INTRODUCTION

Intracranial aneurysms are pathological enlargement of brain arteries that are most commonly located in the circle of Willis (**Weir, 2002).**

Intracranial aneurysms are relatively common with a prevalence of approximately 4%. The real danger of aneurysms is subarachnoid hemorrhage. However, the majority of aneurysms are asymptomatic **(Keedy, 2006).**

The incidence of subarachnoid hemorrhage (SAH) due to rupture aneurysm is 10-25:100,000 and is a devastating event associated with high morbidity and mortality from rebleeding and vasospasm **(Maira et al., 2006).** Ruptured aneurysms not only cause subarachnoid hemorrhage but can also cause subdural or intracranial haematomas **(Ohkuma, 2003).**

Management of intracranial aneurysms has been facilitated by constant improvements in diagnostic and therapeutic procedures which have recently led to an increase of use of non invasive imaging [computed tomography angiography (CTA)and magnetic resonance angiography (MRA)] and percutaneous endovascular treatment rather than conventional surgery **(Forsting et al., 2006)**.

3D digital subtraction angiography (3D DSA) has become a critical imaging tool in neuroradiology allowing for the visualization of detailed cerebral vasculature in nearly real time because of recent advance in C-arm gantry movement and reconstruction algorithm speed .3D DSA has grown from a novel experimental technique into a routine clinical imaging method (**Klucznic, 2002).**

Improvement of diagnostic imaging capability should reduce false negative angiograms.3D digital subtraction angiography (3D DSA) has demonstrated its clinical efficacy in precise depiction of the aneurysmal neck and its relationship to adjacent vessels. Moreover, it has been shown that 3D DSA reveals aneurysms not seen with conventional digital subtraction angiography (DSA) **(Hochmuth et al., 2002).**

3D reconstruction of intracranial vessels is of particular interest for the evaluation of intracranial aneurysms. This technique allows us to assess the aneurysmal neck including it's shape size and relationships with neighboring vessels .It can include views that are impossible to obtain by using only conventional angiographic projections **(Abe et al., 2002)**. These features are important to consider when one decides surgical or endovascular treatment **(Anxionnat et al., 1998).**

AIM OF THE WORK

To assess the diagnostic performance of 3D conventional angiography in the evaluation of intracranial aneurysms compared with the conventional cerebral angiography.

ANATOMY OF THE CEREBRAL CIRCULATION

The brain is one of the most highly perfused organs in the body, though representing 2% of the total body weight It receives one fifth of the resting cardiac output, therefore it is not surprising that the arterial blood supply to the human brain consists of two pairs of large arteries, the right and left internal carotid and the right and left vertebral arteries. The internal carotid arteries principally supply the cerebrum, whereas the two vertebral arteries join distally to form the basilar artery. Branches of the vertebral and basilar arteries supply blood for the cerebellum and brain stem. Proximally, the basilar artery joins the two internal carotid arteries and other communicating arteries to form a complete anastomotic ring at the base of the brain known as the circle of Willis, named after Sir Thomas Willis who described the arterial circle (circulus arteriosus cerebri). The circle of Willis gives rise to three pairs of main arteries, the anterior, middle, and posterior cerebral arteries, which divide into progressively smaller arteries and arterioles that run along the surface until they penetrate the brain tissue to supply blood to the corresponding regions of the cerebral cortex. Fig. (1) (**Moore and Dalley, 2007**).

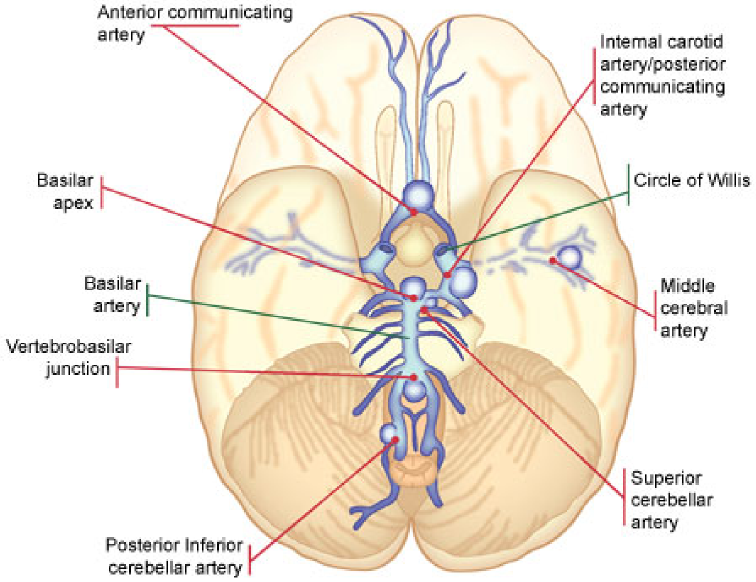

Fig. (1): Anatomy of the Brain (posterior vs. anterior circulation, circle of Willis) – Moore and Dalley, 2007).

