# Circle of Willis in adults 

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#### Abstract

Objective: This study was carried out to describe the main variations of the Circle of Willis and to clarify the clinical importance of these variations, so that practitioners and the students are more alert when dealing with this subject.

Methods: This work is based on the study of 50 Circles of Willis from adult Jordanians who died from diverse causes without signs of cerebrovascular diseases. The arteries of these circles are drawn and measured with the aid of a stereoscopic microscope provided with a drawing tube.

Results: Fourteen types of Willis polygonals have been identified among which 13 would be assimilated to polygonals already described in previous studies. The 14th is original and seems proper to our series. We have described wide diversity of variations found within these 14 types of Willis polygonals. We presented the frequency of the different variations and discussed the clinical significance of these variations.

Conclusion: The variations of the Circle of Willis are very common and they may have important influence on the manifestations and treatment of some diseases that are caused by obstruction of one of the arteries that supply the brain.

Keywords: Circle of Willis, variations, adults. Saudi Med J 2001; Vol. 22 (10): 895-898


Variations in anatomy (morphology) may affect every part of the human body. One of the structures that is known to exhibit considerable anatomical variability is the Circle of Willis at the base of the brain. The so called normal Circle of Willis is usually described in textbooks as complete and symmetrical with thread-like posterior communicating arteries. This circle of arterial vessels is extremly variable. Its variations are of clinical importance since they may have important influences on symptomatology, clinical examinations and investigations. Also, a relationship between variations of the Circle of Willis and the sites of aneurysms of arteries of this circle may exist. ${ }^{1-3}$ Despite the fact that the variations of the Circle of Willis are very common and clinically important, they are not usually described in modern textbooks and atlases. The size of the posterior communicating artery ( PCoA ) relative to the precommunicating
segment (P1) of the posterior cerebral artery (PCA) represent the most common variations of the Circle of Willis. These variations were described in many published studies with wide range of percentages. Basically, in adults, 3 configurations of the posterior bifurcation of the PCoA can be distinguished: 1. Adult configuration. The P1 segment of the PCA has a diameter larger than the PCoA with little (or no) blood reaching the postcommunicating segment (P2) of the PCA through the PCoA. 2. Fetal or embryonic configuration. The diameter of the P1 segment is smaller than that of the PCoA and the blood flow to the P2 segment of the PCA is mainly from the internal carotid artery (ICA) through the PCoA. 3. Transitional configuration. Here, the P1 segment and the PCoA have close diameters and have approximately equal blood contribution to the P2 segment. Wide range of percentages of each of these 3 configurations were reported in adults. The

[^0]percentage of the adult configuration ranged from $34 \%-84 \%$. This configuration which is designated as the normal configurations in adults, has been found in approximately $34 \%,{ }^{4} 58 \%,{ }^{5} 63 \%{ }^{3}$ and $84 \% .^{6}$ The percentage of the fetal configuration range from $11 \%-40 \%$. In adult, it has been found in $11 \%,{ }^{7} 13 \%,{ }^{3}$ $14 \%,{ }^{6} 15 \%,{ }^{8} 17 \%,{ }^{9} 22 \%,{ }^{4} 30 \%,{ }^{10} 32 \%{ }^{11}$ and $40 \% .{ }^{5}$ The percentage of the transitional configuration as reported in the published literature ranges from $2 \% \%^{6}-7 \%^{9}$ in adults. To the best of our knowledge, there is no published data regarding the configurations of the posterior bifurcation of the PCoA or other anatomical variations of the Circle of Willis among Jordanians. The aims of this study were 1. To describe the main variations of the Circle of Willis in adult Jordanians and to discuss their clinical importance, and 2. To alert practitioners and students so that they pay more attention to these very common and important variations.

