APPLICATIONS OF ULTRASOUND IMAGING MODALITY IN NEUROSURGERY

An esay submitted for the partial fulfilment of the master degree in neurosurgery

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قَالُواْ سُبْحَانَكَ

لاَ عِلْمَ لَنَا إِلاَّ مَا عَلَّمْتَنَا

إِنَّكَ أَنتَ الْعَلِيمُ الْحَكِيمُ (32)

سورة البقرة

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Sincerly

Mohamed M. Sayed Ismail

أستخدامات الأشعة فوق الصوتية في جراحات الأعصاب

توطئه للحصول على درجة الماجستير في جراحة المخ و الأعصاب

مقدمه من الطبيب

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مدرس جراحة المخ و الأعصاب

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INTRODUCTION

All through the human history imaging modalities have been used for exploration of the human body secrets ,detecting defects and explaining patient's complaints so helping in treatments and decision making.

Technology offered us different imaging facilities passing from x-ray, Ultra-Sound **(U/S)** imaging and computed tomography **(CT)** to reach magnetic resonance imaging **(MRI)**. Even new advances in the prototype of each mode have been proven to add to our credit as regard the quality of diagnosis and treatment.

Starting from the first few decades of the past century ultrasound imaging modality gained raising credit because of its ease in use and valuable diagnostic information .It was first used in diagnosis of abdominal diseases exploring its content and organic pathologies then advanced towards being used in investigating the heart (ECHO) and the peripheral vasculature **(DOPPLER)** and **(DUPLEX)** modes. (1)

By time the growing use and technical progression have added more advances to ultrasound imaging to be used in a wider fashion all over most of the body parts to reach the top of being used intra-operatively in most of the surgical fields for example hepato-biliary surgery and urology

In the fifties, **French** et al, started the usage of ultrasound imaging modality in neurosurgery for detection of intra-cerebral masses and tumors in cadaveric dissection labs**.** (1)

Wild et al, completed his steps by using ultrasound intra-operatively in detection of malignant cerebral tumors. U/S was able to detect and localize, and facilitate the surgical procedure steps and pathology detection and so improving outcomes**.** (2)

The **A-Mode** used by both of them ,as a primary prototype faced the problem of low quality images ,inability to detect directions , technical and equipmental problems ,and difficulty in differentiating various pathologies**.** (3)

In 1980,**Srubin** et al, and **Patterson et al** have advanced the use of the **B-Mode ultrasonography** using **3** and **7.5 MHz transducers** to

gain real-time imaging intra-operatively to demonstrate intracranial anatomy and excellent demonstration ,localization ,orientation ,size and volume calculation in addition to intra-operative assessment of the extension of tumor excision**.** [4]

Dohrmann et al, Shkolnik et al and **Hassler et al** … ect. followed the expanding uses and modalities recruitment in neurosurgery up to real-time intraoperative mode .[5,8,9,10,11,12,13]

In 1990s, applications modalities including blood flow detection by DOPPLER and DUPLEX modes and 3-D reconstruction mode**.** [6]

Through 2002;the use of ultrasound-neuro-navigation by **Rygh OM, Selbekk T. et al ,**and **JacobSosna et al**, converted the neurosurgical operations to be easier and less time consuming add to better results. [28,29]

By the startof 2004; **Shin-Yuan Chen, Tsrong-Laang Chiou**…..et al,started the usage of three-dimensional intraoperative ultrasound mode**.**[19]

At 2005 ,by **Nobusada Shinoura** ….et al ,the use of ultra-sound contrast enhancement added a great rise in image quality and favored its intraoperative use over the others .[9]

Kolstad F…et al; during 2006 used the Three-dimensional ultrasonography navigation in spinal cord tumor surgery**.**[20]

Coauthor Keith….et al; have begun the ultrasound guided nerve blocks in **2007** ***(42)***

Applications of ultrasound in neurosurgery:

