**Sudan University of science and technology**

**College of Graduate Studies**

# A study of the Relationship between Foramen magnum and Atlas among adult Sudanese using Computed Tomography

دراسة العلاقة بين الفتحة القفوية الكبري و فقرة العنق الأولي لدى البالغين السودانيين باستخدام التصوير بالأشعة المقطعية المحوسبة

A thesis submitted for Partial Fulfillment of the Requirement of M.Sc. Degree in Radiological Diagnostic Imaging

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# Dedication

I would like to dedicate my thesis to my family.
To my sisters and brothers

# Acknowledgement

I thank God for giving me the strength, courage and determination in conducting this study, despite all difficulties.

I would like to thank gratefully Faculty of graduate studies in Sudan University of science and technology, specially my supervisor Dr. Ahmed Mostafa Abukonna.

# Abstract

The foramen magnum as a transition area between skull and spine plays an important role as a landmark, because of its close relationship to vital structures such as the brain and spinal cord. The aim of this study was to study the relation between normal dimensions of foramen magnum and atlas among adult Sudanese for diagnosis of unexplained neck pain and abnormality of the foramen magnum and atlas.

The study was conducted in Omdurman military hospital in the period from (May to December 2019). 100Adults Sudanese were enrolled in the study, length, width and shape of both foramen magnum and atlas were measured using CT Toshiba 64 machine measurements tools. The statistical analysis for sex comparison was made by Student's t-test and was considered significant whenever $P \leq 0.05$. To determine the relationships between the studied parameters, Pearson correlation coefficients were calculated.

The result of the study revealed that mean foramen magnum was 37.189 ± 2.995mm for length and 30.685±2.741 mm for width, the mean atlas foramen was (30.747±3.01 mm length and 28.474±2.849 mm width), and mean magnum/atlas ratio was (84.071±7.901 mm length and 93.223±9.958 mm width), there was no significant difference between male and female in the measurement of foramen magnum as well as magnum/atlas ratio, while male has greater atlas foramen length than female. The differences in measures (length and width) of magnum foramen, atlas foramen and magnum/atlas ratio in adults do not depend on The age and 5% of the sample the length of the foreman of the atlas is bigger than the length of the foreman magnum and18% of the sample the width of the foreman of the atlas is bigger than the width of the foreman magnum.

Study recommend further studies in assessment of the shapes of foreman magnum and atlas in homogeneous nationalism determining which is suitable for the spinal cord when the measurement of foreman magnum is bigger than foreman of atlas and vice versa.

## المستخلص

أجريت هذه الدراسة في قسم التصوير المقطعي بمستشفى أم درمان العسكري في الفترة (سبتمبر إلى ديسمبر 2019)، حيث تم اختيار عينة من (100) من السودانيين البالغين لقياس الثقبة القفوية الكبري والفتحة العنقية الاولي (الطول والعرض والشكل) باستخدام آلة القياسCT Toshiba 64 .

هدف البحث إلى دراسة العلاقة بين الأبعاد الطبيعية للثقبة القفوية الكبري والفتحة العنقية لاولي لدى السودانيين البالغين لتحديد (طول ،عرض والشكل) الثقبة القفوية الكبري وثقب الفتحة العنقية الولي ومقارنة النتيجة للحصول على نسبة العلاقة، ثم استخدام النتائج لتشخيص عدم شرح آلام الرقبة والانحراف فيهما.

تم استخدام طريقة التحليل المقارن، باستخدام البرنامج الإحصائي SPSS اعتماداً على الإحصاءات الوصفية واختبار الفرضيات(مستوى معنوية 0.05)، باستخدام اختبار t واختبار F لدراسة الاختلافات في الطول والعرض (الثقبة القفوية الكبري والثقبة العنقية الاولي) بين البالغين السودانيين حسب النوع والعمر.

توصلت الدراسة إلى أن متوسط الثقبة االقفوية الكبري (37.189 ± 2.995 ملم طول 30.685 ± 2.741 ملم عرض)، متوسط ثقبة العنقية الاولي (30.747 ± 3.01 ملم طول 28.474 ±2.849 ملم عرض)،متوسط نسبة الثقبة القفوية الكبري والثقبة العنقية الاولي (84.071 ± 7.901 ملم طول 93.223 ± 9.958 ملم عرض) وأن متوسط الثقبة وقياس نسبة الثقبة القفوية الكبري(الطول والعرض) لا يختلف بين الذكور والإناث،بينما للذكور طول الفتحة العنقية الاولي أكبر من الإناث، كما أن الاختلاف في المقاييس (الطول والعرض) للثقبة القفوية الكبري والثقبة العنقية الاولي ونسبة الثقبة القفوية الكبري والثقبة العنقية الاولي عند البالغين لاتعتمدعلى العمر و ك\ك توصلت الدراسة ان شكل الثقب القفوية الكبري لا يختلف كثيرا في كل العينات بينما هنالك عدة اشكال مختلفة في الثقبة العنقية الاولي هنالك 5% من جملة العينات طول ثقب الفتحة العنقية الاولي اكبر من طول الثقبة القفوية الاولي و18%من جملة العينات عرض ثقب الفتحية العنقية الاولي اكبر من عرض الثقبة القفوية الكبري .

وعليه يوصي الباحث بدراسة الثقبة العنقية الاولي في عينة متماثلة ومقارنة النتائج مع هده النتائج وكذلك دراسة ايهما انسب للنخاع الشوكي عندما تكون قياسات الثقبة القفوية الكبري اكبر من قياسات الثقبة العنقية الاولي او العكس .

# Table of content

## List of table

# List of figures

# *Chapter one*

# Chapter One
# Introduction

## 1.1 Introduction:

The first cervical vertebra, the atlas, a name derived from the Greek god who bore the world on his shoulders, least resembles a typical vertebra. Anteriorly, there is no body but simply a thick arch of bone called the anterior arch. The anterior arch includes a small anterior tubercle, has a posterior arch that generally bears a small posterior tubercle at the midline. Each of the left and right C1 superior articular processes presents a large depressed surface called a superior facet for articulation with the respective left and right occipital condyles of the skull. These articulations, between C1 and the occipital condyles of the skull, are called occipitoatlantal joints (Fitzpatrick et al., 2018). The transverse processes of C1 are smaller but still contain the transverse foramina distinctive of all cervical vertebrae. The articular pillars, the segments of bone between the superior and inferior articular processes, are called lateral masses for C1. Because the lateral masses of C1 support the weight of the head and assist in rotation of the head, these portions are the most bulky and solid parts of C1(Lipsett and Alsayouri, 2019).

The large opening at the base of the occipital bone through which the spinal cord passes as it leaves the brain is called the foramen magnum (literally meaning “great hole”). The two lateral condylar portions (occipital condyles) are oval processes with convex surfaces, with one on each side of the foramen magnum. These articulate with depressions on the first cervical vertebra, called the atlas. This two-part articulation between the skull and the cervical spine is called the atlantooccipital joint (Graffeo et al., 2019).