The Circle of Willis: is an arterial circle at the base of the brain that is of critical importance. The circle of Willis is formed when the internal carotid artery (ICA) enters the cranial cavity bilaterally and divides into the anterior cerebral artery (ACA) and middle cerebral artery (MCA). The anterior cerebral arteries are then united by an anterior communicating (ACOM) artery. These connections form the anterior half (anterior circulation) of the circle of Willis. Posteriorly, the basilar artery, formed by the left and right vertebral arteries, branches into a left and right posterior cerebral artery (PCA), forming the posterior circulation. The PCAs complete the circle of Willis by joining the internal carotid system anteriorly via the posterior communicating (PCOM) arteries. (Fig. 2 a,b,c. and Fig.3)

All the principal arteries that supply cerebral hemispheres of the brain branch off from the circle of Willis (**Purves et al., 2008**).

The Circle of Willis, long considered being an important anatomic vascular formation, as it provides backup circulation to the brain.

The circle of Willis is often not complete. Maximally, only a third of people enjoy a complete circle of Willis. This circle is the most important source of collateral circulation in the presence of extra cranial carotid or vertebral artery disease. In case one of the supply arteries is occluded, the circle of Willis provides interconnections between internal carotid arteries and basilar artery along the floor of the cerebral vault, providing blood to tissues that would otherwise becomes ischemic.

The presence of a complete circle of Willis permits a continuing supply of blood to the entire brain and helps avert a stroke (**Boorder et al., 2006**).

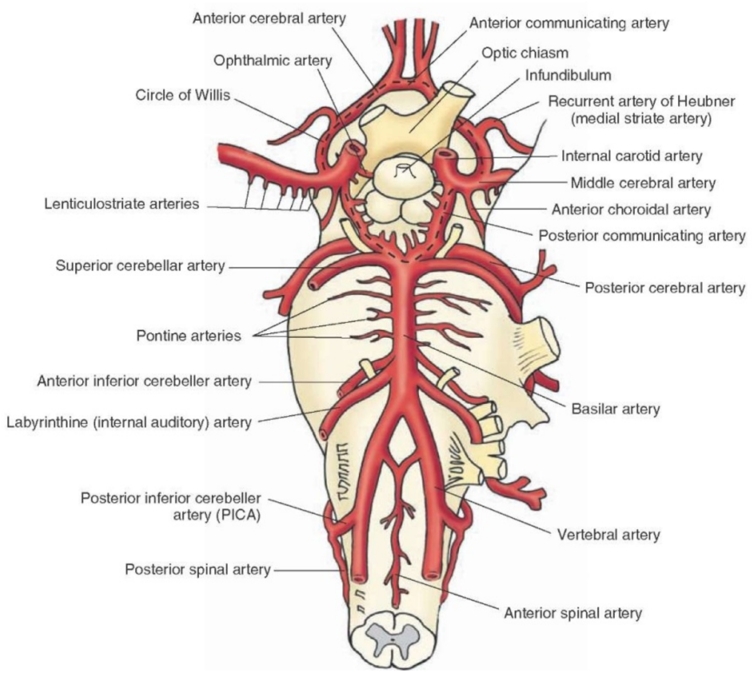
Anterior cerebral artery
Anterior communicating artery
Ophthalmic artery
Optic chiasm
Infundibulum
Circle of Willis
Recurrent artery of Heubner (medial striate artery)
Internal carotid artery
Middle cerebral artery
Lenticulostriate arteries
Anterior choroidal artery
Posterior communicating artery
Superior cerebellar artery
Posterior cerebral artery
Pontine arteries
Anterior inferior cerebeller artery
Basilar artery
Labyrinthine (internal auditory) artery
Posterior inferior cerebeller artery (PICA)
Vertebral artery
Posterior spinal artery
Anterior spinal artery

Fig (2a)

