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Comparative study of formation of circle of Willis in human and sheep brain

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ABSTRACT

Introduction: Brain is one of the most metabolically active organs of the mammalian body receiving adequate blood supply, which is essential to maintain the glucose and oxygen levels. This demand is derived from circle of Willis (CoW) and its arterial anastomosis at the base of the brain.

To describe the arteries contributing to the formation of CW in sheep brain and to compare it with that of human. Sheep circle of Willis forms an animal model for undertaking further studies on blood supply of certain cranial nerves.

Materials and methods: In present study, 20 formalin fixed human brains from the Department of Anatomy, Mamata Medical College and 20 fresh sheep brains from local slaughterhouse were obtained. Sheep brain was removed as per the human brain removal procedure, and circle of Willis was studied by Radiological study.

Results: In sheep a well-developed four-sided arterial rete called 'Rete Mirabile cerebri' (RMC) was noted at the base of the brain in inter-peduncular fossa. Internal carotid arteries were either vestigial or absent in sheep. Two emergent arteries arising from steady pool of blood from RMC entered the inter-peduncular fossa. These arteries ascended on either side of infundibulum of pituitary gland and then diverged in cranial and caudal directions to form the Circle of Willis.

1. Introduction

The circle of Willis, Willis' circle, loop of Willis, cerebral arterial circle, and Willis polygon is a circulatory anastomosis that supplies blood to the brain and surrounding structures. It is named after Thomas Willis (1621–1675), an English physician.[1]

The brain is particularly susceptible to increased temperature (hyperthermia). To protect the brain from any potential heat stress a number of species have developed protective mechanisms with the ability to selectively cool the brain. This protective system is often referred to as the Rete Mirable[2] (in animals).

In humans blood supply to the brain is provided by four arteries, two vertebral, and two internal carotid arteries. The branches of these arteries anastomose at the base of the brain around the inter-peduncular fossa forming a six-sided polygon of arteries called circulus arteriosus.[3] The main blood vessels of the brain and their principal branches lie in the subarachnoid space between the arachnoid and pia mater and smaller vessels ramify on the piamater before sinking in to the substance of the brain.[4]

In sheep common carotid artery usually divides in the retromandibular space at the cranial part of the neck, ventral to first cervical vertebra (Atlas). It divides either in to three branches, i.e. external carotid artery, internal carotid artery, and occipital artery (or) in to two branches with disappearance of internal carotid artery in ruminants.[5]

Internal carotid artery is not well developed in sheep brain. Internal maxillary artery, which is a branch of external carotid artery, contributes to the formation of circle of Willis via the anatomosing ramus. In this situation the basilar artery carries blood *away* from the circle of Willis (unlike in man). The carotid rete is an intracranial arterial plexus that consists of a large number of short, thin, and parallel arteries that merge into one vessel before leaving the cavernous sinus.[6]

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Emergent artery arises as a single trunk on either side of the carotid rete and divides in to cranial and caudal primary branches. The cranial primary branch gives origin to middle cerebral and is continued as cranial cerebral artery. Caudal primary branch traverses backward to give rise to caudal cerebral artery and cranial cerebellar artery. Caudal primary branch continues inward at midline joining the corresponding branch of the opposite side to form basilar artery in the lower part of the midbrain. The union of cranial primary branches and caudal primary branches of opposite side formed a complete circle termed as circle of Willis.[7]

The arrangement of the arteries forming the circle of Willis creates redundancies or collaterals in the cerebral circulation. If one branch of the circle becomes blocked (or) stenosed blood flow from the other blood vessels can often preserve the cerebral perfusion well enough to avoid the symptoms of ischemia.[8]

2. Aim and objectives

1) To describe arteries contributing for the formation of the circle of Willis in sheep brain.
2) To compare the formation of circle of Willis between human and sheep brain.
3) To find out the effectiveness of Sheep brain model for human brain experiments.

3. Material and methods

3.1. Material

20 formalin fixed human brains from the department of anatomy Mamata Medical College, Khammam, 20 fresh sheep brains from local slaughterhouse.

3.2. Method

1) Dissection method
2) Injecting contrast material
3) Radiological Method

3.3. Procedure

Sheep heads were washed under the running tap water to remove the debris. 10% formalin were injected in to right and left common carotid arteries after flushing with normal saline.

Brain removal was done by sawing the calvaria manually 1 cm above the supraorbital margin anteriorly and basilar part of occipital bone posteriorly. In neck region after removing the muscle mass, lamina was chiseled up to 4th cervical vertebra.