Since the FM includes specific neuroanatomical structures and their lesions in that region which require particularly microsurgical intervention, choosing and establishing the most suitable surgical techniques need a careful planning mainly based on the FM size to refrain from any neurological injury. Moreover, intradural and extradural tumors, common congenital abnormalities such as FM syndrome produced by atlanto-occipital assimilation and cerebellar tissue herniation which invaginated into the FM may lead to neural compression and even death are commonly met pathological disorders in this region (Olszewski and Proctor, 2018).

The bone around the foramen magnum constitutes the uppermost border of an extremely complex three-unit joint with intricate functional relationships between the occiput, atlas, and axis (ie, the CCJ or occipitoatlantoaxial complex). Its integrity is of vital importance for the stability of the craniovertebral junction. The difficulties and high rate of morbidity associated with surgical approaches. The transcondylar surgical approach has been used to access lesions in areas close to the (FM) and it is performed directly through the (OC), therefore the anatomical landmarks of the (FM) should be well known in order to make a safe occipital condyle resection. The surgical errors in this region may result in injury to the vascular structures and cranial nerves and result in craniocervical instability. Consequently, neurosurgeons should be more familiar with the anatomy and variations of this region. Therefore, radiological (Osborn et al., 1978) and anatomical morphometric studies were performed to contribute to the knowledge of this area (Ishii et al., 2019).

## 1-2 Problem of study:

Configuration and size of the foramen magnum play an important role in the pathophysiology of various disorders of the craniovertebral junction. Thus, a fundamental knowledge of normal anatomy and basic craniometric measurements for assessing craniovertebral relations is important to the clinician who diagnoses disorders affecting this region or the surgeon who operates on this anatomy. Not many studies have been done pertaining to morphometry and sexual dimorphism in foramen magnum in Sudanese population. Hence, this study of discriminant function analysis of foramen magnum variables involving cranial CT scans becomes essential.

## 1-3 Objective of study:

### 1-3-1 General Objective:

The general objective of this research was to study the relationship between normal dimensions of foramen magnum and atlas foramen in the adult Sudanese.

### 1-3-2 Specific Objective:

-To determine the width of foramen magnum and atlas foramen.

-To determine the length of foramen magnum and atlas foramen.

-To compare the result to obtain the relation ratio.

## 1-5 Thesis over view:

Chapter one is introduction will discuss prelude, problem ,objective of study, Chapter tow is literature review will discuss back ground (anatomy physiology pathology and previous study), Chapter three is material and methods will discuss the study sample, methods, variables, data collection and data analysis, Chapter four is result will discuss study results, Chapter five is discussion, conclusion ,recommendation and references.

# ***Chapter Tow***

# Chapter Tow
# Literature Review

## 2-1 Anatomy of the foramen magnum and atlas foramen:

The vertebral column is composed of small segments of bone called vertebrae. Disks of fibrocartilage are interposed between the vertebrae and act as cushions. The vertebral column is held together by ligaments, and it is jointed and curved so that it has considerable flexibility and resilience. In early life, the vertebral column usually consists of 33 small, irregularly shaped bones. These bones are divided into five groups and are named according to the region they occupy (Fig. 2-1). The seven superiormost vertebrae occupy the region of the neck and are termed cervical vertebrae.cervical curve is termed lordosis (Lomax et al., 2019).

### 2-1-1 First cervical vertebra (atlas):

The first cervical vertebra is named the atlas because it supports the globe of the head. Its chief peculiarity is that it has no body, and this is due to the fact that the body of the atlas has fused with that of the next vertebra. Its other peculiarities are that it has no spinous process, is ring -like, and consists of an anterior and a posterior arch and two lateral masses. The anterior arch forms about one-fifth of the ring: its anterior surface is convex, and presents at its center the anterior tubercle for the attachment of the Longus colli muscles; posteriorly it is concave, and marked by a smooth, oval or circular facet (fovea dentis), for articulation with the odontoid process (dens) of the axis. The upper and lower borders respectively give attachment to the anterior atlantooccipital membrane and the anterior atlantoaxial ligament; the former connects it with the occipital bone above, and the latter with the axis below (Piaggio et al., 2018).

The posterior arch forms about two-fifths of the circumference of the ring: it ends behind in the posterior tubercle, which is the rudiment of a spinous process and gives origin to the Recti capitis posteriores minores. The diminutive size of this process prevents any interference with the movements between the atlas and the skull. The posterior part of the arch presents above and behind a rounded edge for the attachment of the posterior atlanto-occipital membrane, while immediately behind each superior articular process is a groove (sulcus arteriæ vertebralis), sometimes converted into a foramen by a delicate bony spiculum which arches backward from the posterior end of the superior articular process (Vasquez et al., 2019).

This groove represents the superior vertebral notch, and serves for the transmission of the vertebral artery, which, after ascending through the foramen in the transverse process, winds around the lateral mass in a direction backward and medial ward; it also transmits the suboccipital (first spinal) nerve. On the under surface of the posterior arch, behind the articular facets, are two shallow grooves, the inferior vertebral notches. The lower border gives attachment to the posterior atlantoaxial ligament, which connects it with the axis. The lateral masses are the most bulky and solid parts of the atlas, in order to support the weight of the head. Each carries two articular facets, a superior and an inferior. The superior facets are of large size, oval, concave, and approach each other in front, but diverge behind: they are directed upward, medial ward, and a little backward, each forming a cup for the corresponding condyle of the occipital bone, and are admirably adapted to the nodding movements of the head. Not infrequently they are partially subdivided by indentations which encroach upon their margins (Novegno et al., 2019).

The inferior articular facets are circular in form, flattened or slightly convex and directed downward and medialward, articulating with the axis, and permitting the rotatory movements of the head. Just below the medial margin of each superior facet is a small tubercle, for the attachment of the transverse atlantal ligament which stretches across the ring of the atlas and divides the vertebral foramen into two unequal parts—the anterior or smaller receiving the odontoid process of the axis, the posterior transmitting the medulla spinalis and its membranes. This part of the vertebral canal is of considerable size, much greater than is required for the accommodation of the medulla spinalis, and hence lateral displacement of the atlas may occur without compression of this structure. The transverse processes are large; they project lateralward and downward from the lateral masses, and serve for the attachment of muscles which assist in rotating the head. They are long, and their anterior and posterior tubercles are fused into one mass; the foramen transversarium is directed from below, upward and backward (Bilgin et al., 2019).

### 2-1-2 Foramen Magnum:

In anatomy, the foramen magnum (Latin: “great hole”) is a large opening in the occipital bone of the cranium. The foramen magnum is a large oval aperture with its long diameter antero-posterior; it is wider behind than in front where it is encroached upon by the condyles. It transmits the medulla oblongata and its membranes, the accessory nerves, the vertebral arteries, the anterior and posterior spinal arteries, and the membrana tectoria and alar ligaments (Williams et al., 2019).

