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RESEARCH ARTICLE

PREVALENCE OF ANATOMICAL VARIATIONS OF CIRCLE OF WILLIS IN SOUTH INDIAN POPULATION SUCCUMBING TO ISOLATED TRAUMATIC BRAIN INJURY - A CADAVERIC STUDY

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Abstract

Introduction: The Circle of Willis (COW) is a large arterial anastomotic ring present at the basal cistern of the brain, uniting the internal carotid and the vertebro-basilar system. Sir Thomas Willis was the first to describe the importance of the circle in maintaining collateral flow. It was observed that there is very little mixing of blood between the collateral branches of the circle. These collaterals may however open up during occlusive episodes of the proximal feeding vessels or in case of severe stress such as stroke and traumatic brain injury (TBI) in order to maintain metabolic activity in the brain. This phenomenon is affected to various degrees in the presence of anomalies. The prevalence of anomalies of COW in the general population is up to 75.72% was demonstrated in other studies.

Materials and Methodology: This is a cross sectional observational study. 20 consecutive patients above 18 years of age succumbed to isolated TBI who were subjected to medico-legal autopsy in our hospital were included. The anomalies were classified as per the criteria laid down by Stojanovi´c et al.

Results: 9 Normal variants (Type A) of COW (45%) was found. The most common type of anomaly was Type C which was noted in 4 cases (20%).

Conclusion: Anatomical variations of COW has proven association in the areas of stroke, aneurysm, migraine, carotid endarterectomy and ageing brains. Further studies are needed to determine whether the anomalies of COW really contribute to the mortality in TBI.

Introduction:-

The Circle of Willis (COW) is a large arterial anastomotic ring present at the basal cistern of the brain uniting the internal carotid and the vertebro-basilar system. The anterior circulation comprises of two Internal carotid arteries which branch to give middle cerebral artery (MCA) and anterior cerebral artery (ACA). The two ACA connect via anterior communicating artery (ACom). The posterior circulation originates from the two vertebral arteries (VA) joining to form basilar artery (BA) and giving posterior cerebral artery (PCA) branches. These arteries connect with the MCA (anterior circulation) via posterior Communicating Artery (PCom) (Fig.1). Branches from this arterial ring are then distributed to supply the brain. In the year 1664, Sir Thomas Willis was the first to describe the importance of the COW in maintaining collateral flow. It was observed that there is very little mixing of blood between the collateral branches of the COW during normal homeostasis, however these collaterals may open up during occlusive episodes of the proximal feeding vessels or in times of stress. In patients with diseases damaging the brain, the COW

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can maintain adequate blood flow and decrease damage through its potential blood redistribution function. Both anterior circulation and posterior circulation support each other. This compensation however depends on the anatomical morphology of COW [1]. Anatomical variations of COW such as incomplete COW with hypoplasia of the individual arteries and its variant forms [Fig.2]may diminish collateral backup thereby contributing to the morbidity and mortality. The variation of COW can also alter cerebral blood flow resulting in various diseases such as aneurysms. It also affects outcomes in carotid endartrectomies and other neurosurgical procedures. In particular severe stress due traumatic brain injury (TBI), where the shearing of vessels might lead to ischemia to the concerned vascular territory needs collateral backup to prevent secondary brain injury and its sequelae. Studies also showed that effective collateral circulations have a lower risk of transient ischemic attack and stroke than those with ineffective collaterals. The anatomy of COW is known to vary considerably and functionally a complete COW is a rare finding. A study of anomalies in the COW using magnetic resonance angiography (MRA) in north eastern India revealed that only 24.28% MRA's presented with a complete (classic) COWand the prevalence of anomalies in the general population is up to 75.72% [2]. Autopsy studies of the anatomical variations of the COW in cadaveric human brains revealed high percentage of anatomical variations of COW in patients dying following surgical and neurovascular intervention proving its association. The studyalso concludes that awareness of these anatomical variations is important in neurovascular procedures in view of high prevalence of such anomalies and suggested that all surgical interventions be preceded by angiography as a precautionary measure. [3]. The aim of the present cadaveric study is to find the prevalence of anatomical variations of the COW in south Indian population who died following TBI. The objective is to classify the anatomical variations according to the classification given by Stojanovi´c et al and find the percentage of occurrence of each anomaly. The anatomical variations of COW in TBI have not been studied much in the Indian subcontinent.