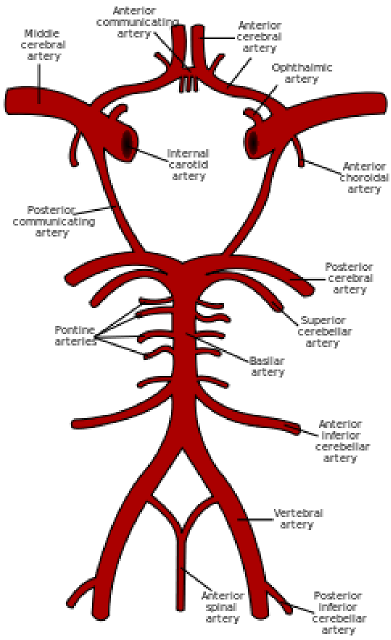
Anterior communicating artery
Middle cerebral artery
Anterior cerebral artery
Ophthalmic artery
Internal carotid artery
Anterior choroidal artery
Posterior communicating artery
Posterior cerebral artery
Superior cerebellar artery
Pontine arteries
Basilar artery
Anterior inferior cerebellar artery
Vertebral artery
Anterior spinal artery
Posterior inferior cerebellar artery

Fig (2b)

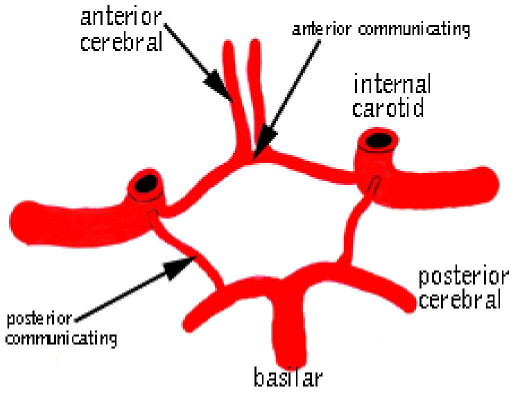

Fig. (2C)

Fig. (2): (a,b,c): Schematic representation of the circle of Willis, arteries of the brain and brainstem ***(Afifi and Bergman, 1998).***

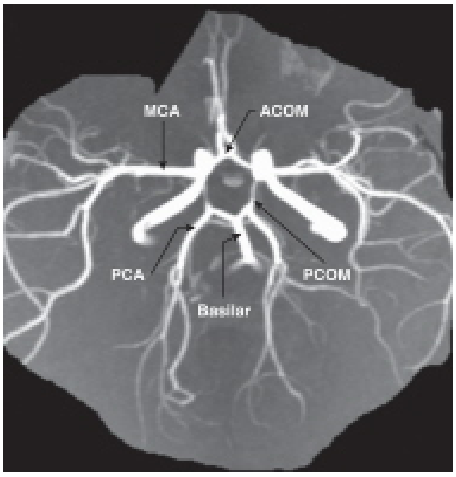

Fig. (3): Arteriography illustrating the circle of Willis and its branches ***(Osborn, 1999).***

Since the mode of distribution of the vessels of the brain has an important bearing upon a considerable number of the pathological lesions which may occur in this part of the nervous system, it is important to consider a little more in detail the manner in which the vessels are distributed. Anatomic variants are very frequent and demand certain knowledge on the part of the radiologist for guaranteeing successful catheterization **(Grand and Hopkins, 1999).**

The brain receives its blood supply from the heart by way of the aortic arch that gives rise to the brachiocephalic (innominate) artery, left common carotid artery (CCA) and the left subclavian artery **(Sheldon 1981).**

In about two-thirds of individuals the innominate artery is the first vessel to originate from the aortic arch Fig (4), the left carotid artery the second, and the subclavian artery the third. In this arrangement the right carotid and right vertebral arteries are supplied by the innominate artery, and the left vertebral artery is supplied by the left subclavian artery.**(Stanley, 1998)**

In the remaining one-third of individuals, variations may be displayed. The most usual variation, the left common carotid artery either forms a common origin with the innominate artery or originates from the proximal portion of the innominate artery itself. Less frequently, the left vertebral artery originates directly from the aortic arch between the left carotid and left subclavian arteries. The least frequent variation is the aberrant origin of the right subclavian artery from the aortic arch distal to the left subclavian artery ***(Lo et al., 2006).***

Selective catheterization of the carotid and vertebral arteries may be difficult if these variations are not recognized.

