for ablative neurosurgical procedures. Nearly simultaneously, Leksell developed a separate stereotactic system in 1949 based on the concept of the arc quadrant. ***(Spiegel, et al 1947).***

The first human stereotaxy was most likely performed using the encephalometer, a stereotactic device developed by Professor D. N. Zernov, professor of anatomy in Moscow, Russia, in 1890s, even before Horsley and Clarke's stereotactic frame for animals was developed. ***(Pineau, et al 2009).***

Sir Victor Horsley was both a neurosurgeon and neurophysiologist, and is generally recognized as the father of human functional neurosurgery. He had collaborated with Robert Clarke, a mathematician and also a surgeon, and recruited him to help him design their device. The design and mathematics of the instrument was mainly Clarke's, and the details of how it might be used were Horsley's. ***(Pereria, et al, 2008).***

The concept originated with Clarke in 1895, the original device was constructed in 1905 and first used in 1906 after which the two pioneers ceased further collaboration **.**Together with other colleagues, Clarke went on to publish functional atlases of both primates and cats. ***(Fodstad, et al. 1991).***

Clarke suggested to Horsley that the technique might be useful in humans, and even patented the idea of a human stereotactic apparatus, still based on using the boney landmarks to establish the landmarks from which Cartesian coordinates might be determined ***(Levy, et al., 1992).***

The original device, manufactured by Swift & Son, currently resides in the Science Museum in London (Fig. 1a). Two subsequent copies of Clarke’s frame were constructed; one device, brought to the United States by neurosurgeon Ernest Sachs, who had trained under Horsely, is located in the Department of Neurosurgery at UCLA. In the subsequent decades, several efforts were made to improve on the Clarke-Horsley device to make it suitable for human use***.(Pereria , et al.,2008).***

In 1918, however, Mussen, an engineer who had been involved in making the Horsley-Clarke apparatus designed a similar device for use with the human skull. There is no evidence that he persuaded any of his neurosurgical colleagues to use it, so he eventually wrapped it in newspaper and stored it in a box in his attic. When his family discovered the box almost 60 years after the Mussen frame had been made, they could determine when it had been stored by the date on the newspaper wrapping. ***(Olivier , et al., 1983).***

In 1933, Martin Kirschner, a German neurosurgeon, developed a stereotactic apparatus for a skull approach for treatment of trigeminal neuralgia ***(Kirschner, et al., 1933).***

The first successful cranial application of stereotactic surgery in humans is credited to the team of Ernest Speigel and Henry Wycis in the Department of Experimental Neurology at Temple University in Philadelphia **.**Their original frame, using a Cartesian coordinate systems and similar in design and operation to the Clarke-Horsley device, was fixed to a patient's head by means of a plaster cast. The frame and cast were removable, allowing separate imaging and surgery sessions. Contrast radiography, ventriculography and later pneumoencephalography permitted the visualization of intracranial reference points from which the location of target structures of interest could be determined. Initial applications were for psychosurgery, ''…in order to reduce the emotional reactivity by a procedure much less drastic than frontal lobotomy'' **.**The authors envisioned further application for pain (lesioning of the spinothalamic tract and Gasserian ganglion), movement disorders (pallidotomy), and draining of fluid from cysts. ***(Speigel, et al., 1947).***

The work of Speigel and Wycis spawned an enormous interest in the development and application of stereotactic apparatus. The most notable development was the device constructed by Lars Leksell (1949) (Fig. 1c). In contrast to the Cartesian coordinate system of the Speigel-Wycis device, Leksell's frame employed used three polar coordinates (angle, depth and anterior–posterior location). This ''arc-quadrant'' device provided maximum flexibility in choosing probe entry point and trajectory, and was therefore much easier to use***.(Gildenberg ,2001).***

The frame has been modified over the ensuing years, but remarkably remains very similar in function and appearance to the original 1949 device. Only two years after its development, Leksell would use his frame to target narrow beams of radiation ***(Leksell, 1951).***

Following the invention of X-ray computerized tomography, Leksell was also quick to build a CT-compatible device ***(Leksell ,et al., 1980).***

Other developments in stereotactic frames included the efforts of Talairach (1949, 1952), Narabayashi (1952), Reichert and Mundinger (1955) and Wells and Todd (1998) (Fig. 1d).

