Gender determination based on CT cranium measurements of adults in Hospital USM

By

Dr Nurashikin binti Jamaluddin

DISSERTATION SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF MEDICINE RADIOLOGY

SCHOOL OF MEDICAL SCIENCES

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بسم الله الرحمن الرحيم

In the name of Allah SWT, Most Gracious, Most Merciful

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LIST OF SYMBOLS, ABBREVIATIONS AND ACRONYMNS

HUSM	Hospital Universiti Sains Malaysia
CT head	Computed Tomography of head
CT cranium	Computed Tomography of cranium
MDCT	Multidetector Computed Tomography
ICC	Inter class Correlation Coefficient
MPR	Multi Planar Reformation
PACS	Picture Archiving and Communication System
PACS IW	Picture Archiving and Communication System Imaging Workflow
BMI	Body Mass Index
GOL	Glabello Occipital Length
BNL	Basion Nasion Length
BBL	Basion Bregma Length
FRC	Frontal Chord/ Bregma nasion length
PAC	Parietal Chord/ Bregma occipital length
OCC	Occipital Chord/ Occipital Opisthion length
DBB	Diploeic space 1cm below Bregma
DBL	Diploeic space 1cm below Lambda

Menentukan jantina berdasarkan ukuran CT kepala di kalangan dewasa di Hospital USM.

ABSTRAK

Tujuan: Tujuan kajian ini dibuat adalah untuk menentukan jantina berpandukan pengukuran kepala menggunakan CT skan kepala di kalangan dewasa. Kaedah ini belum pernah lagi dijalankan di sini. Kajian termasuklah ukuran pada kepanjangan Glabello- Occipital (GOL), kepanjangan Basion- Nasion (BNL), kepanjangan Basion- Bregma (BBH), kepanjangan Nasion Bregma chord atau frontal chord (FRC), kepanjangan Bregma- Lambda atau Parietal Chord (PAC), kepanjangan Lambda- Opisthion atau Occipital Chord (OCC), rongga Diploe 1 cm di hadapan Bregma (DBB) dan 1 cm di belakang Lambda (DBL).

Kaedah: Seramai 180 pesakit dewasa yang berumur 18 tahun ke atas di Hospital Universiti Sains Malaysia yang menjalani CT skan kepala telah menyertai dalam kajian ini. Imaj telah dikaji dalam tetingkap tulang ‘bone window’.

Keputusan:

Mean untuk kepanjangan Glabello- Occipital, Basion- Nasion, Basion- Bregma, Nasion- Bregma cord, Bregma- Lambda, Lambda- Opisthion dan ketebalan Diploe 1cm below lambda menunjukkan perbezaan statistik antara lelaki dah perempuan. Terdapat hubungan positif berkadar terus untuk kepanjangan Glabello- Occipital, Basion- Bregma dan Nasion- Bregma dengan tinggi dan berat. Di samping itu, kepanjangan Basion- Nasion mempunyai hubungan statistik dengan ketinggian.

Kesimpulan:

Untuk populasi ini, kajian ini menyokong kajian yang lain berkaitan dengan pengukuran kepala bersama jantina, tinggi dan berat. Oleh itu, ia dapat sekaligus membantu pada masa akan datang berkaitan perubatan forensic radiologi menggunakan CT skan kepala bagi menentukan jantina, tinggi dan berat untuk pesakit atau si mati.

Gender determination based on CT cranium measurements of adults in Hospital USM

ABSTRACT

Purpose: The purpose of this study was to determine gender based on cranial measurements using Computed Tomography of adult. This study has not yet been done in this population. The measurements include the Glabello- Occipital Length (GOL), Basion- Nasion Length (BNL), Basion- Bregma length (BBL), Nasion- Bregma cord i.e. Frontal Chord (FRC), Bregma- Lambda i.e. Parietal Chord (PAC), Lambda- Opisthion i.e. Occipital Chord (OCC), Diploeic space 1 cm in front of the Bregma (DBB) and 1 cm behind lambda (DBL).

Methods: A sample size of 180 adult patients in Hospital Universiti Sains Malaysia who underwent CT head were included in this study. The age taken was between the range of 18 years old and above. Images were reviewed in bone window.

Results:

The mean of glabello-occipital length, basion-nasion length, basion-bregma length, nasion - Bregma cord, Bregma- Lambda, Lambda- Opisthion and Diploeic space 1cm below lambda were statistically different between male and female. There was positive linear relationship for Glabello- Occipital Length, Basion- Bregma Length and Nasion Bregma cord between height and weight. Meanwhile Basion- Nasion Length only has a significant relationship with height.