1) Brain surgery: planning, intra-operative accurate localization of the lesions, delineating the surrounding anatomy, assisting and controlling tumor resection, identifying residuals. [2:20]
2) Identification of feeding vasculature and blood flow detection by Doppler and Duplex modes. [27]
3) Vascular brain tumors including AVM and aneurysm operations by power Doppler and 3D-Mode. [25:30]
4) Intra-cerebral hematomas evacuation.[28]
5) Accurate placement of V-P shunt ventricular catheters. [21,22]
6) Frameless ultrasound guided biopsy.[23]
7) Frameless ultrasound guided Abscess tape. [23]
8) Intra-operative Sono-Navigation. [34:41]
9) Endoscopy assisted skull base surgery [31]
10) Spinal cord lesions; tumors, cysts and syringomyelias .[34]
11) Survey of pediatric brain anatomy
12) Ultrasound-guided nerve blocks and injections for pain therapy and regional anesthesia.[42]

Aim of the Work

The aim of this study is to outline the beneficial role of ultrasound imaging modality in the field of neurosurgery either pre-operatively or intra-operatively and interpretation of the appearance of the different pathologies using ultrasound imaging and how ultrasound modality affected the surgical outcome with some illustrative cases.

Anatomy of the Nervous System

For purposes of description; The nervous system is divided into two main parts: the central nervous system and the peripheral nervous system.

The Central Nervous System

❶ *The brain*

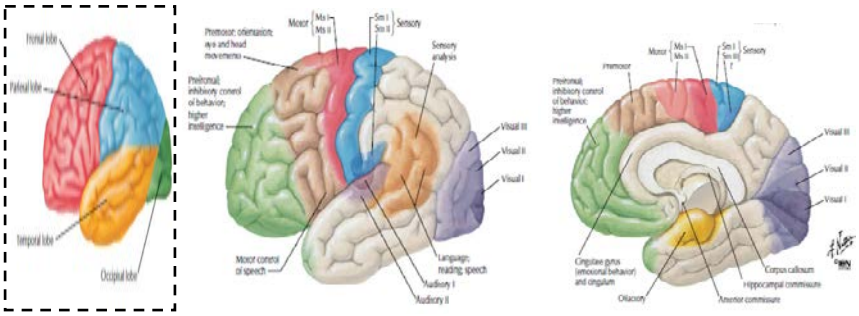
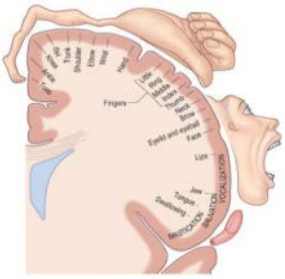


Figure (1): Topographic presentation of the cortical areas[113].

📖 Frontal Lobe: *representing the following cortical areas:*

Primary motor area (Brodmann area 4): if electrically stimulated, produces isolated movements on the opposite side of the body. The movement areas of the body are represented in inverted form; Starting from below and upwards are structures involved in swallowing and the tongue, jaw, lips, larynx, eyelid, and brow; Then area for the fingers, hand, wrist, elbow, shoulder, and trunk. Then movements of the hip, knee, and ankle in the highest areas while; the movements of the toes are situated on the medial surface of the hemisphere.



Pre (secondary) - motor area (6): stores programs of motor past experience activity, programs the activity of the motor area.
Frontal eye field (6, 8, 9): control voluntary scanning movements of the eye independent of visual stimuli.

The motor speech "Broca 's" area (44, 45): formation of words by its connections with the motor areas to the muscles of the larynx, mouth, tongue, soft palate

The prefrontal cortex (9, 10, 11, 12); individual's personality.

📖 Parietal Lobe:

- ***The primary somatic sensory cortex (S1) (3, 1,2):*** The opposite half of the body is represented as inverted. The pharyngeal region, tongue, and jaws are represented in the most inferior part followed by the face, fingers, hand, arm, trunk, and thigh, The leg and the foot areas are found on the medial surface of the hemisphere
- ***The secondary sensory cortex (S2).***

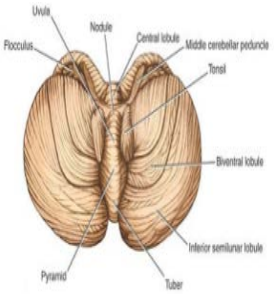
📖 *Occipital Lobe:*

- ***The primary visual area (17***): receives fibers from the temporal half of the ipsilateral retina and the nasal half of the contralateral retina.
- ***The secondary visual area (18 and 19***): enabling the individual to recognize and appreciate what is seen.