In humans, the foramen magnum is farther underneath the head than in great apes. Thus in humans, the neck muscles do not need to be as robust in order to hold the head upright. Comparisons of the position of the foramen magnum in early hominid species are useful to determine how comfortable particular species was when walking on two limbs (bipedality) rather than four. The location of the foramen magnum plays a crucial role in our understanding of human evolution. Usually, the location of the foramen magnum is linked to bipedal behavior. Due to the thickness of the cranial base and its relatively protected anatomical position, this area of skull tends to withstand both physical insults and inhumation somewhat more successfully than many other areas of the cranium (Chae et al., 2019).

The foramen magnum (FM) is an important landmark of the base of skull and is of particular interest to many fields of medicine. (Gruber P etal., 2009). Variations of the shape of FM have got diagnostic, clinical and radiological importance. Also there exists some correlation between the shape of FM and ancestry of an individual. The dimensions of FM have clinical importance because the vital structures that pass through it may suffer compression as in cases of FM achondroplasia (Lieber et al., 2019).

Foramen magnum is about 3cm wide by 3.5 cm anteroposteriorly. It is located midway between and on a level with mastoid processes. The foramen magnum is surrounded by different parts of the occipital bone, squamous part lies behind and above, basilar part in front and a condylar part on either side. On each side its antero-lateral margin is encroached by occipital condyles, hence the foramen magnum is narrow anteriorly. The anterior edge of the foramen magnum is slightly thickened and lies between the anterior ends of the condyles (Aranciaga Rolando et al., 2019).

The posterior half of the foramen magnum is thin and semicircular. Upper ends of anterior and posterior atlanto-occipital membranes are attached to the anterior and posterior margins of the foramen magnum respectively, and their lower ends are attached to the superior surface of anterior and posterior arches of the atlas respectively. (Romanes GJ et al 1981) The foramen magnum is a wide communication between posterior cranial fossa and the vertebral canal. The narrow anterior part of the foramen magnum has apical ligament of dens, upper fasciculus of the cruciate ligament and membrana tectoria; both are attached to the upper surface of basioccipital bone infront of the foramen magnum. Its wide posterior part contains the medulla oblongata and itsmeninges. In subarachnoid space spinal rami of the accessory nerve and vertebral arteries, with their sympathetic plexus, ascend into the cranium; the posterior spinal arteries descend posterolateral to the brain stem, whereas anterior spinal artery descends anteromedian to brain stem. The cerebellar tonsils may project into the foramen magnum (Kournoutas et al., 2019).

Relations of foramen magnum, anteriorly - basilar part of occipital bone, Anterolaterally - occipital condyles, hypoglossal canal, jugular foramen Posteriorly - squamous part of occipital bone with the internal occipital crest (Drake, 2010).

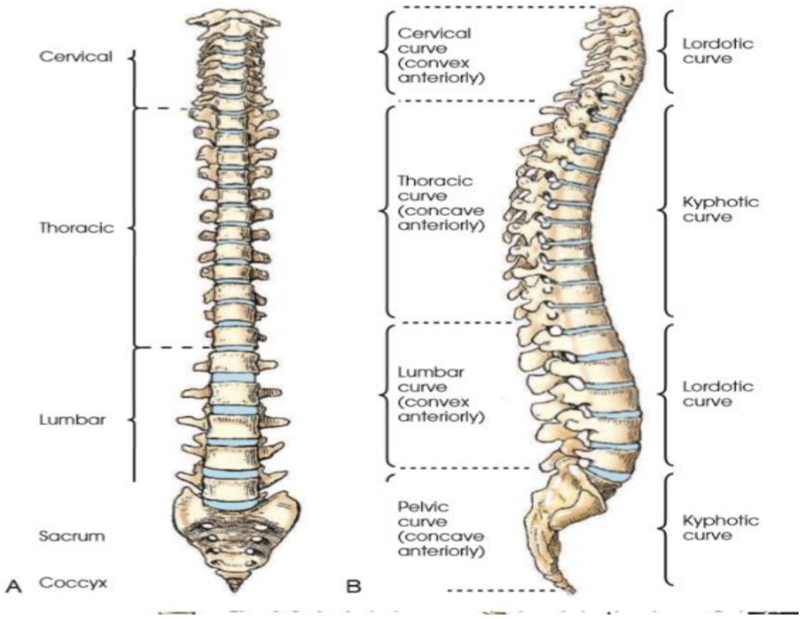


**Figure (2-1):** A, Anterior aspect of vertebral column. B, Lateral aspect of vertebral column, showing regions and curvatures.

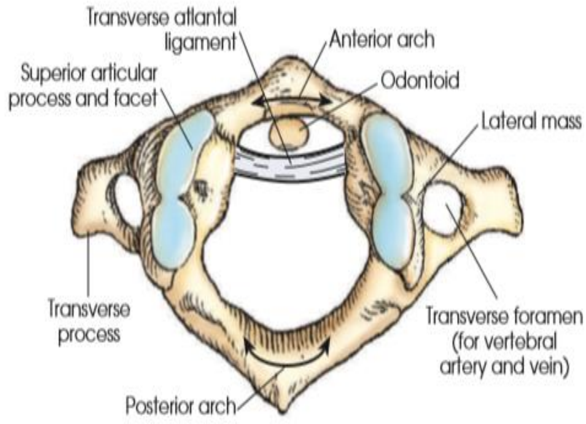


Figure (2-2): Superior aspect of atlas (C1).

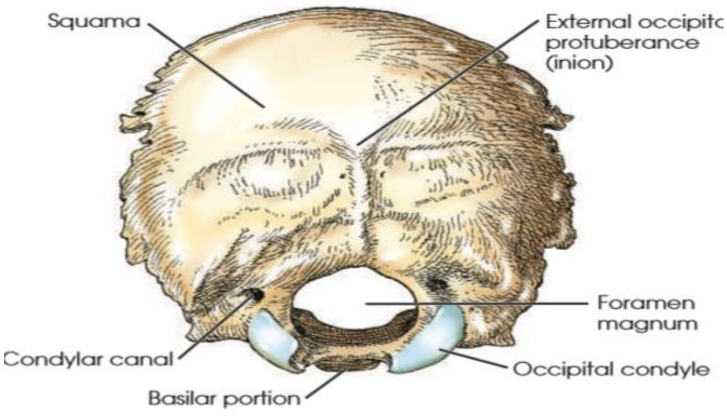


Figure (2-3): External surface of occipital bone show foramen magnum.

**2-1- 2Physiology:**

The vertebral column, or spine, forms the central axis of the skeleton and is centered in the mid sagittal plane of the posterior part of the trunk. The vertebral column has many functions: It encloses and protects the spinal cord, acts as a support for the trunk, supports the skull superiorly, and provides for attachment for the deep muscles of the back and the ribs laterally. The upper limbs are supported indirectly via the ribs, which articulate with the sternum. The sternum articulates with the shoulder girdle. The vertebral column articulates with each hipbone at the sacroiliac joints.