Conclusion:

For this population, this study as well as other studies support for correlation in between certain cranial morphometry measurements with gender, height and weight. Thus, it might help to assist the future forensic radiology medicine using CT cranium to determine the gender, height and weight of patient or deceased.

INTRODUCTION

CHAPTER 1 : INTRODUCTION

Forensic medicine is a branch of medicine applied in the investigation and establishment of facts or evidence in the court of law. In other words, it deals with the application of medical knowledge to establish facts in civil or criminal legal cases, such as an investigation into the cause and time of a suspicious death. The term forensic medicine is also known as forensic pathology.

Radiology is defined as the branch of medical science dealing with the medical use of X-rays or other penetrating radiation. Nowadays, radiography is used in the collection of forensic evidence and is especially useful for confirming the identity of both living and deceased subjects, identifying pre-existing skeletal trauma, locating hidden foreign bodies, such as fragments of explosives material and packages of illegal substances and assisting in the determination and/ or confirmation of cause of death. Thus, forensic radiologists use X-rays or other imaging technology to gather evidence to be used in civil or criminal trials.

The role of forensic radiologist is now growing. Previously, conventional radiography was used to help to determine the cause of death. However, now as time goes by, the role of cross sectional imaging such as Multidetector Computed Tomography (MDCT) and Magnetic Resonance Imaging (MRI) is now used to establish diagnosis sometimes without dissection or to evaluate areas that are difficult to dissect. Also, in those cases that do not undergo autopsy, cross-sectional imaging findings add anatomic information to the external examination, toxicology, and biochemical findings that may have been previously used alone to determine the cause of death. Thus, forensic radiologist is there to help the forensic pathologist to ascertain the diagnosis and the role of diagnostic medical imaging are proving useful to forensic investigators.

Part of forensic medicine is to determine sex of a given skeleton without any identification. In other way, sex determination is a key analysis that forensic anthropologists need to perform in order to construct a biological profile of human remains. There are various parts of a skeleton that are useful in sex determination such as the pelvis, femur, tibia, humerus, radius, mandible and cranium (O'Donnell *et al.*, 2011). Among these, the skull can be used to ascertain individual sex with high accuracy (Bruzek and Murail, 2006) .

Before imaging was being introduced, many studies have been conducted base on dry skull measurement alone (Giles and Elliot, 1963; Ryan and Bidmos, 2007; Naikmasur *et al.*, 2010; Orish *et al.*, 2014). There are many studies or research done before to evaluate the cranium measurements to correlate with the gender, age and sex. Some studies used diploe thickness and few measurement of the cranium base on x-ray biopsy (Lynnerup *et al.*, 2005), MDCT (A Ahmed *et al.*, 2012) or MRI (Hatipoglu *et al.*, 2008a; Sabancıoğulları *et al.*, 2012; Royle *et al.*, 2013). Some studies even used 3D CT volumetric study (Selma Uysal *et al.*, 2005).

CT scan or computerized tomography scan was first invented by Godfrey Hounsfield in the early 1970's. The images can be viewed individually or in rapid sequence, or reconstructed as a three - dimensional model. Multiplanar reconstruction (MPR) is the simplest method of reconstruction. On other hand, a volume is built by stacking the axial slices Three Dimentional (3D) rendering techniques include surface rendering, volume rendering or image segmentation.

The skull consists of 8 cranial bones and 14 facial bones. Cranial vault and base of skull are the main structure of the skull. The cranial bone consists of an ethmoid bone, an occipital bone, a frontal bone, a sphenoid bone, two parietal bone, and two temporal bones. Besides that, there are sutures that are immovable that acts as interlocking joints that join skull bones together.

The skull provides protection for the brain and the organs of vision, hearing, stability, taste and smell. Besides that, it also provides muscle attachment to move the head and control the facial expressions and chewing.

The purpose of this study was to determine gender based on cranial measurements using Computed Tomography of adult using MPR technique. For this study, few measurements of CT skull have been taken. Thus, cranial morphometry of adult patient in this region could be determined and gender correlation with the craniometry was significant or not. This is important as to assist in forensic medicine.

Rationale of the study

CHAPTER 2 : RATIONALE OF THE STUDY

Previously, there were multiple studies based on direct skull measurements (anthropology), skull radiograph and MRI. There was no study comparing CT cranium morphometry with gender, age and height. No similar study has been conducted in this region or population. Thus, from this study, CT scan could be used as an alternative tool in assisting to determine the cranial morphometry. Furthermore, CT scan is widely available and accessible everywhere. Besides, this study might served as a preliminary step for future study.

From this study, the mean cranial measurement for adults in this region could be determined and compared between gender. Furthermore, it would assist in forensic medicine and general medicine, especially in case of mass disaster, where only skull is available for gender determination.