📖 Temporal Lobe:

- ***The primary auditory area (41, 42***): The anterior is concerned with the reception of sounds of low frequency, and the posterior part with the sounds of high frequency.
- ***The secondary auditory area (auditory association cortex) (22):*** for the interpretation of sounds and association of the auditory input with other sensory information.
- ***The sensory "Wernicke's" speech area:*** understanding of the written and spoken language and enables a person to read a sentence, understand it, and say it out loud.
- ***The Insula***: important for planning or coordinating speech articulatory movements[(113)].

❷ The cerebellum:

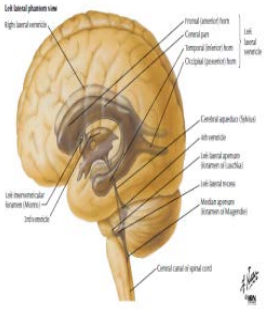


It lies within the posterior cranial fossa of the skull posterior to the pons and the medulla oblongata. It consists of two laterally placed hemispheres connected by a median portion "the vermis".

The cerebellum is connected to the midbrain by the Superior Cerebellar Peduncles, to the pons by the Middle Cerebellar Peduncles, and to the medulla by the Inferior Cerebellar Peduncles[(216)].

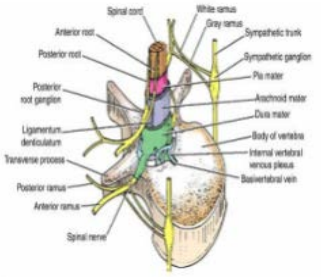
❸ Ventricular system:

The cavity present within each cerebral hemisphere **"lateral ventricle".** The lateral ventricles communicate with the **third ventricle** through the interventricular foramina .The medulla oblongata, the pons, and the cerebellum surround a cavity filled with cerebrospinal fluid, called the **fourth ventricle**. This is connected superiorly to the third ventricle by the cerebral aqueduct inferiorly, it is continuous with the central canal of the spinal cord. It communicates with the subarachnoid space through three openings in the inferior part of the roof, through these openings the cerebrospinal fluid within the central nervous system can enter the subarachnoid space [(113)].



❹ *The spinal cord:*

It is situated within the vertebral canal of the vertebral column. It begins superiorly at the foramen magnum where it is continuous with the medulla oblongata. It terminates inferiorly and tapers off into the conus medullaris, from the apex of which a prolongation of the pia mater, the filum terminale, descends to attach to the back of the coccyx. It is composed of an inner core of gray matter, which is surrounded by an outer covering of white matter. The gray



matter is seen on cross section as an H-shaped pillar with anterior and posterior gray columns "horns" united by a thin gray commissure containing the small central canal.

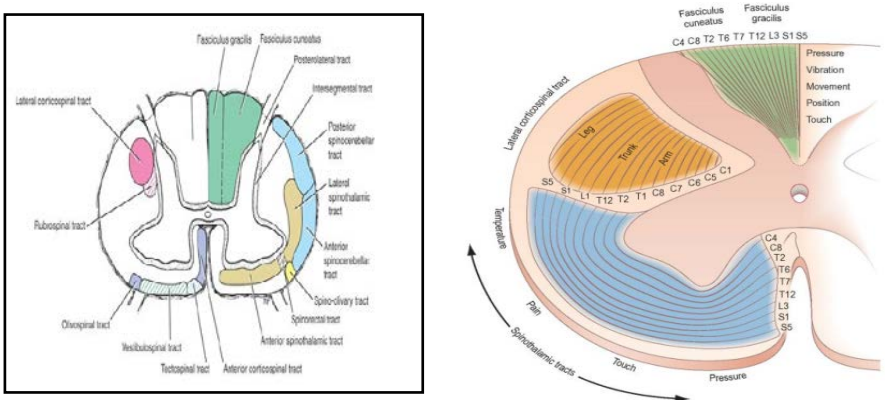


Figure (2) Diagrammatic illustrations of **Transverse section of the cord** at the mid-cervical level showing the general arrangement of the ascending tracts (right) and the descending tracts (left). Lamminar organization of the major spinal tracts[216].