This articulation supports the vertebral column and transmits the weight of the trunk through the hip joints and to the lower limbs (Shen et al., 2019).

### 2.3 The vital structures pass through the foramen magnum:

#### 2.3.1 The medulla oblongata (or simply medulla)

Is the most caudal part of the brainstem and sits between the pons inferiorly and spinal cord superiorly. It is the transition from the spinal cord to the brain. The medulla contains the vital autonomic cardiovascular and respiratory centers controlling heart rate, blood pressure, and breathing. It is composed of grey matter, cranial nerve (CN) nuclei IX-to-XII, and white matter tracts. The medulla is approximately 3cm in length and 2cm in greatest (Shen et al., 2019).

The caudal border of the medulla is the 1st cervical spinal nerves. The superior broad part of the medulla joins the pons. Medulla is separated into two main parts: ventral (anterior) medulla which contains the olive, pyramidal tracts, and CN 9-12 rootlets, and tegmentum (dorsal) medulla which contain the CN nuclei and white matter tracts. Ventral medulla: Pyramids are paired structures located at the medial aspect of ventral medulla and flank the anterior median fissure. It contains the corticospinal tracts. At the caudal end of pyramids the corticospinal tracts decussate. Olivary bodies are paired structures located at lateral aspect of ventral medulla, lateral to the pyramids. They are separated from the pyramids by an anterolateral sulcus (pre-olivary sulcus). There is also a post-olivary sulcus lateral to the olivary bodies. Olivary bodies contain the superior and larger inferior olivary nuclei. Medulla tegmentum: The dorsal aspect of the medulla contains the posterior median sulcus (most dorsal medial sulcus) and more lateral posterolateral sulcus. Between these sulci are the fasciculus gracilis and nuclei forming gracilis tubercle at the midline and fasciculus cuneatus and nuclei forming cuneate tubercle more laterally (Vinutha et al., 2018).

The superior dorsal aspect of medulla forms the floor of the inferior 4th ventricle. It is occupied by the inferior cerebellar peduncle situated between the lower parts of the fourth ventricle. The inferior dorsal and lateral aspect of the medulla is surrounded by the cisterna magna (posterior cerebellomedullary cistern), and lateral cerebellomedullary cistern (Vinutha et al., 2018).

The median aperture (foramen of Magendie) and the more superior lateral apertures (foramina of Luschka) open at the level of the pons, with the canals projecting to the level of the medulla region and terminating into the cisterna magna and lateral cerebellomedullary cistern respectively( Rogers L, 2008) .

### 2.3.2 The meninges

Is a collective term for the three membranes that cover the brain and spinal cord, cerebral meninges surround the brain and is made up of three layers (from outermost to innermost): dura mater, arachnoid mater and pia mater. The dura mater can also be known as pachymeninx. The arachnoid mater and pia mater are collectively known as the leptomeninges. The spinal meninges are similar but have some important differences. The meninges function to protect the brain but also provides a framework for blood vessels, nerves, lymphatics and CSF (Aranciaga Rolando et al., 2019).

### 2.3.3 The spinal accessory nerve

Also called accessory nerve, is the eleventh cranial nerve (CN XI) and is composed of two parts, the cranial part and the spinal part. The cranial part (accessory portion) is the smaller of the two. Its fibers arise from the cells of the nucleus ambiguus and emerge as four or five delicate rootlets from the side of the medulla oblongata, below the roots of the vagus. It runs laterally to the jugular foramen, where it interchanges fibers with the spinal portion or becomes united to it for a short distance. (Wilson et al 2002). The spinal part (spinal portion) is firm in texture, and its fibers arise from the ventral horn cells in the cord between C1 and C5 of the cervical plexus. The fibers emerge from the cord laterally between the anterior and posterior spinal nerve roots to form a single trunk, which ascends into the skull through the foramen magnum (Lopez-Capp et al., 2018).

### 2.3.4 The vertebral arteries (VA)

The vertebral artery (VA) arises from the subclavian artery, ascends in the neck to supply the posterior fossa and occipital lobes as well as provides segmental vertebral and spinal column blood supply. (Cloud GC, et al 2003). The origin of the VA is usually from the posterior superior part of the subclavian arteries bilaterally, although the origin can be variable; Brachiocephalic artery (on the right) and Aortic arch: 6% of cases.

The VA is normally 3-5 mm in diameter and the ostium is the most common site of stenosis. When the origin is from the arch, then it is common for the artery to enter the foramen transversarium at a level higher than normal (C5 instead of C6). The duramater around the FM is supplied by the anterior and posterior meningeal branches of the vertebral artery, and the meningeal branches of the ascending pharyngeal and occipital arteries (Sayyahmelli and Baskaya, 2019).

### 2.3.5 The venous structures

The venous structures in the region of the FM are divided into three groups; Extraduralveins (extraspinal& intraspinalpart), Intradural (neural) veins and Dural venous sinuses (superior petrosal, marginal & occipital). The three groups anastomose through bridging and emissary veins (Lipsett and Alsayouri, 2019).

## 2-2 previous study:

Gokharman D., et al., (2005), Estimation of Sex by 3D CT Measurements of the Foramen Magnum: the purpose of this prospective study is to investigate the value and accuracy of the measurements of the foramen magnum (FM) by using three-dimensional computed tomography (3DCT). Cases were randomly selected among 100 patients (48 males, 52 females) who had temporal CT in the Radiology Department. Seven measurements of the foramen magnum on 3D images, modified from the nine lines previously defined by Giles and Elliot were made. Using Fisher's linear discriminant functions test, the length and width of right condyle and width of FM diameters were found to be statistically different in each sex ($p < 0.001$) with 81% accuracy. To our best knowledge, this is the first report studying 3DCT measurements of FM, resulting with a sex determination accuracy rate of 81%. CT/3DCT can be reliably used in further investigations to provide basis for anthropometric and forensic issues.

Singh G. and Talwar I. (2013), Morphometric analysis of foramen magnum in human skull for sex determination:this study aim to Morphometric analysis of foramen magnum in human skull for sex determination, the morphometric measurements taken on foramen magnum in a documented Indian collection were analyzed for sex differences using standard osteometric techniques. Fifty adult skulls of known sex were included in the study. Morphometric analysis of foramen magnum was conducted using digital vernier calipers. Six standard parameters were measured and analyzed by discriminant function analysis using SPSS 16. Males displayed larger mean values than females for all measured variables but only one of the variables (maximum bicondylar breadth) exhibited statistically significant differences between the sexes. The results demonstrated a low level of sexual dimorphism in the cranial base of this sample. Based on sectioning point derived by the discriminant function, a value higher than the sectioning point was deemed to be male and value below it deemed to be female. The accuracy of sex prediction based on discriminant function analysis ranged from 66% to 70%.