The posterior fossa (infratentorial region) is supplied by the vertebral arteries and its major extension, the basilar artery. Selective catheterization of the left vertebral artery is easier than the right because it is located along a more vertical axis and there are also other arterial branches to traverse before reaching the vertebral orifice **(Hendrikse et al., 2005).**

A. Carotid Arterial System

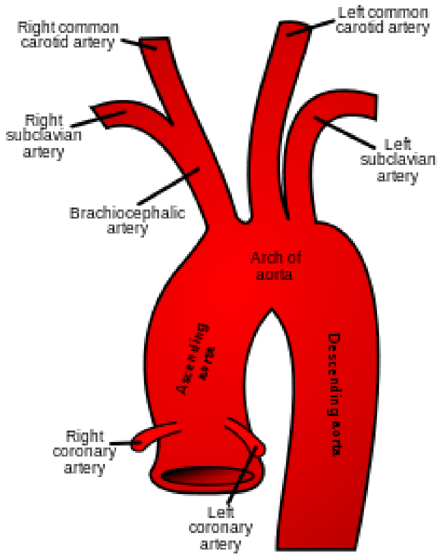

Fig. (4): Common carotid artery and its branches **(Ashrafian, 2007).**

1. Common Carotid artery (CCA):

The carotid artery is enclosed within the carotid sheath with the vagus nerve and jugular vein. The right common carotid artery (CCA) normally arises from the brachiocephalic trunk immediately behind the right sternoclavicular joint. It is shorter than the left CCA which originates directly from the aortic arch (approx. 9.5 cm vs 14cm respectively). The normal

CCA gives no angiographically detectable branch. Its caliber (approximately 8 mm) thus remains constant during its entire course. The superior thyroid artery is the most frequent unusual branch of the CCA **(Hendrikse et al., 2005).**

The carotid bifurcation is most commonly located between the C3 and C5 vertebral levels but extreme positions ranging from C1 to T3 may be encountered. Both carotid bifurcations are found at the same level (28%) or within one vertebral level difference (65%). The bifurcation angle between the external carotid artery (ECA) and internal carotid artery (ICA) generally increases with age. Its average value in normal bifurcations is about 53 degree, with a 20 degree standard deviation. Immediately distal to the bifurcation, the ICA is lateral and posterior to the ECA. The ICA then bends medially to reach the external orifice of the carotid canal at the skull base while the ECA ascends laterally towards the parotid gland where it divides into its terminal branches. Morphological features helping to differentiate the ECA from the ICA at sonography include both their relative position at the bifurcation and the presence of branches on the ECA. The carotid bulb is a normal widening of the carotid bifurcation extending both to the distal CCA and the proximal ICA. The carotid bulb harbors a complex blood flow pattern which seems to predispose to atheromatous plaque constitution, particularly along the posterolateral aspect of its wall **(Casserly and Yadav, 2005)**.

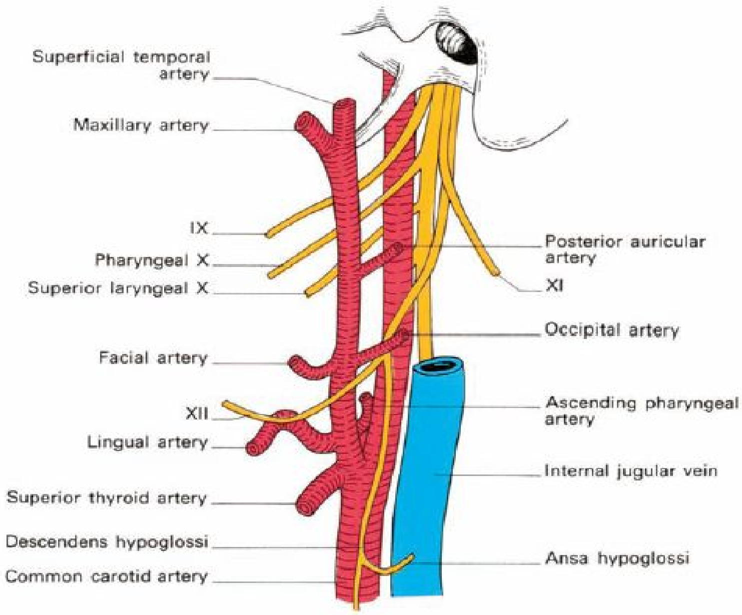

Fig. (5): Branches of external carotid artery. ***(Richard L. Drake, Wayne Vogel & Adam W.M Mitchell, "Gray's Anatomy for Students", Elsevier Inc., 2005).***

2. External carotid artery (ECA):

It starts at the CCA bifurcation. Its branches supply the jaw, face, neck and meninges. The bulk of the meningeal circulation is supplied by the middle meningeal artery, the most important branch of the maxillary artery which is one of the two terminal branches of the ECA (the other terminal branch is the superficial temporal artery). These two terminal branches in addition to the occipital artery can serve as collateral channels for blood supply to the brain in instances of obstruction of the ICA. The ascending pharyngeal artery can serve as a source of blood in instances of occlusion of the ICA **(Schwartz et al., 1992).**

The external carotid artery usually arises medial and anterior to the internal carotid artery. However, in approximately 15 percent of individuals the external carotid artery originates lateral to the internal carotid artery. This external carotid artery variation tends to occur more frequently on the right.

