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An Overview of Medical Applications in Meningitis Detection

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Abstract. Meningitis remains one of the common infections among young children with high morbidity and mortality rates. In Southeast Asian, only few studies were reported published which evaluated meningitis clinically in the last two decades. Similarly, few studies in Malaysia evaluated meningitis among adolescents and children. Globally, more than one million cases with 135,000 deaths has been recorded yearly, and in Malaysia, severe neurological complications occurs in 9-25% of cases which affirms the most serious risk manifests from bacterial meningitis. Therefore, early detection and effective treatment are required before the irreversible damages occur. This paper reviews the current states and perspectives of diagnostic techniques on meningitis detection. Currently, there are three diagnostic techniques available for meningitis detection, such as blood cultures, spinal tap (lumbar puncture), and imaging techniques (CT scan, MRI, EIT, Ultrasonography, Nuclear imaging and X-ray). However, these techniques have limitations that may limit the chances of carrying out the early detection of the disease. The essence of this review is that meningitis requires an effective technique that is capable of carrying out the early detection of the disease by differentiating normal people and Meningitis infected patients so as to promote longevity worldwide. In this review magnetic induction tomography (MIT) technique is proposed to diagnose meningitis earlier as it is non-intrusive, non-invasive, contactless, and electrode-less imaging technique which does not expose the patients to a harmful radiation.

1. Introduction

Bacterial meningitis is one of the most common and prominent infections which infects the central nervous system through the tissue layers and membranes that cover brain and spinal cord. More than one million cases and 135,000 deaths has been recorded yearly worldwide because of bacterial meningitis. In Malaysia, significant, enduring neurological complications occurs in 9–25% of cases, which affirms the most serious risk from bacterial meningitis is in early life [1].Bacterial meningitis is one of the most common and prominent infections which infects the central nervous system through the tissue layers and membranes that cover brain and spinal cord. The meningitis is an infection within the subarachnoid space and they are 3 layers which are the Dura mater, the Arachnoid and the Pia mater.

Meningitis can progress in the protective tissues rapidly, and can cause death or debilitation [2].The brain has multiple layers or membranes and spinal cord called the meninges. Bacterial meningitis is one of the types that cause meninges. Also, there is viral meningitis that is the most popular form of meningitis, while bacterial is the most dangerous form. Without early treatment and detection, the bacterial infection may cause you to become paralyzed, have a stroke, or even lead for death [2].

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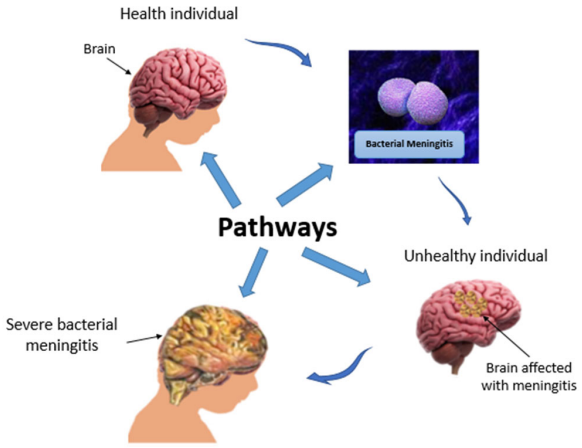

Figure 1. Bacterial Meningitis stages

Bacterial of meningitis is significantly infectious to the central nervous system (CNS), can progress rapidly, and can cause a death or eternal brain damage [2]. The symptom may occur to anyone at age 2 and above and the sign like sudden high fever, serious headache, vomiting, stiff neck and different sign for newborn and infants, bacteria could infect poor feeding, high fever, constant crying or inactivity [2]. Meningitis remains one of the common infections in the young children with high morbidity and mortality. Despite many studies being done on meningitis the level of meningitis among children remain high and also with the availability of newer antibiotics and preventive strategies. It is pivotal for pediatricians to stay cautious in their comprehension of epidemiology, pathogenesis, and management. Early detection and start of sufficient treatment are considered as the main determinants for better result [3].

In medical field, there are several types of diagnosing techniques that are used to detect meningitis such as blood cultures [4,5], spinal tap (lumbar puncture) [2] and tomography modalities: Computed tomography (CT) [3,6,7] scan, Magnetic Resonance Imaging (MRI) [3,8-10], Electrical impedance tomography (EIT) [11,12], X-ray [13,14], Ultrasonography [15,16], Nuclear imaging [17] and several

others. They are used for high resolution imaging procedures with high details images because they apply high radiation and high magnitude of magnetic field method in their principles. Despite the advantages of these modalities, there are drawback as well, like ionizing radiation and very high magnetic field which is not suitable for certain patients especially those with pacemaker [18].Therefore, the technique that proposed to detect meningitis is magnetic induction tomography (MIT). Tomography is studying the characteristics of a subject through its interaction with several frequency components of the electromagnetic tomography [19]. Tomography is a general methodology that can be adapted in many ways to extract the desired information such as (electronic energies, vibration, structure and similarity of molecules, the dynamic information). The mechanism of MIT technique is non-contact electrodes of impedance measurement [19].

Magnetic induction tomography is highlighted as non-invasive application. MIT consist of transmitters (Tx) and receivers (Rx) coils [19]. In this field is disclosed about passive electrical field (PEP) which focuses on the three parameters which are dielectric permittivity, electrical conductivity, and magnetic permeability [20]. In addition, this process will make a varying in magnetic field time that is from an exciting coil, then induce the field to matter which is under study. Information of the data is attainable from coils reaction environment system or disturbance where through sensor coil or receiver coil [20].