Omer, I.M (2016), Measurement of Foramen Magnum in Adult Sudanese using Computed Tomography Khartoum:this study aims to measure the foramen magnum and characterize the shape of it through the use of reconstructed helical CT images. For verify the morphological characteristics of the (FM) for gender determination in Sudanese individuals by measuring the saggital, transverse diameter and characterizing its shape. A total of 100 Sudanese patients (52 males and 48 females) with mean ages were 49.69±15.53 were examined using reformatted axial CT and three dimensional CT referred to the Radiology Department in the Dar Al Elaj Specialized Hospital, Khartoum, Sudan The foramen magnum shapes were determined as a round shape in 17(17%) of the cases, oval in 53 (53%), irregular in 15(15%) and arrow head in 15(15%), the mean sagittal and transverse diameters of the foramen magnum were determined as 35.37±2.49 mm and28.57±2.48 mm respectively.

(Makaju) for example, worked on 300 samples of CT scan image of head. He studied the antero posterior diameter, transverse diameter, area, shape of foramen magnum and also the presence of the accessory hypoglossal canal in the posterior margin of foramen magnum based on the ethnicity of Nepal. It was concluded that CT scan image of head can provide valuable measurements of the foramen magnum and could be used for sexual dimorphism and neurosurgery when other methods are inconclusive. Singh et al also analyzed the foramen magnum of human skulls. Fifty adult skulls of known sex were included in the study. Six standard parameters were measured and analyzed by discriminant function analysis. The accuracy of sex prediction based on discriminant function analysis ranged from 66% to 70% and was found a useful parameter for sex determination (Makaju etal., 2013).

Uthman et al studied 88 samples for his study (Uthman et al., 2012). Foramen magnum sagittal diameter, transverse diameter, area and circumference were measured. Foramen magnum circumference and area were the best discriminant parameters with an overall accuracy of 67% and 69.3%, respectively. Raghavendra babu et al studied sexual dimorphism of the antero-posterior diameter, transverse diameter and area of foramen magnum in a population of coastal Karnataka region using statistical considerations (Raghavendra Babu, et al, 2012). The predictability of foramen magnum measurements in sexing of crania was 65.4% for the antero- posterior diameter.

# ***Chapter Three***

# Chapter Three

# Material and method

## 3-1 Material

### 3-1-1 Study sample:

100Adults Sudanese male and female were enrolled in the study with their age ranged (25-45years) with normal neck and no neck pain. Children and subjects with disease affect the shape and dimension of foramen magnum and atlas were excluded.

### 3-1-2 Machine used:

CT Toshiba machine with 64slice was used.

## 3-2 Methods:

### 3-2-1 Place of study:

The study was conducted in Omdurman Military hospital CT department.

### 3-2-2 Period of study:

The study was conducted in the period from May 2019 to December 2019.

### 3-2-3 Method of Data collection:

The data were collected from patients refer to cervical and neck CT then the measurements of foramen magnum and atlas were taken (length, width and shape of both). Then data were analyzed using SPSS statistical program, descriptive statistics and frequency distribution were performed.

The statistical analysis for sex comparison was made by Student's t-test and was considered significant whenever $P \le 0.05$. To determine the relationships between the studied parameters, Pearson correlation coefficients were calculated.

### 3-2-4 Method and Analysis

The data analyzed by using SPSS

# ***<u>Chapter Four</u>***

# Chapter Four

# Results

## 4.1 Results:

**Table (4.1): Participants gender distribution**

| Gender | Frequency | Percent |
|---|---|---|
| Male | 72 | 72.0 |
| Female | 28 | 28.0 |
| **Total** | **100** | **100.0** |

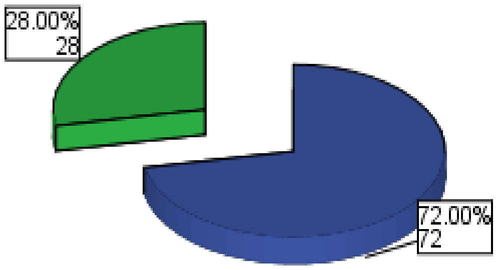


Figure (4.1): Participants distribution with respect to gender

**Table (4.2): Participants distribution with respect to age:**

| Age | Frequency | Percent |
|---|---|---|
| Less than 30 years | 37 | 37.0 |
| 30-35 years | 30 | 30.0 |
| 36-40 years | 17 | 17.0 |
| More than 40 years | 16 | 16.0 |
| **Total** | **100** | **100.0** |

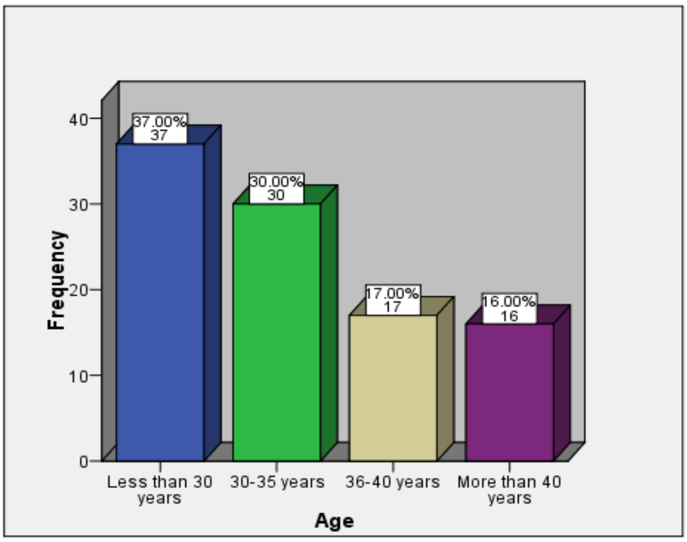


**Figure (4.2): Participants distribution with respect to age**

**Table (4.3): Descriptive statistics for foramen magnum dimensions:**

| N=100 | Minimum | Maximum | Mean | Std. Deviation |
|---|---|---|---|---|
| Magnum foramen length | 28.8 | 46.8 | 37.189 | 2.9945 |
| Magnum foramen width | 25.3 | 38.3 | 30.685 | 2.7409 |

**Table (4.4): Descriptive statistics for atlas foramen dimensions:**

| N=100 | Minimum | Maximum | Mean | Std. Deviation |
|---|---|---|---|---|
| Atlas foramen length | 24.1 | 38.9 | 30.747 | 3.0096 |
| Atlas foramen width | 23.0 | 39.5 | 28.474 | 2.8489 |

**Table (4.5): Descriptive statistics for magnum/atlas ratio:**

| N=100 | Minimum | Maximum | Mean | Std. Deviation |
|---|---|---|---|---|
| Length magnum/atlas ratio | 67.0 | 112.1 | 84.071 | 7.9008 |
| Width magnum/atlas ratio | 68.1 | 127.8 | 93.223 | 9.9578 |