Fig.1:- The Circle of Willis.

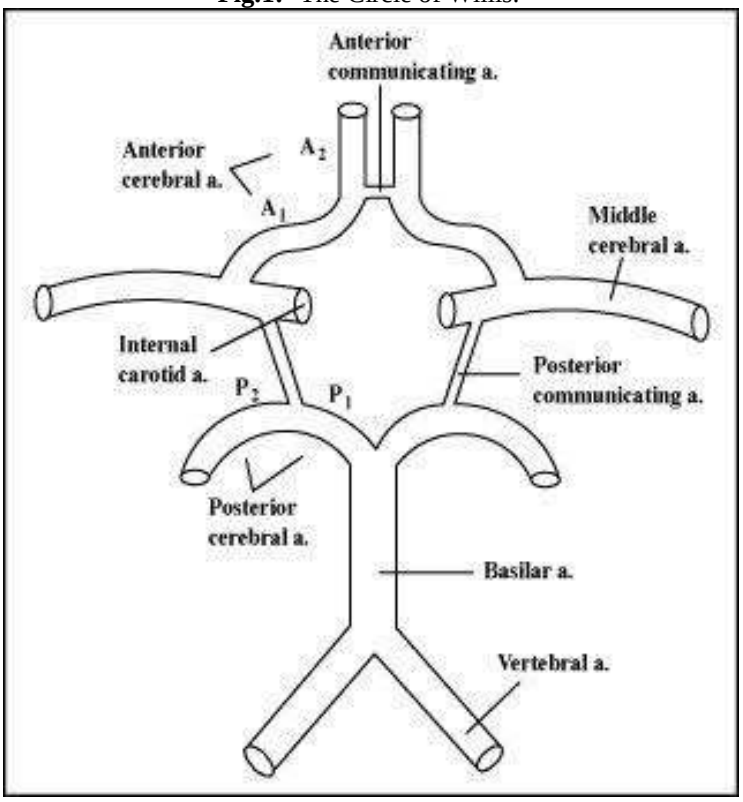
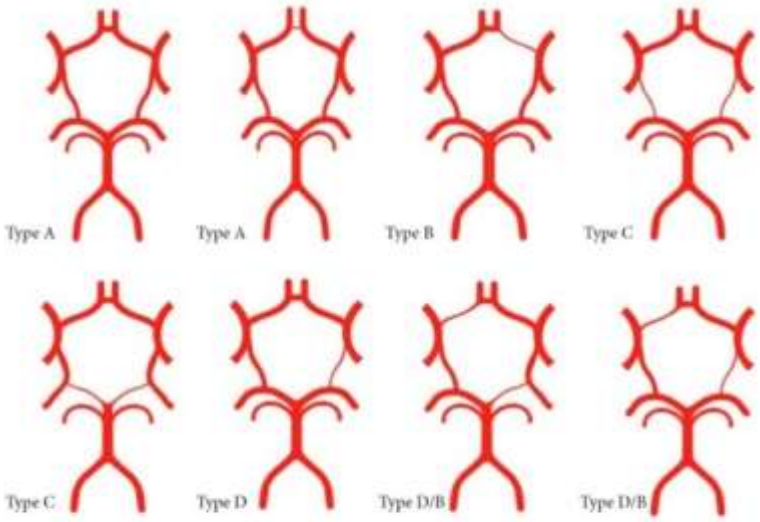


Fig.2:- Classification of basic types of anomalies of COW (Stojanovi´c et al).



Basic types of configurationof the circle of Willis.