LITERATURE REVIEW

CHAPTER 3 : **LITERATURE REVIEW**

3.1 Introduction to Computed Tomography scan system in medicine

Computed tomography (CT scan) is a technology that uses computer-processed x-rays into tomographic images of the specific areas of the body that being scanned, thus allowing the practitioner to see internal structure without cutting or dissecting. CT scan was first being introduce by British engineer Godfrey Hounsfield from EMI Laboratories, England and by South Africa-born physicist Allan Cormack of Tufts University, Massachusetts. The first CT was CT brain where they able to detect cystic lesion within the brain. Initially, it is only confined to head imaging, however the whole body system CT become available in 1976. Thus, the first clinical CT scanners were installed between 1974 and 1976. Since then, it was widely used and widely available in 1980. Hounsfield and Cormack were later awarded the Nobel Peace Prize for their contributions to medicine and science.

Initially, CT images were obtained in few days to reconstruct from the raw data. However, as time goes by, with the latest multislice system, it can collect up to 4 slices of data in about 350 ms and reconstruct a 512 x 512-matrix images from millions of data points in less than a second. The CT technology nowadays are fast, with good resolution and less noise. CT images are best to review for the bone structure and anatomy which includes the skull, vertebrae, pelvis and long bones especially in case of trauma. MRI is best to access the soft tissue lesion (Hill *et al.*, 1991). However, as it is time and money consuming, CT is the imaging of choice. Thus, it is the best modality for urgent cases (Laine *et al.*, 1990). CT scanning also provide excellent assessment of body anatomy and localization of body anatomy and localization of foreign materials

(O'Donnell *et al.*, 2011). Besides that, its primary advantage is that it can afford fast, general overview of the deceased that in many cases allow for rapid identification of age, gender, medical device, disease processes, commingling and discrimination of human and animal remains (O'Donnell *et al.*, 2011).

CT compared to other modalities such as MRI and ultrasound utilized high radiation or X-rays. The other disadvantage is that it is large and non portable. However, tremendous research and development have been made to provide the lowest possible x-ray dose besides having excellent image quality. Nowadays, portable CT is being introduced and CereTom® portable CT scanner was approved by both the US FDA and European Commission (Mr Beh Joo Sin, 2009).

In Malaysia, 19 CT scanners were introduced in 1990 and this number has slowly increased to 38 in 1994. In 2005 this number were than increased to 109 (Ng and Abdullah, 1999)126 scanners were reported to be installed in 2009(Abdullah, 2009).

In 2009, Hospital Universiti Sains Malaysia (HUSM) bought Siemens Somatom Definition AS 128- Slice. This scan has the advance of Multidetector CT (MDCT) which provides excellent anatomical details with the improved spatial resolution and capability to generate multiplanar reformation (MPR) image with devoid of artifact.

Picture Archiving and Communication System (PACS) was introduced in 1982 by the American College of Radiology (ACR) and National Electrical Manufacturers Association (NEMA) or known as ACR-NEMA committee (Inamura *et al.*, 2003; De Backer *et al.*, 2004). The PACS uses the Standard Digital Imaging and Communications in Medicine (DICOM)(Bidgood Jr and Horii, 1992).

The PACS acts as a secured network for the transformation of patient information, workstation for interpreting and reviewing images, and archives for the storage and retrieval for the images and report. Thus, medical imaging such as

Computed Tomography (CT scan), Magnetic Resonance Imaging (MRI), Fluoroscopy, Ultrasound, digital radiography (DR), computed radiography (CR), Positron Emitting Tomography (PET) which were in digital format, can be readily manipulated for better viewing quality (Bauman *et al.*, 1996). Using PACS, we can also review images in any area within the local or extended computer network, within the hospital or remotely to other hospitals or to general practitioner.

If previous images were in hard copy which is expensive and time consuming, using PACS reduces cost, promotes space advantage over film archives and provides instant access to prior images at the same institution. It also enables the practitioner in different field and locations to access the same information simultaneously (Weatherburn *et al.*, 2000).

In HUSM, the PACS was introduced in 1990. Using the PACS, it is conducive, costless, easy and fast. Previously Picture Archiving and Communication System Imaging Workflow (PACS IW) was used. Currently, since November 2014, Picture Archiving and Communication System Universal Viewer (PACS UV) is used. For this study, PACS IW was used.