**Table (4.6) Mean magnum foramen measures (length and width) with respect to gender:**

| | Gender | N | Mean | Std. Deviation |
|---|---|---|---|---|
| Magnum foramen length | Male | 72 | 37.600 | 3.0134 |
| | Female | 28 | 36.132 | 2.7189 |
| Magnum foramen width | Male | 72 | 30.840 | 2.6722 |
| | Female | 28 | 30.286 | 2.9223 |

**Table (4.7) t-test for equality of mean magnum foramen measures (length and width) for males and females:**

| | t-test for Equality of Means | | | | |
|---|---|---|---|---|---|
| | t | Df | Sig. (2-tailed) | Mean Difference | Std. Error Difference |
| Magnum foramen length | 2.245 | 98 | 0.027 | 1.4679 | 0.6537 |
| Magnum foramen width | 0.908 | 98 | 0.366 | 0.5546 | 0.6110 |

**Table (4.8) Mean atlas foramen measures (length and width) with respect to gender:**

| | Gender | N | Mean | Std. Deviation |
|---|---|---|---|---|
| Atlas foramen length | Male | 72 | 31.293 | 3.1459 |
| | Female | 28 | 29.343 | 2.0848 |
| Atlas foramen width | Male | 72 | 28.804 | 3.0010 |
| | Female | 28 | 27.625 | 2.2449 |

**Table (4.9) t-test for equality of mean atlas foramen measures (length and width) for males and females:**

| | t-test for Equality of Means | | | | |
|---|---|---|---|---|---|
| | t | df | Sig. (2-tailed) | Mean Difference | Std. Error Difference |
| Atlas foramen length | 3.605 | 74 | 0.001 | 1.9502 | 0.5410 |
| Atlas foramen width | 1.882 | 98 | 0.063 | 1.1792 | 0.6265 |

**Table (4.10) Mean magnum/atlas ratio measures (length and width) with respect to gender:**

| | Gender | N | Mean | Std. Deviation |
|---|---|---|---|---|
| Length magnum/atlas ratio | Male | 72 | 84.725 | 8.5111 |
| | Female | 28 | 82.389 | 5.8587 |
| Width magnum/atlas ratio | Male | 72 | 93.815 | 10.5681 |
| | Female | 28 | 91.700 | 8.1577 |

**Table (4.11) t-test for equality of mean magnum/atlas ratio measures (length and width) for males and females:**

| | t-test for Equality of Means | | | | |
|---|---|---|---|---|---|
| | t | Df | Sig. (2-tailed) | Mean Difference | Std. Error Difference |
| Length magnum/atlas ratio | 1.333 | 98 | 0.186 | 2.3357 | 1.7528 |
| Width magnum/atlas ratio | 0.953 | 98 | 0.343 | 2.1153 | 2.2188 |

**Table (4.12) Mean magnum foramen measures (length and width) with respect to age:**

| | | N | Mean | Std. Deviation |
|---|---|---|---|---|
| Magnum foramen length | < 30 years | 37 | 37.565 | 3.2580 |
| | 30-35 years | 30 | 36.803 | 2.1144 |
| | 36-40 years | 17 | 37.753 | 4.0187 |
| | > 40 years | 16 | 36.444 | 2.4980 |
| | Total | 100 | 37.189 | 2.9945 |
| Magnum foramen width | < 30 years | 37 | 30.178 | 2.8536 |
| | 30-35 years | 30 | 30.593 | 2.3415 |
| | 36-40 years | 17 | 31.276 | 2.8239 |
| | > 40 years | 16 | 31.400 | 3.0568 |
| | Total | 100 | 30.685 | 2.7409 |

**Table 4.13: ANOVA table for difference between age groups in magnum foramen measures (length and width):**

| | | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| Magnum foramen length | Between Groups | 23.982 | 3 | 7.994 | 0.888 | 0.450 |
| | Within Groups | 863.776 | 96 | 8.998 | | |
| | Total | 887.758 | 99 | | | |
| Magnum foramen width | Between Groups | 23.876 | 3 | 7.959 | 1.061 | 0.369 |
| | Within Groups | 719.892 | 96 | 7.499 | | |
| | Total | 743.768 | 99 | | | |

**Table (4.14) Mean atlas foramen measures (length and width) with respect to age:**

| | | N | Mean | Std. Deviation |
|---|---|---|---|---|
| Atlas foramen length | < 30 years | 37 | 30.535 | 3.4939 |
| | 30-35 years | 30 | 30.527 | 2.5423 |
| | 36-40 years | 17 | 31.635 | 2.8076 |
| | > 40 years | 16 | 30.706 | 2.9110 |
| | Total | 100 | 30.747 | 3.0096 |
| Atlas foramen width | < 30 years | 37 | 27.678 | 2.7883 |
| | 30-35 years | 30 | 28.917 | 3.1976 |
| | 36-40 years | 17 | 28.994 | 2.6209 |
| | > 40 years | 16 | 28.931 | 2.3087 |
| | Total | 100 | 28.474 | 2.8489 |

**Table 4.15: ANOVA table for difference between age groups in atlas foramen measures (length and width):**

| | | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| Atlas foramen length | Between Groups | 16.558 | 3 | 5.519 | 0.602 | 0.615 |
| | Within Groups | 880.131 | 96 | 9.168 | | |
| | Total | 896.689 | 99 | | | |
| Atlas foramen width | Between Groups | 37.244 | 3 | 12.415 | 1.555 | 0.205 |
| | Within Groups | 766.268 | 96 | 7.982 | | |
| | Total | 803.512 | 99 | | | |

**Table (4.16) Mean magnum/atlas ratio measures (length and width) with respect to age:**

| | | N | Mean | Std. Deviation |
|---|---|---|---|---|
| Length magnum/atlas ratio | < 30 years | 37 | 83.411 | 10.0148 |
| | 30-35 years | 30 | 83.943 | 6.5907 |
| | 36-40 years | 17 | 84.571 | 5.9857 |
| | > 40 years | 16 | 85.306 | 6.7874 |
| | Total | 100 | 84.071 | 7.9008 |
| Width magnum/atlas ratio | < 30 years | 37 | 92.208 | 10.6237 |
| | 30-35 years | 30 | 95.680 | 9.2388 |
| | 36-40 years | 17 | 92.559 | 9.6060 |
| | > 40 years | 16 | 91.669 | 10.1207 |
| | Total | 100 | 93.223 | 9.9578 |

**Table 4.17: ANOVA table for difference between age groups in magnum/atlas ratio measures (length and width):**

| | | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| Length magnum/atlas ratio | Between Groups | 45.272 | 3 | 15.091 | 0.236 | 0.871 |
| | Within Groups | 6134.614 | 96 | 63.902 | | |
| | Total | 6179.886 | 99 | | | |
| Width magnum/atlas ratio | Between Groups | 265.366 | 3 | 88.455 | 0.889 | 0.450 |
| | Within Groups | 9551.211 | 96 | 99.492 | | |
| | Total | 9816.577 | 99 | | | |

# ***Chapter five***

# Chapter five

# Discussion, conclusion and recommendations

## 5.1 Discussion:

Foreman magnum shape; there are no significant differences between shapes of foreman magnum in the samples (see figure 4.1).Foreman of atlas shape: there are many different shapes in the samples (see figure 4.2).There are no relationship between the shapes of foreman magnum and foreman of atlas (see figures 4.1and 4.2).