Materials and Methodology:

This is a cross sectional observational study wherein convenient type of sampling was employed. All patients above the age of 18 who died due to TBI following road traffic accidents (RTA), who undergo medico-legal autopsies in a tertiary care centre was included. Patients with polytrauma were excluded. A sample size of 20 was calculated as per open EPI calculator. (Prevalence of anomalies of COW was 75.72%) [2]. All patents subjected to post mortem evaluation who satisfied the inclusion and exclusion criteria had their COW isolated and dissected. The COW was then analysed with special reference to the following factors i.e. whether the COW is complete or incomplete, any asymmetry in the configuration and variations in the sizes, number of the component vessels and absence or duplication or triplication of any of the vessels. The arteries examined were the ACom, the proximal and the distal 1cm segments of the ACA, the internal carotid distal to the origin of the PCom, MCA at its beginning, the PCom, the proximal and distal 1cm segments of the PCA, BA and the sub-arachnoid portion of the VA. The COWfindings were classified into two main groups namely normal circles and anomalous circles. Thiswas further sub-divided as attenuated vessels (hypoplasia of one or other components of the circle) and normal vessels. Arteries of less than 1 mm in external diameter were considered hypoplastic. In communicating arteriesless than 0.5 mm was considered hypoplastic. Also the corresponding blood vessel diameters were compared to the symmetric blood vessel diameters on the opposite side. Reduction of the blood vessel diameter by $1/3^{rd}$ to $2/3^{rd}$ was marked as hypoplasia, and a decrease in the blood vessel diameter below $1/3^{rd}$ of the thickness was marked as pronounced hypoplasia. The presence of hypoplasia determined the symmetry or asymmetry of the COW. The variations were classified according to the classification given by Stojanovi´c et al as four basic types of configuration and one sub-type. Type A represents a symmetric COW with different variations at the level of the ACom. Type B is an asymmetric COW with hypoplasia or aplasia of the A1 segment of the ACA. Type C represents a symmetric COW with varying degrees of the hypoplasia or aplasia of the PCom bilaterally or the presence of a bilateral fetal PCom type. Type D is an asymmetric COW with single-sided PCom hypoplasia or a single-sided fetal PCom type. Subtype B/D represents an asymmetric COW with hypoplasia or aplasia of the A1 segment of the ACA in combination with changes in the posterior segment (due to hypoplasia of PCom or PCA). The results were tabulated.

Results:-

A total of 20 cases undergoing medico-legal autopsy following death due to TBI following RTA were studied. The minimum age was 21 and maximum age was 73. The mean age group was 53 and M:F ratio was 2.3:1.The age distribution sample size was maximum in 60 to 70 years age group. The classification of COW was done as per Stojanovi´c et al. Out of the 20 cases, there were 9 Normal variants (45%) and 11 anomalies (55%). The variations were as follows. Type A was 9 cases (45%), type B was 2 cases (10%), type C was 4 cases (20%), type D was 2

cases (10%) andtype B/D was 3 cases (15%) (Table.2). The most common type of anomaly was type C (Fig.3 and 4), and least common was type B and type D.

Fig 3:- post mortem brain specimen showing Type C anomaly (bilateral PCom hypoplasia).

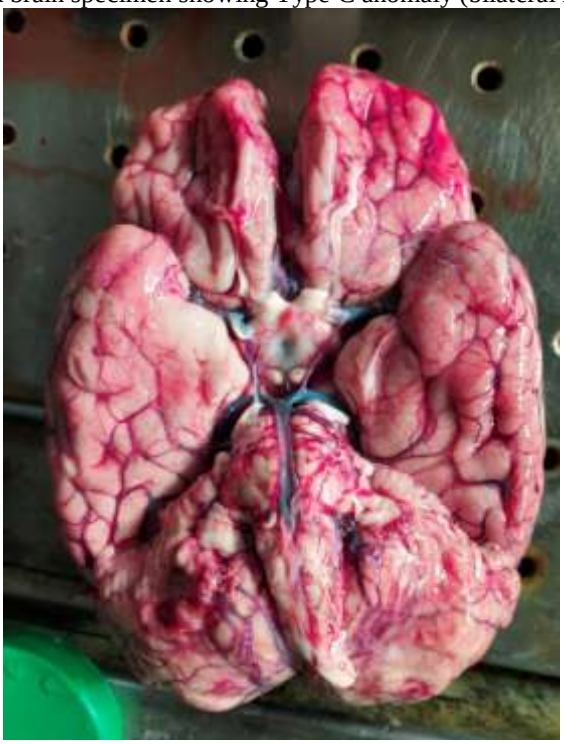


Fig 4:- Post mortem brain specimen showing Type C anomaly (bilateral PCA hypoplasia)

Table 2:- Distribution of anomalies.