Multiplanar reformation (MPR) software is where the image is reconstruct into three orthogonal axes which is the left-right, anterior- posterior and superior- inferior. Reformation planes follow the planes. The 3 favourite planes include axial, sagittal and coronal. The sagittal plane is parallel to both the anterior-posterior and superior- inferior axes. The coronal plane is parallel to both right-left and superior-inferior axes. The axial is perpendicular to both sagittal and coronal (Hsieh, 2009)

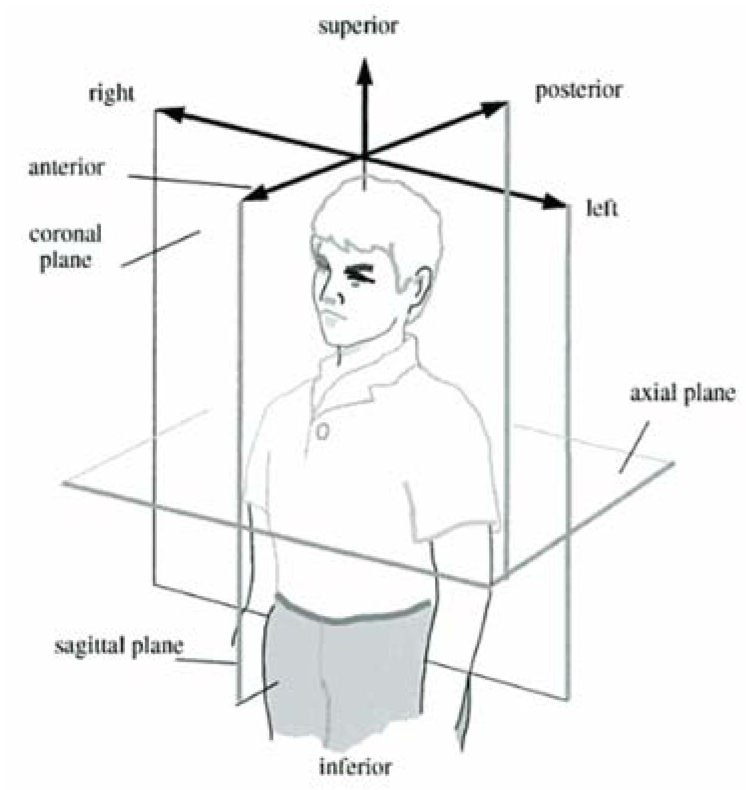

Figure 3.1 : Definition of a patient based coordinate system and different plane orientation.

(Adapted from Hsieh in 2009).

Image reconstruction in CT is a mathematical process that generates images from the X-ray projection data acquired at many different angles around the patient. It is a post processing technique to create new images using a pixel data from a stack of planar images as described above. The use of thin slices increases the spatial resolution in the scan axis direction, allowing high spatial resolution in all planes.

The MPR software uses virtual voxel data to create the pixel values for the reconstructed images. When the dimensions of the scanned voxels (as set by slice thickness and in-plane resolution) are equal, the data set is said to be isotropic. Where the dimensions of the scanned voxel are not equal in all three planes, the data set is said to be anisotropic. Isotropic data yields the best reconstructions.

MPR software typically uses an interactive interface that allows the user to prescribe the reconstruction planes and parameters from simple reconstructed images, in a manner analogous to scanning the real patient. Using MPR, the radiologist or the practitioner can select plane orientation and can prescribe the number, location, and separation of reconstructed slices. MPR software can be applied for CT and MRI images.

3.2 Anatomy of skull.

The cranium is the skeleton of the head. The skull is the receptacle for the most highly developed part of the nervous system, the brain and also for the sensory organ connected to it.

As a whole, the skull consists of 8 cranial bones and 14 facial bones. Cranial vault and base of skull are the main structure of the skull. The cranial bone consists of an ethmoid bone, an occipital bone, a frontal bone, a sphenoid bone, two parietal bones, and two temporal bones.

The facial skeleton or known as splanchnocranium or viscerocranium consists part of the skull. Embrologically, it is derived from brachial arches (Zollikofer and De León, 2002). The facial bones are located at the anterior and lower skull (Laine *et al.*, 1990).

Sutures are immovable fibrous joint (synarthroses) that acts as interlocking joints that join skull bones together. It allows a tiny amount of movement, which contributes to the compliance and elasticity of the skull. Sutures are strong consists of fibrous tissue that hold the bones of the baby's skull together until the bones start to fuse which normally occur around the age of 2. There are multiple skull sutures. However the 4 main sutures are coronal suture, saggital suture, lambdoid suture and squamous suture. Others include occipitomastoid, parietomastoid, sphenofrontal, sphenoparietal, sphenosquamosal, sphenozygomatic, squamosal, zygomaticotemporal, zygomaticofrontal, metopic, frontoethmoidal, petrosquamous, sphenoethmoidal and sphenopetrosal suture. Figure 3.2 showing cranial anatomy with identified sutures.