Table (4.3) shows that a total of (100) adult Sudanese were selected mostly males (table 4.1) and 35 years old or less (4.2), whom present magnum foramen evaluated in (28.8-46.8 mm with 37.189±2.995 mm mean length), and (25.3-38.3 mm with 30.685±2.741 mm mean width), and atlas foramen evaluated in (24.1-38.9 mm with 30.747±3.01 mm mean length), and (23-39.5 mm with 28.474±2.849 mm mean width) (table 4.4), as well as magnum/atlas ratio evaluated in (67-112.1 mm with 84.071±7.901 mm mean length), and (68.1-127.8 mm with 93.223±9.958 mm mean width) (table 4.5).like to (Omer, I. M., 2016), the mean sagittal and transverse diameters of the foramen magnum were determined as 35.37±2.49 mm and28.57±2.48 mm respectively.

Table (4.7) t-test results tell if the mean magnum foramen measures (length and width)for the two groups were statistically different (significantly different) or they were relatively the same. Moreover, study found that the male and female magnum foramen measures (length and width) are statistically, insignificantly different because the values of P-values in "Sig. (2-tailed) are more than 0.05. Looking at the Distributions of two groups table (4.6), we can conclude that there were statistically insignificant differences in magnum foramen (length and width) mean between males and females, therefor females as same as males in (length and width) of magnum foramen. Male and female atlas foramen mean measure of (length) is statistically, significantly different because the value of P-values in “Sig. (2-tailed) =0.001”is than 0.05. Looking at the Distributions of two groups table (4.8), we can conclude that there were statistically significant differences in atlas foramen mean length between males and females; therefor male has greater atlas foramen length than female (4.9). While male and female magnum/atlas ratio measures (length and width) are statistically, insignificantly different because the values of P-values in "Sig. (2-tailed)”are more than 0.05. Looking at the Distributions of two groups table (4.10), we can conclude that there were statistically insignificant differences in magnum/atlas ratio (length and width)mean between males and females, therefor females as same as males in (length and width) of magnum/atlas ratio (4.11). Disagree with (Singh and Talwar, 2013), males displayed larger mean values than females for all measured variables but only one of the variables (maximum bicondylar breadth) exhibited statistically significant differences between the sexes, and (Uysal et al., 2005), the length and width of right condyle and width of FM diameters were found to be statistically different in each sex ($p < 0.001$) with 81% accuracy.

Table (4.13) shows the results of (1-WayANOVA) test for differences between subjects (age groups) in mean in magnum foramen measures (length and width) as in tables (4.12, 4.14 and 4.16), and according to the (Sig. values); which determine if the different age groups were relatively have the same magnum foramen measures (length and width) or if they were significantly different from one another. The Sig. values for both length and width are more than 0.05, and we can conclude that the differences in mean magnum foramen measures (length and width) with respect to age are likely due to chance and they are relatively the same for different age groups.

Therefore, magnum foramen (length and width) in adults does not depend on age. Differences in mean atlas foramen measures (length and width) with respect to age are likely due to chance and they are relatively the same for different age groups. Therefore, atlas foramen (length and width) in adults does not depend on age (table 4.15). While the differences in mean magnum/atlas ratio measures (length and width) with respect to age are likely due to chance and they are relatively the same for different age groups. Therefore, magnum/atlas ratio (length and width) in adults does not depend on age.

## 5.2 Conclusion:

A sample of (100) adult Sudanese whom present mean magnum foramen evaluated (37.189±2.995 mm length and 30.685±2.741 mm width), mean atlas foramen evaluated (30.747±3.01 mm length and 28.474±2.849 mm width) (table 4.4), and mean magnum/atlas ratio evaluated (84.071±7.901 mm length and 93.223±9.958 mm width).

The study found that males and females magnum foramen and magnum/atlas ratio mean measures (length and width) are statistically, insignificantly different, where females as same as males in (length and width) of magnum foramen and magnum/atlas ratio (length and width), while there were statistically significant differences in atlas foramen mean length between males and females; male has greater atlas foramen length than female.

The mean differences in measures (length and width) of magnum foramen, atlas foramen and magnum/atlas ratio in adults do not depend on age.

The study found that; there are no significant differences between shapes of foreman magnum in the samples, while they have different foreman of atlas shapes, whereas no relationship between the shapes of foreman magnum and foreman of atlas.

### 5.3 Recommendations:

- Recommend for future studies in assessment of shapes of foreman of atlas in homogeneous nationalism with comparing the results with this study.
- Determine which is suitable for the spinal cord when the measurement of foreman magnum is bigger than that for foreman of atlas or the vice versa.
- Special study to the people that have the measurement of foreman of atlas is bigger than that for foreman magnum.