Brain was removed along with dura mater (meningeal layer and endosteal layer) to prevent the injury to the arteries. 2% eosin 1 ml and 9 ml of distilled water was injected in to basilar artery to observe the fine capillaries after cutting endosteal layer of duramater of sheep brain.

Formation of circle of Willis was observed in both human and sheep brains. Photographs were taken by digital camera (Figs. 1–5).

5 ml of Iopomidal and 5 ml of distilled water were injected in to basilar artery after cutting the endosteal layer in both human and sheep brains for radiological study.

4. Discussion

Sulman Rahmat, reported modifications in carotid and vertebral artery sources. These modifications include reduction or elimination of either the internal carotid or vertebral arteries, along with a variety of anastomotic connections between branches of internal carotid branches and those of the external carotid, stapedial, and their cranial arteries.[9]

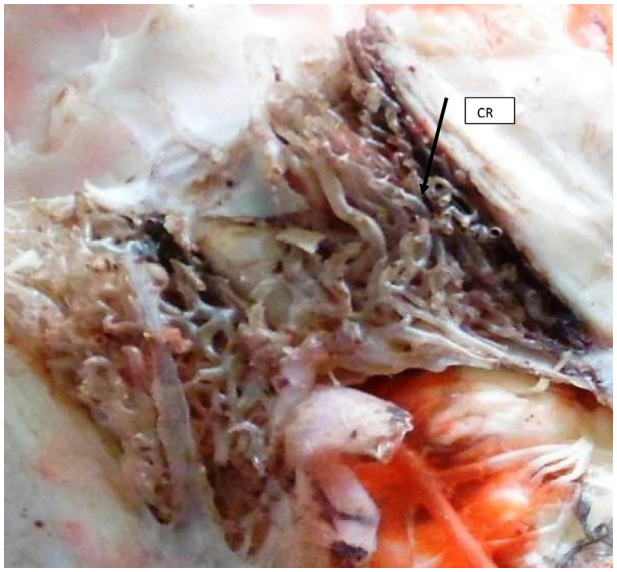

Fig. 1. Rete Mirable Cerebri in sheep lies on either side of pituitary gland, CR, carotid rete.

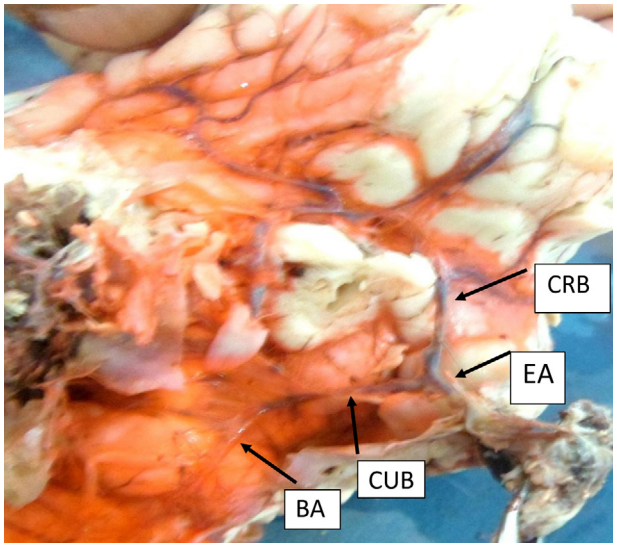

Fig. 2. After cutting the carotid rete identify the emergent artery divides in to cranial and caudal branches. EA, emergent artery; CRB, cranial branch; CUB, caudal branch; BA, basilar artery.

Parmeggiani noted that in species like sheep, cat, goat the carotid blood supply to brain is thermally conditioned prior to formation of circle of Willis by countercurrent heat exchange between carotid rete and venous sinuses.[10]

Baldwin described the basilar artery in both sheep and ox having tenuous connections with the vertebral. In both species, the basilar artery tapers caudally and is continued as the ventral spinal artery. Hence basilar artery was regarded as a caudally directed branch of the circle of Willis in both these animals. A well-developed occipito-vertebral anastomosis was reported as marked feature of the cephalic circulation in both sheep and ox.[11]

According to Ashwini[12,13] circle of Willis in sheep was complete due to anastomosis between the two cerebral arteries. This compensation may provided by nature prevents the discrepancy of