The coronal suture joins the frontal bone with the two parietal bones. The parietal bones are attached to each other in the median plane of the top of the head, by the sagittal suture, which runs from the coronal suture (bregma point) to the lambdoid suture (lambda point). The lambdoid suture joins the two parietal bones to the occipital bone at the back of the skull as shown in Figure 3.2 (Rozzi *et al.*, 2005).

Besides that, the skull consists of multiple small holes or foraminas which connect the important structure from the brain to the near structure or organs. These include the nerves, blood vessels, lymphatic channels and spinal cord. Below are few pictures that describe better the normal skull anatomy.

Another structure that consists within the skull is the Diploeic space. Diploeic space is a homogenous spongy bone tissue in between the lamina external and interna within the cranium or in between the compact bone. The Diploeic space will become more porous and hollow as the trabecular pattern within the spongy bone and decreased with aging (Skrzat *et al.*, 2004). Figure 3.4 to 3.6 showing coronal and lambda sutures with diploeic space. Figure 3.7 shows Diploeic space in x- ray image in biopsied skull.

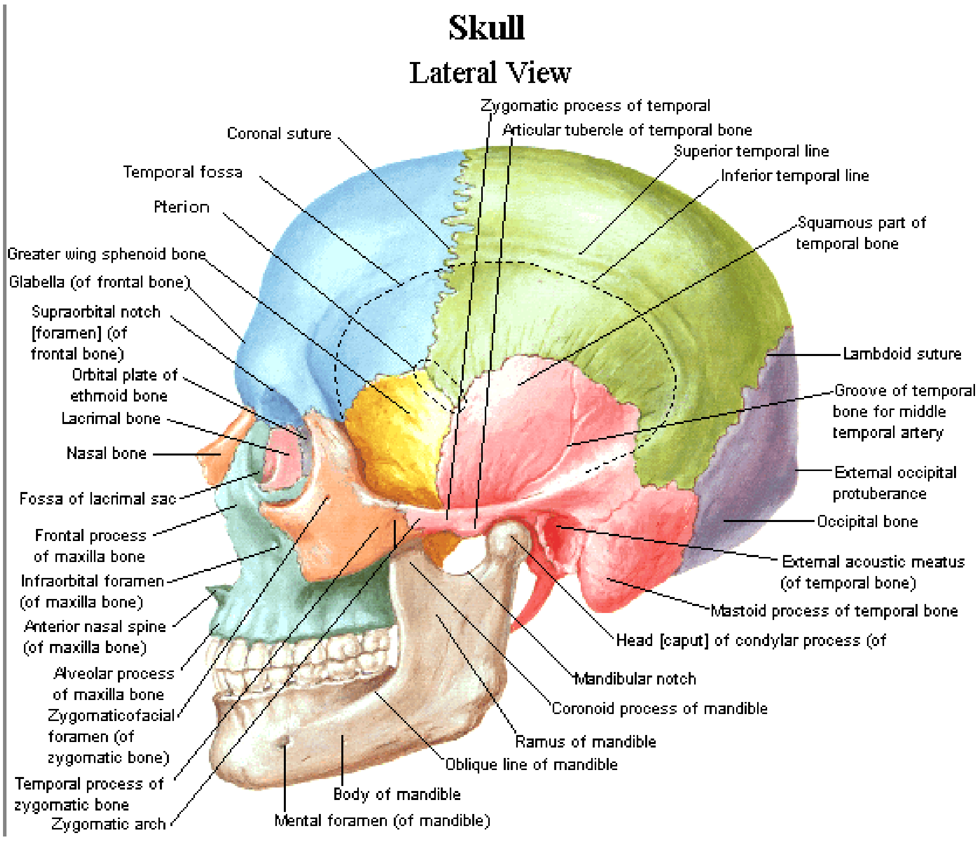

Figure 3.2 : Lateral view of skull
(Source: http://www.aboutcancer.com/brain_anatomy_normal.htm)