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# Appendix

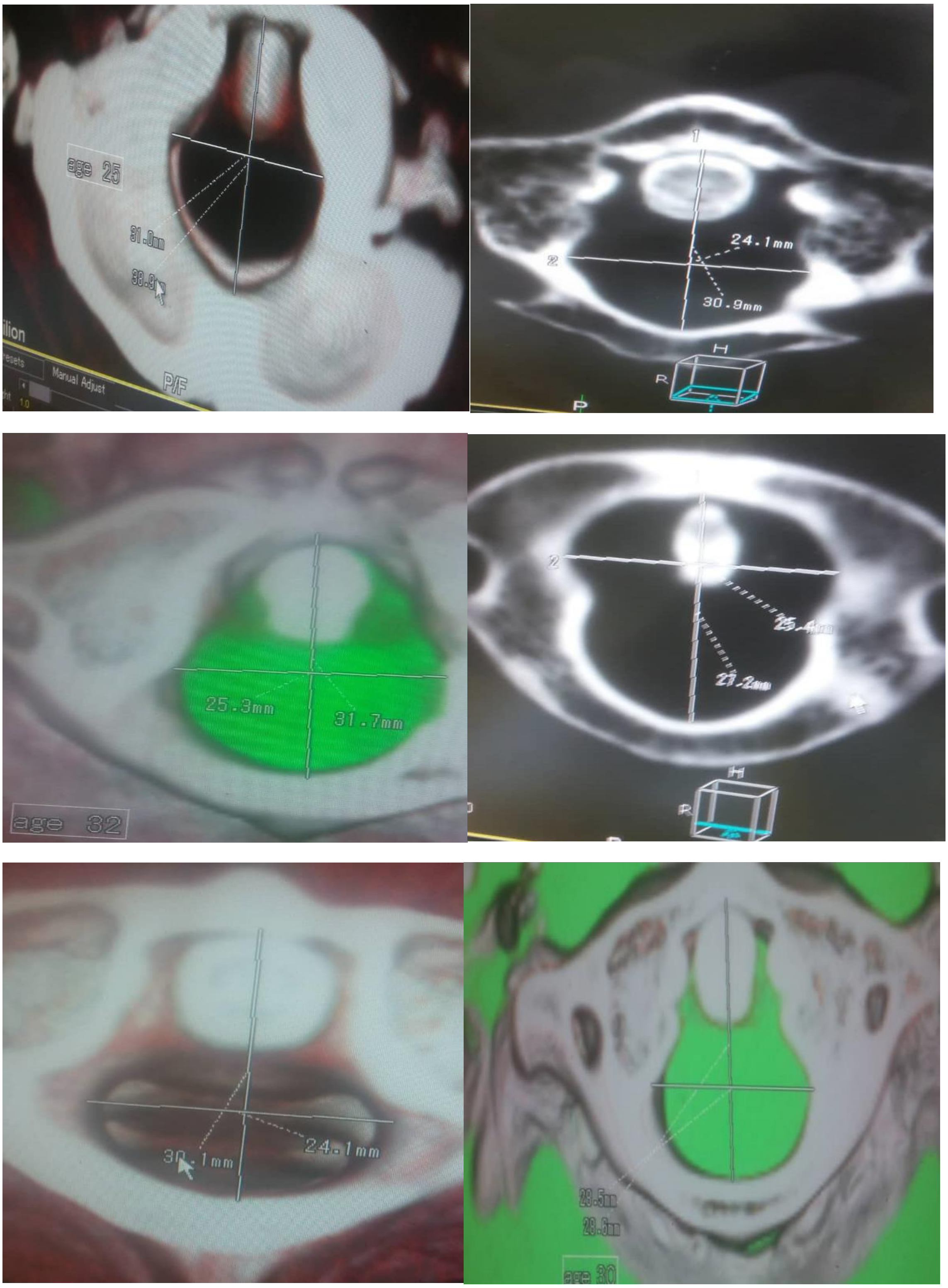


Figure (4.2 a): fireman of atlas foramen shape


Figure (4.2-b): fireman of atlas foramen shape

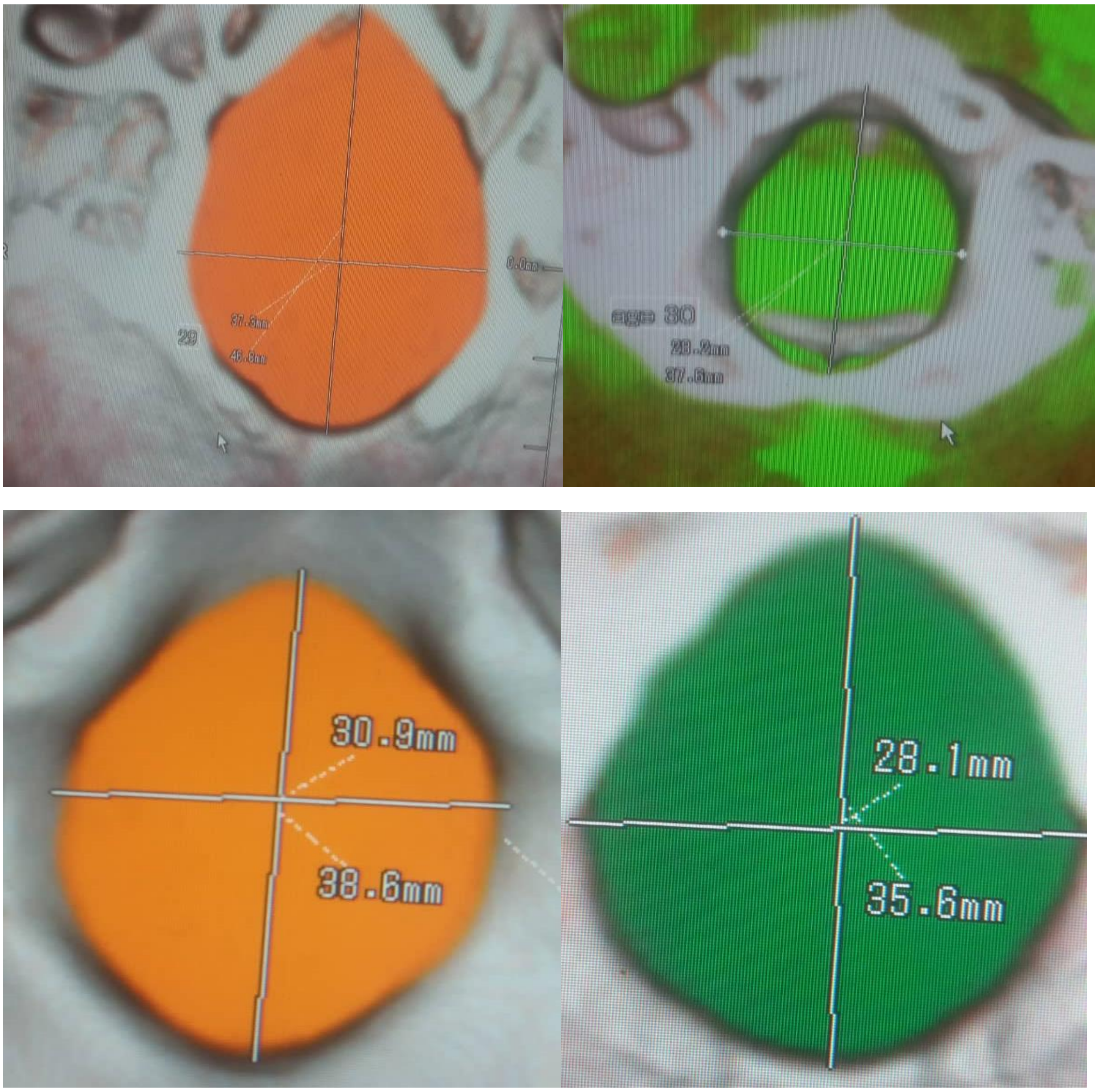


Figure (4.1): fireman of foramen magnum shape

***Sudan university for science and technology***

***Faculty of post graduate studies***

***Diagnostic department***

***Relation between normal dimension of foramen magnum and atlas foramen in the adult Sudanese population by using computed tomography***

***<u>Data collecting sheet</u>***

| *Pt. No* | *Gender* | *Age* | *Foramen magnum* | | *Atlas foramen* | | *Magnum /atlas ratio* | | *Magnum /atlas shape* | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | *Length* | *Width* | *Length* | *Width* | *Length* | *Width* | *same* | *differ* |
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