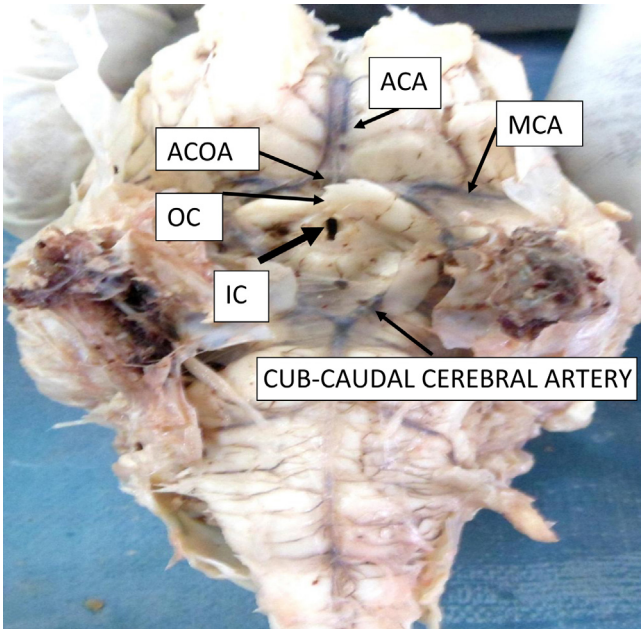

Fig. 3. Circle of Willis in sheep brain. ACA, anterior cerebral artery; MCA, middle cerebral artery, ACoA, anterior communicating artery; OC, optic chiasma; IC, infundibular recess of III ventricle; CUB, caudal cerebral artery.

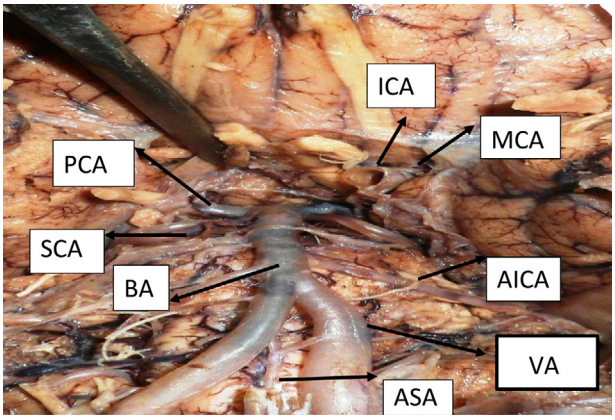

Fig. 4. Circle of Willis in Human brain. ICA, internal carotid artery; MCA, middle cerebral artery AICA, antero inferior cerebellar artery; VA, vertebral artery; ASA, anterior spinal artery; BA, basilar artery; SCA, superior cerebellar artery; PCA, posterior cerebral artery.

blood supply to frontal lobe. This is essential because in man frontal lobe is the seat of higher functions like intelligence, memory, skilled movements, and social behavior differentiating mankind from animals.

According to literature the exact location of the carotid rete in mammals was on both sides of the pituitary gland with cranial extension up to orbital foramen and caudal extension up to oval foramen.[13,14]

Skipor reported Carotid rete as a complex network of arteries and veins lying very close to each other and depends on counter current blood flow between arterioles and venules. It exchanges heat and ions between vessel walls. The counter current mechanism helps to controlling the temperature of blood.[16]

According to Danial the rete is present bilaterally and there is a variable degree of communication across the mid-line with the rete of the opposite side.[17]

In humans cortical arterial branches traverse over long distance (up to 20 cm) within the subarachnoid space. They are thin-walled vessels with diameters similar to those of the carotid rete of other species. Because of the structural similarities to the carotid rete cortical arterial vessels are thought to have highly effective CSF-arterial thermal interaction.[18]

In our study, branches of internal maxillary artery are contributing for the formation of circle of Willis in sheep brain. In human both carotid and vertebral arteries are forming the circle of Willis.

Fig. 5. X-ray image of circle of Willis in sheep and human brain.

Table 1
Differences in formation and branching pattern of circle of Willis between human and sheep.

Brain	Formation	Anterior communicating artery	Basilar artery formation	Direction of basilar artery	Anastomosis	Ventral (or) anterior spinal artery
Human	Internal carotid and basilar	Single vessel	Union of two vertebral arteries	Runs toward the circle of Willis	Vertebral and carotid systems	Medial side of two vertebral arteries
Sheep	Internal maxillary artery	Network	Is a branch of circle of Willis	Away from circle of Willis	Occipito vertebral artery	Basilar artery continues as ventral spinal artery

Table 2
Territories supplied by different branches of circle of Willis in human and sheep.