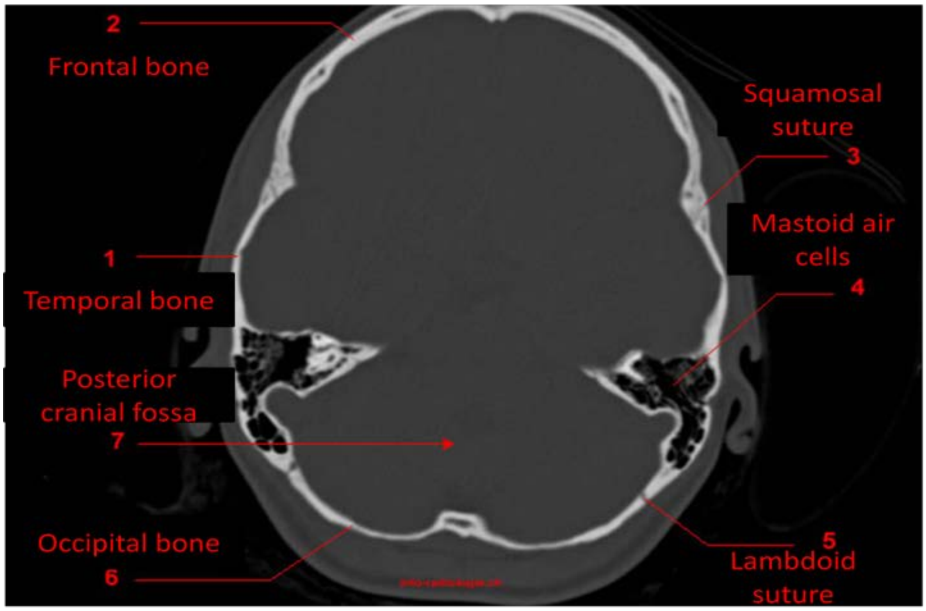

Figure 3.3: Axial CT brain bone window shows anatomical structure which can be identified.

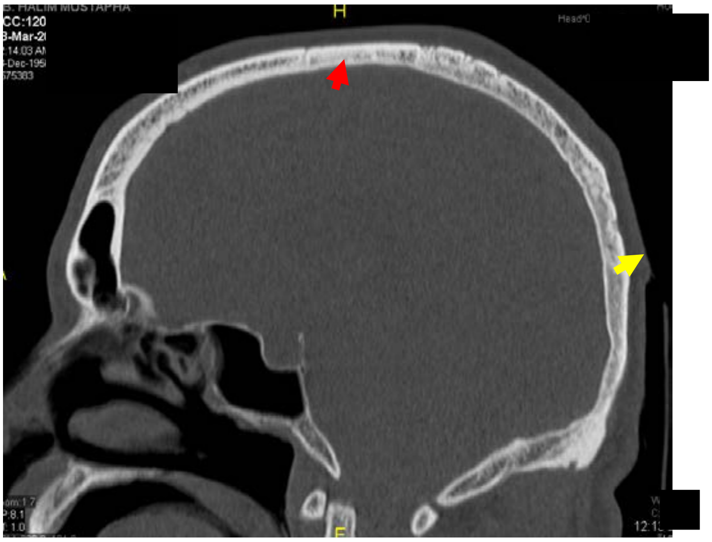

Figure 3.4: Mid sagittal image of CT brain in bone window setting showing coronal suture and lambda suture. Red arrow head line showing coronal suture and yellow arrow head line showing lamdoid suture.

Figure 3.5: Magnified image of mid sagittal CT cranium in bone setting showing coronal suture and star showing diploeic space. Red arrow head line showing coronal suture.

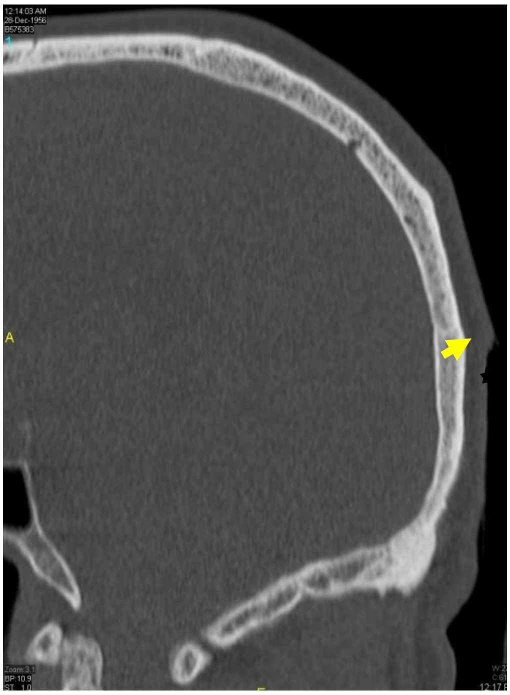

Figure 3.6: Magnified CT cranium bone window setting. Yellow arrow head line showing lamdoid suture and star sign showing lambda suture and star showing diploeic space.