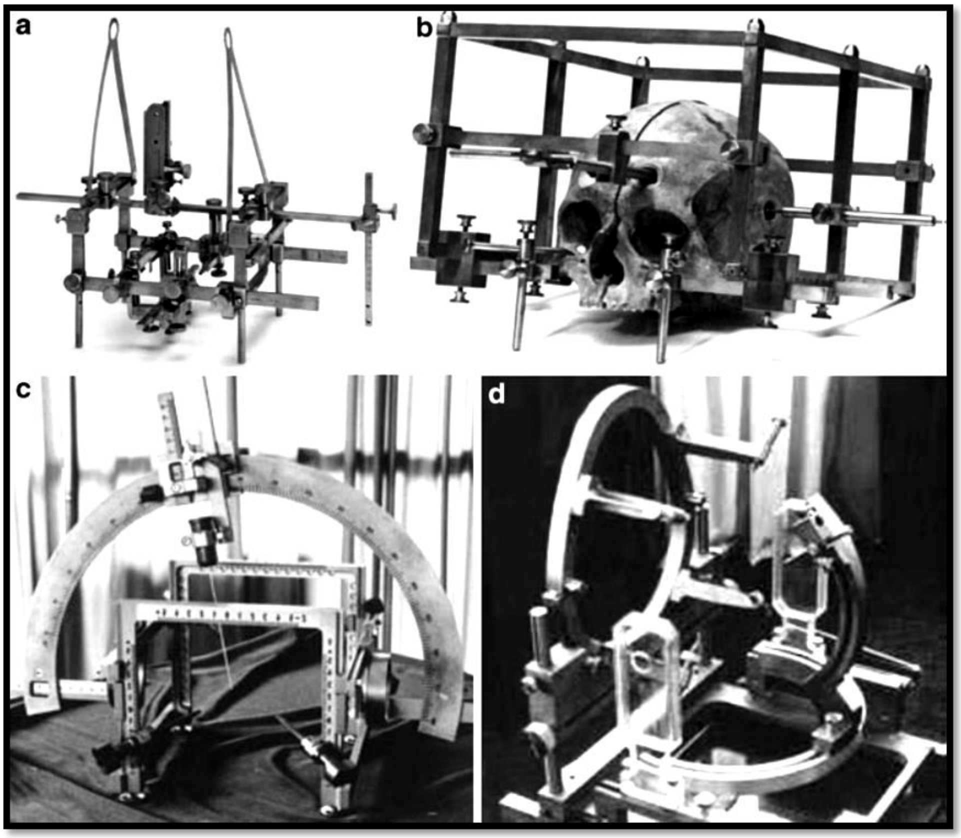

Fig. 1 Early examples of stereotactic frames. a)The original device of Horsely and Clarke (courtesy of the Science Museum, London); b) the Mussen frame; c) an early Leksell frame; d) an early version of the Todd–Wells frame. ***.(Gildenberg PL ,2001).***

The Talairach frame is particularly notable as it was used in the first stereotactic radiosurgery procedure ever performed using a linear accelerator ***(Betti ,et al., 1982).***

During the 1960's, the Todd-Wells stereotactic apparatus became the most popular in the United States, and the Leksell and Riechert- Mundinger systems in Europe. There was little further modification of apparatus during the next decade, when the emphasis shifted to indications and results***.(Gildenberg PL et al, 1985).***

Similarly, modification to the Todd–Wells device resulted in a widely used commercial frame The Brown-Roberts-Wells (BRW) coordinate system is the foundation of present day frames made by both Integra Radionics (Burlington,MA) and Brain LAB (Feldkirchen, Germany). ***(Brown et al. 1980).***

By most accounts the concept of using small cross firing beams of charged particles to ablate or alter the function of cranial structures originated with John Lawrence and Cornelius Tobias in the late 1940s ***(Larsson,et al., 1996).***

One key to this field was the first introduction of X-ray equipment into the operating room with rapid film development. The key to human stereotactic surgery is to identify landmarks within the brain by X-ray or by other imaging and calculating where a target lay in relation to those landmarks. Ventriculogram X-rays could be taken to visualize internal cerebral landmarks about the third ventricle, from