Brain	Forebrain	Mid brain	Hind brain
Human	Internal carotid system	Branches of anterior choroidal, posterior cerebral arteries	Vertebro basilar system
Sheep	Cranial primary branch of emergent artery	Caudal primary branch of emergent artery	Branches of basilar artery

5. Conclusion

In sheep well developed carotid rete along with degeneration of internal carotid artery acts as a thermo regulator.

In human and sheep main difference is internal carotid and vertebral systems provides the blood supply to human brain, in case of sheep internal maxillary artery contributes the blood supply to most of the sheep brain caudally by the occipito vertebral anastomosis (Tables 1 and 2).[18–20]

The present study being a comparative one provides a base for further investigative and advanced dynamic studies, as a detailed morphology of circle of Willis regarding its formation has been done extensively. This study creates a success models for cerebral ischemic research and source of blood supply of certain cranial nerves.

6. Results

6.1. Formation of carotid rete

External carotid artery gives a terminal branch, i.e. internal maxillary artery and superficial temporal artery. The internal maxillary artery gives meningeal and condylar branches. Meningeal branches enter the cranial cavity through the foramen oval, condylar branches enters the cranial cavity through the orbitoforamen rotundum. These arteries unite forming the carotid rete.

Conflicts of interest

The authors have none to declare.

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References

1. Mayer A, Hierons R. Observations on the history of the circle of Willis'. *Med Hist.* 1962;6(2):119–130.
2. Sophie S. *CNS Vasculature – Anatomy & Physiology – Wikivet English*. 2014;8.
3. Singh V. 1st ed. *Anatomy of Head Neck & Brain*. Vol. 3. Churchill Livingston Elsevier; 2009: 446.
4. Romanes GJ. 15th ed. *Cunningham Manual of Practical Anatomy*. Vol. 3. Head, Neck, and Brain Oxford Medical Publications; 1998.
5. Parchami A, Fatahian Dehkordi RA, Derakshan A. Comparative histomorphometric study of the common carotid artery and its terminal branches in sheep and goats. *Bulg J Vet Med*. 2009;12(3):165–170.
6. McGrath P. Observations on the intracranial carotid rete and the hypophysis in the mature female pig and sheep. *J Anat*. 1977;124(3):689–699.
7. Prakash T, Jain RK. Blood supply to the brain in goat (*Capra hircus*) Indian. *J Vet Anat*. 2014;26(1):19–21.
8. Boorder Michiel J, Van Der Grond J, Van Dongen AJ, et al. Spect measurements of regional cerebral perfusion and carbon dioxide reactivity: correlation with cerebral collaterals in internal carotid artery occlusive disease. *J Neurol*. 2006;253(10): 1285–1291.
9. Rahmat S, Gillard E. Comparative anatomy of carotid-basilar arterial trunk and hindbrain penetrating the in vertebrates. *Open Anat J*. 2014;6:1–26.
10. Parmeggiani PL. REM sleep related increase in brain temperature a physiologic problem archievers. *Ital Biol*. 2007;154:14–21.
11. Baldwin BA. The anatomy of the arterial supply to the cranial regions of the sheep and ox. *Am J Anat*. 1964;115:101–117.
12. Aswini CA, Shubha R, Jayanthi KS. Comparative anatomy of circle of Willis in human, pig, goat, sheep. *Neuroanatomy*. 2008;7:54–85.
13. Senbulingam K, Senbulingam P. *Essentials of Medical Physiology*. 3rd ed. India: Jaypee Brothers Medical Publishers Ltd.; 2004.
14. Bamel S. Anatomical studies on the arteries of the brain of buffalo. The rete mirable cerebri. *Anat Anz*. 1975;137:140–146.
16. Sukru H, Kutul I. Morphological observation of the Rostral epidural Rete Mirable in the Goat. *Vet Bil Derg*. 2011;177–181.
17. Skipor J, Neiner J. Local transfer of substances between the blood vessels at the base of the brain. *J Anim Feed Sci*. 2006;15:533–543.
18. Daniel PM, Dawes JDK, Marjorie M, Prichard L. Studies of the carotid rete and its associated arteries. *Phil Trans R Soc Lond*. 1953;237(7):173–208.
19. Wang H, Wang B, Normoyle K, et al. Brain temperature and its fundamental properties: a review for clinical neuroscientists. *Front Neurosci*. 2014;8:307.
20. Simoens P, Lauwers H, De Geest JP, De Schaepdrijver L. Functional morphology of the cranial retia mirabile in the domestic mammals. *Schweiz Arch Tierheilkd*. 1987;129:295–307.