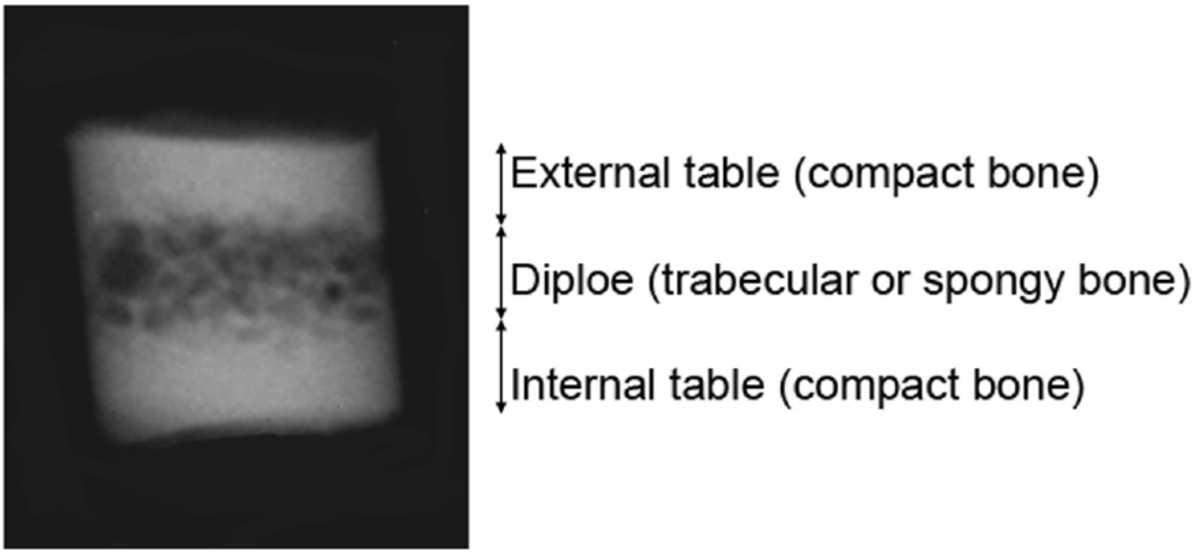

Figure 3.7: X- ray of cranial biopsy shows 3 layers of cranial vault. (Adapted from Lynnerup *et al*, 2005).

3.3 Cranial measurements in literature.

Skull is the second most reliable methods in determining sexual dimorphism after the pelvic bone (Bruzek and Murail, 2006). Different ethnic have different cranial morphometry. Thus, many research have been conducted in different population (Howells, 1996).

Before the advance of imaging modalities such as Xrays, CT scan and MRI, dry skull were measured directly. Some of the studies were conducted to determine the gender, age and origin of the remaining skull.

Study by Sangvichien in 2007, evaluating sexual dimorphism in the cranium and mandible of 100 dried Thai's skull (cadavers) by using Jorgensen's craniometry and develop a statistical model to determine sex from craniometrical measurements and indices. Based on the craniometry they measure, the male skull is larger than female. Using multiple logistic regression model, on 4 measurements, they finally come to conclusion that Jorgensen's craniometry of the cranium and mandible can be used to determine gender among Thai's via a multiple logistic regression model on nasion-basion length (M5), maximum breadth of the cranium (M8), facial length (M40) and bizygomatic breadth of the face (M45) with the overall accuracy of 88.8%.

Dayal in 2008 used traditional anthropometric measurement methods in assessing 100 of South African skull (cadavers) of which 14 cranial and 6 mandibular measurements were analyzed using the discriminant function analysis. The conclusion from the study is that the skull of the South Africans has been shown to be sexually dimorphic using cranial and mandibular measurements. They also manage to derive discriminants function equation from various combinations of the measurements with acceptably high average accuracies.

Giles and Elliot in 1963 studied total of 408 whites and Negros skulls in America with 9 cranial measurements taken shows that an accuracy of 82- 89% to determine the gender. Orish in 2014 also used anthropometry measurements to determine gender in Nigerian population.

Krishan in 2008 studied 996 alive adult male Gujjars of North India which conclude that cephalo-facial measurements are strongly positively correlate with stature. The regression analysis also shows that the cephalic measurements give better prediction of stature. Another study conducted by Ryan and Bidmos in 2007, at South Africans also used certain skull measurements in the estimation of the adult stature. They also conclude that regression formula for stature estimation from the measurements of the skull derived based on total skeletal height.

With the advanced of X rays, CT scan and MRI, similar study has been conducted using the modalities which was being mention. Using X rays, standardize radiographic techniques like cephalometry have advantages of being more precise and objective when compared to morphologic methods (Naikmasur *et al.*, 2010).

Studies base on plain radiograph include by Niels Lynnerup in 2005, Institute of Forensic Medicine, University of Copenhagen, Denmark. 64 individuals (43 males, 21 females) were autopsied at the Institute of Forensic Medicine, University of Copenhagen, Denmark where the thickness was measured by trephine X-raying biopsies at four specific locations on the skull. It revealed that there was a statistically significant difference in diploeic thickness between males and females in the frontal region only. Besides that, it also showed that subsequent analyses failed to reveal any correlations between the diploeic thickness, age, height and weight of the individual (Lynnerup *et al.*, 2005).