Type of COW	Number	Percentage
Type A	9	45%
Type B	2	10%
Type C	4	20%
Type D	2	10%
Type B/D	3	15%

Discussion:-

This is an observational study where the prevalence of anatomical variations of the COW in south Indian population who died following TBI were studied. The prevalence of COW anomalies in general population have come close to 75.72% as per otherstudies [2,4]. The overall prevalence of anomalies in our study is 55%. According to Stojanovi´c et al the anomalies were subdivided into 5 groups and the distribution noted were as follows. Stojanovi´c et al showed that statistically significantly higher presence of asymmetry of the COW compared to normal COW with a significant presence of asymmetric type B ($p < 0.001$). The most common anomaly noted in our study was type C which was seen in 4 cases (20%). The distribution of other types of COW noted in our study was as follows. Type A 9 cases (45%), type B 2 cases (10%), type C 4 cases (20%), type D 2 cases (10%) and type B/D 3 cases (15%) respectively. Literature review highlights other studies analysing the association of anomalies of COW in various diseases like stroke, migraine, blunt cerebrovascular injury, aneurysms and neurosurgical procedures like carotid endarterectomy in addition to TBI. The COW anomaly was found to be associated with worse outcome compared to normal COW. This may imply that abnormal COW contributes to the morbidity and mortality in these diseases stated above. In a study by Fleur van Raamt et al. [5] it was found that in a fetal-type posterior COW patients could be more prone to develop vascular insufficiency in ICA occlusion. In disease like migraine, Brett Cucchiara et al [6] concluded that an incomplete COW is more common in migraine with aura subjects than controls as it is associated with alterations in cerebral blood flow. Mohammed Oumer et al [7] concluded that the presence of any variation in COW was 1.38 times more likely to develop ischemic stroke as compared to the patent COW. The presence of hypoplasia or incompleteness in a PCom and ACom were a contributing factor for the development of ischemic stroke. In Marc A Lazzaro et al [8][9] multivariate analysis revealed a higher risk of aneurysm rupture when a COW anomaly was present. In neurosurgical interventions such as carotid endarterectomiesVarga et al [10] concludes that an incomplete MCA COW anomaly carries more than 10-fold higher risk of immediate neurologic events after carotid endarterectomy with cross-clamping without shunt protection compared to normal COW. In these patients routine shunting is recommended to prevent immediate neurologic events. This study [10] also suggests that as abnormal COW has poor prognosis and elective angiography prior to intervention to identify abnormal COW is advisable. In ageing brains theanomaly of COW was associated with more morbidity as noted byWijesinghe et al [11].Also a significant association was observed between microscopic infarcts in deep white matter and hypoplasia in communicating arteries. Shahan et al [12] showed that COW anatomy has a role in blunt cerebrovascular injury-related stroke where increased collaterals between anterior and posterior circulation is found to be protective. Jones et al [15]quoted that over half of the population exhibit some form of variation in COW and knowing the prevalence of variations and how they can impact neurosurgical approaches or patterns of ischemic pathology can be crucial in providing effective patient care.Since the occurrence of anomalies of COW is not higher than found in general population as demonstrated in other studies [2][4], we presume that anomalies of COW could not be a contributing factor of increased mortality in isolated TBI

Conclusion:-

The COW is nature's way of preserving the blood flow in times of acute insult like stroke and TBI. Various studies have concluded that anomalies of COW are associated with more morbidity and mortality in cases of stroke, aneurysm, migraine and blunt cerebrovascular injury. In our studythe prevalence of anomalies in autopsied cases of isolated TBI is lesser than the general population so that it was indirectly assumed that anomalies of COW may not contribute to increased mortality in isolated TBI. However a study of large number of samples with statistical significance is necessary either to prove or disprove this.

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