2. Physiologgy of Miningitis

Meningitis is an infection of the layers surrounding the brain and spinal cord. Meningitis may be caused by some kinds of bacteria or viral due to infection and these kinds of bacteria are the common etiological factors. Bacterial meningitis remain as a serious infection disease. The bacteria enter the circulatory system and turn the blood cerebrum, then the defensive layers will be excited. The brain and the spinal cord which are protected by the meninges lined the cranial and the vertebral cavities called meningeal. The cranial bones internal surfaces were attached to them and the cranial bones work as stabilizer position of the brain, vein, lymphatic vessels and nerves.

The meninges consist of three layers which are is the dura mater that is composed of harsh , not stretches, thick connective tissues and stick to the skull and vertebral column and pia mater, in particular squamous epithelial cells ensures collagenous and elastic connective tissue and stretchy connective tissue. Arachnoid resemble a spider web, and its position is in the center layer comprising of thick fibers and stretchy connective tissue referring to the dura mater and has a delicate spider web-like projections that is connected to the third layer of pia mater [2].

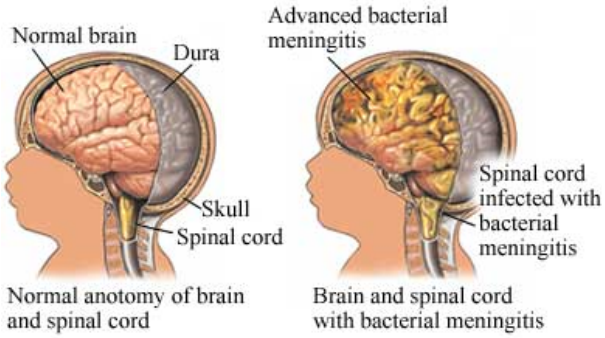

Figure 2. Comparison of normal brain and meningitis affected brain [3]

3. History of Miningitis

Bacterial meningitis considered as a possibly life minatory with worthy morbidity and death rate all over the world and is a considerably huge issue in different regions worldwide, especially in the countries that considered as developed countries [21]. The bacteria that cause meningitis are vary depends on the

age. In the last few researches, the medium age of holding meningitis is over 25 years. The possibility of being infected by meningitis will increase if the skull got injured because that will allow the bacteria to enter the meningeal space [21].

The person who is suffering from a cerebral shunt or a device related are at widened risk of disease. Repetitive meningitis might be caused by enduring anatomic deformation, either congenital or obtained, or by parasitize of the immune system [21]. According to the research done by Kornelisse, in the early 19th of century the first pathological of bacterial meningitis were recorded by Gaspard Vieusseux of Geneva in 1806. According to Vieusseux, after death he observed that a large number of his patients had a purple spots on their skin and marked engorgement of the brain [3]. About 1860, some sorts of poison or factor was involved in pathogenesis meningitis. The first technique use for meningitis diagnosis is a lumbar puncture found by Quincke in 1891 [19, 22] and the first identification of pathogens in a living patients by Heubner in 1896 [22].

Bacterial meningitis is a mortal disease in most conditions (90%) around the pre-antibiotic era. The first efficient therapeutic intercession in bacterial meningitis bringing in reducing of death rate to 25% by installation of immune plasma supplemented immediately. Thereafter, bacterial meningitis and meningococcal sepsis turn into curable illness entities with variable death-rates dependent on the patient characteristics and individual pathogen [3]. Meningitis disease mostly attacks young children. From epidemiological studies, researchers say that there are several risk factors for bacterial meningitis. Age is the main factors of bacterial meningitis risk. Although, the disease can attack anyone at any age, newborns, young children and young adults [3].

4. Electronic Properties of Biological Tissues

Electrical properties of biological tissue consist of conductivity, permittivity and permeability with the relation as given in the equation (1)

$$\Delta B/B = \omega (\omega\varepsilon 0\ \varepsilon r\text{-}j\sigma) \quad (1)$$

B is magnetic field, ω is frequency, ε0 is permittivity at free space, εr is relative permittivity and σ is conductivity.

In MIT applications only conductivity will be the interest as it is the dominant property in biological tissue [22, 23]. A biological tissue has their cell group that's not essentially same instead having the same origin, but they are working together to perform certain functions. Conductive of body fluid provide resistance component and the cell membrane act as imperfect capacitors that cause to a frequency dependence reactance. For this reason, the parameter of conductivity is complex. The opposition to the flow of electric current through biological tissue was measured by bio-impedance. Electromagnetic tomography aims to image the physical properties of biological human tissue by the opposite the electric conductivity in human tissue. Bio-impedance in the human body contains a lot of information, including the characteristic and identity of cells based on their impedance and the other representing the cell size, orientation and thickness of the membrane. For instance, the measure of impedance can be used to characterization and identification of the meningitis cells, since they exhibit different impedance compared to normal tissue [24].

5. Conclusion and Future Prospective

Meningitis is a serious and fatal disease that kills patients within hours. Despite several new antibacterial specialists, bacterial meningitis casualty rates still high. It is the reason for mortality of 1,000 individuals around the world daily; large portions of them are children and young adults. Survivors can be left with serious disabilities.

So far, the related techniques and modalities used for meningitis diagnosis are blood cultures, lumbar puncture and image modalities such as x-ray, ultrasonography, Nuclear imaging, EIT, CT scan, and MRI but they have limitations as mentioned above. Also, there are several potentially non-ionizing techniques introduced in medical imaging but the technologies still at research stage. Among the techniques are, Electrical Capacitance Tomography (ECT), Magnetostatic Tomography and Magnetic Induction Tomography (MIT). MIT is a non-invasive, non-intrusive and non-ionizing radiation modality which

has the potential to be applied in the meningitis detection and monitoring as an alternative to the current technology.

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