Naikmasur in 2010, study is based on 11 caphalometric parameters of cranio mandibular lateral and postero- anterior cephalogram in South Indian and Indian Imigrant of Tibetan populations. The discriminants accuracy in South Indian population was 81.5 and Tibetan population was 88.2%. Thus as conclusion, cephalometric cranio-mandibular parameters can be used to discriminate the sex using discriminant function analysis.

With the progress in radiological imaging technique, CT scan now become more favorable as an alternative to traditional antropological bone collection due to the increasing lack of recent bone collection and ethical issues concerning maceration procedures. Not only that, the role of CT assists in cases of mass disaster to identify the deceased. Age range was able to be determined on CT in 94% with accuracy of 76% (O'Donnell *et al.*, 2011). Several studies have been done base on CT as discussed below.

A. Ahmad in 2012, conduct a study based on CT scan of 110 crania from recent Northern Sudanese involving 69 males and 41 females crania. Seven radiological complete crania measurements were taken and shows a high degree of sexual discrimination. 83.6 % shows success for all variables and 81.8% using best variables. The face and the vault alone showed discrimination in 70 % and 78.2% respectively. The conclusion of the study revealed that males had statistically significantly greater measurements than females.

DNS and D Eng in 2010 used 3D CT to evaluate the craniometric data of 91 Thai cadeveric dry skull. The conclusion from the craniometric study was Thai males were larger than females especially in maximum cranial length, basion bregma height, nasion basion length and bizygomatic breadth parameters.

Volume rendered cranial CT images are also suitable for the collection of recent data concerning the morphologic sex determination of skulls (Ramsthaler *et al.*, 2010). According to Giurazza in 2010, both femur and skull have correlation with stature through CT scan in Caucasian population.

On MRI few studies were mention below.

Hatice Gul Hatipoglu from Forensic science international in 2008 conducted study of a total 107 subject of Caucasian population using 1.5T Magnetic Resonance Imaging to determine age, sex, body mass index in relation to calvarial dipole thickness and craniometric data. From the study they performed, 3 hypothesis were concluded. First, there was significant correlation between gender dimorphism in measuring the glabellar diploe, distance of glabella-opisthocranion, vertex basion, basion-opisthion, eurion-eurion and calvarial volume. Second, there was significant linear corelation between age and the diploe thickness of glabella, bregma, lambda, opistocranion, right and left euryon. The third conclusion was linear corelation observed between Body mass index (BMI) and basion- opistheion length. (Hatipoglu *et al.*, 2008b)

MRI study was conducted in mid Anatolian population in 2010 showed there was a statistically significant positive corelation between age and diploe thickness in all measurements points taken (Sabancıoğulları *et al.*, 2012). Besides that it was also concluded that the diploe thickness increased with age and craniometric result revealed that cranium in males was bigger.

Rozzi in 2005 stated that cranial vault measurements on MRI do not vary with age after 20 years, but were related to sex and body size.

Royle in 2013 mentioned that there was an effect of skull thickening in aging as they could obscure gender diffrence.

OBJECTIVES

CHAPTER 4 : OBJECTIVES

4.1 General objective:

The purpose of this study was to determine the gender based on cranial measurements using Computed Tomography of head in adults.

4.2 Specific objectives:

4.2.1 **To determine cranial morphometry among adult population**

4.2.2 **To correlate the cranial morphometry between age, height and weight.**

4.2.3 **To determine mean difference between cranial morphometry with gender.**

4.3 Research hypothesis:

4.3.1 **No significant mean difference between cranial morphology and gender.**

4.3.2 **No significant correlation in cranial morphometry between age, height and weight.**

MATERIAL AND METHOD

CHAPTER 5 : MATERIAL AND METHOD

5.1 Study design

This was a cross sectional study of CT scan of the head in Hospital Universiti Sains Malaysia age 18 and above. The study was conducted for 10 months starting from January to October 2014.

5.2 Study approval

This study was undertaken as a dissertation study for the Master of Medicine (Radiology) under Hospital Universiti Sains Malaysia and approved by Human Research Ethics Committee, University Sains Malaysia (FWA Reg. No: 00007718; IRB Reg. No: 00004494) on 25th March 2014.

5.3 Sampling method

No specific sampling method was applied in this study. Source of population were all patients who underwent CT scan of the head in the Department of Radiology, HUSM using 128 Multidetector CT scan Siemens Somatom Definition AS.