The branches of the external carotid artery are important because interventional radiologic procedures are frequently performed in this circulation. The branches can be divided into those that are directed anteriorly and those that are directed posteriorly (Fig.5).

Anteriorly directed branches include the superior thyroid, lingual, facial, and internal maxillary arteries. Posteriorly directed arteries include the ascending pharyngeal, posterior auricular, and occipital arteries **(Stanley, 1998).**

Anterior Branches:

The superior thyroid artery is the first anterior branch to originate from the external carotid artery. The lingual and facial arteries are the second and third anterior branches. On lateral angiograms, the initial course of the lingual and facial arteries may be difficult to distinguish in the submental and oral regions because of their similar course and tortuosity. On anteroposterior angiograms the course of these vessels in the submental region and floor of the mouth may again be difficult to differentiate until the facial artery courses superficially to the mandible and angles medially toward the corner of the eye.

The internal maxillary artery is one of two terminal branches, it is considered as one of the anterior branches because its course is largely anterior. It can be divided into three segments: mandibular, pterygoid, and pterygopalatine **(Ashrafian, 2007).**

Posterior Branches:

Of the three posterior branches of the external carotid artery, the occipital artery is the largest. It courses posteriorly to supply the muscles and skin in the suboccipital and occipital regions. The ascending pharyngeal artery, another posterior branch, passes almost directly upward, giving off anterior branches to the pharynx and the prevertebral muscles. It terminates by supplying the meninges around the foramen magnum and jugular foramen.

The posterior auricular artery, the last posterior branch, originates in the parotid gland and then courses upward and posteriorly. It supplies the parotid gland, the pinna, and the scalp posterior to the ear **(Schwartz 1992).**

Terminal Branches:

The superficial temporal artery, a terminal branch of the external carotid artery, arises within the parotid gland and continues upward as the natural extension of the external carotid artery; the internal maxillary artery is the other terminal branch **(Osborn, 1999)**.

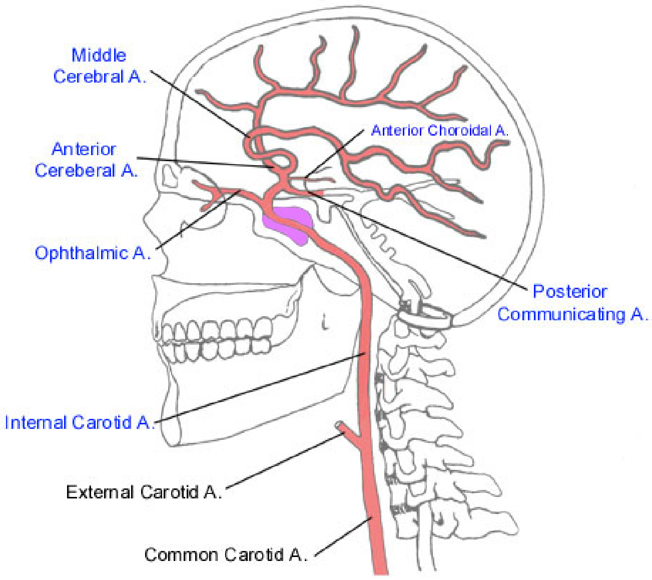

Figure (6): Branches of internal carotid artery. ***(Richard L. Drake, Wayne Vogel & Adam W M Mitchell, "Gray's Anatomy for Students", Elsevier Inc., 2005).***

3. Internal carotid artery (ICA)

It starts at the carotid sinus at bifurcation of CCA at the level of the upper border of the thyroid cartilage at the level of the fourth cervical vertebra. It ascends just behind and lateral to the hypopharynx where it can be palpated **(Hollinshead 1982)**.

It passes up the neck without any branches to the base of the skull where it enters the carotid canal of the petrous bone. It then runs through the cavernous sinus in an S-shaped curve (the carotid siphon), then it pierces the dura (beginning its