Methods. Circles of Willis of 50 brains from adults aged from 20-55 years were studied. All brains were obtained at autopsy $4-10$ hours post mortem from adult individuals without signs of cerebrovascular diseases. After the brains were immersed in $10 \%$ buffered formalin, the Circles of Willis were studied within 1-2 months. The Circles of Willis were studied for:

Variations of the posterior portion of the Circle of Willis. 1. Absence of one or both of the posterior communicating arteries. 2. Posterior communicating artery hypoplasia (thread-like PCoA). The configuration of the posterior bifurcation of the PCoA was considered as adult if the PCoA was absent or hypoplastic or the diameter of the P1 segment of the PCA was twice (or more) that of the PCoA. 3. Posterior communicating arteries (PCoAs) asymmetry. 4. Hypoplasia of the P1 segment of the PCA. The configuration of the posterior bifurcation of the PCoA was considered as fetal if the P1 segment was hypoplastic or if the diameter of the PCoA was twice (or more) that of the P1 segment. The configuration of the posterior bifurcation of the PCoA was considered as transitional if one of the P1 segment and the PCoA has a diameter less than twice that of the other.5. Precommunicating segment asymmetry. 6. Othervariations.

Variations of the anterior portion of the Circle of Willis. 1. Hypoplasia of the A1 segment of the ACA (the A1 segment is the part of the ACA proximal to the anterior communicating artery). 2. A1 segments asymmetry. 3. Variations of the anterior communicating artery (ACoA). 4. Other variations.

To measure the mean diameter, the arteries were cut perpendicular to their long axis into small pieces at 2 or 3 points under a stereoscopic microscope provided with drawing tube. The outline of these small pieces was drawn, their external longest and shortest diameters were measured and their mean

Table 1 - Variations of the posterior communicating artery ( PCoA ) and the P1 segment of the posterior cerebral artery (PCA).

| Artery | Variations | Total (\%) |
| :--- | :---: | :---: |
| PCoA | Absence <br> Hypoplasia <br> (thread-like) <br> Asymmetry | $13 / 100(13)$ <br> $33 / 100(33)$ |
| P1 segment | Asymmetry <br> Hypoplasia <br> (thread-like) | $12 / 41$ (29) $50(28)$ <br> $1 / 100 \quad(1)$ |
| PCoA=posterior communicating artery, P1=precommunicating segment. |  |  |

Table 2-Variations of the anterior cerebral artery (ACA) and the anterior communicating artery (ACoA).

| Artery | Variations | Total (\%) |
| :---: | :---: | :---: |
| A1 segment | Hypoplasia (thread-like) Asymmetry | $\begin{array}{ll} 4 / 100 & (4) \\ 4 / 50 & (8) \end{array}$ |
| ACA | Branches to contralateral hemisphere | 3/ 50 (6) |
|  | Single | 1/ 50 (2) |
| ACoA | Double | $5 / 50$ (10) |
| A1 segment=part of the ACA proximal to the anterior communicating artery, $\mathrm{ACA}=$ anterior cerebral artery, $\mathrm{ACoA}=$ anterior communicating artery. |  |  |

diameters were then calculated. An artery was considered as hypoplastic artery if its external diameter was less than 1 mm . Paired arteries were considered asymmetrical if the diameter of one of them was twice or more than that of the other.

Results. The so called normal Circle of Willis which is usually described in textbooks as complete, symmetrical and has thread-like posterior communicating arteries (Figure 1a) is present in $20 \%$ ( 10 out of 50 ) of the circles in this study. The remaining 40 circles have variations in the posterior or the anterior portions of the circles, or both. The main variations of the Circle of Willis and their frequency are shown in Figure 1, and Tables 1 and 2. The side of variations was not indicated as none of these variations showed preference to either side. All branches of the Circle of Willis were present in 41 circles. In the remaining 9 circles, one PCoA was


Figure 1 - Main variations of Circle of Willis as found in 50 Jordanians. $\quad \mathrm{B}=$ Basilar artery, $\mathrm{P} 1=$ Precommunicating segment of the posterior cerebral artery, $\mathrm{P} 2=$ Postcommunicating segment of the posterior cerebral artery, $\mathrm{PCoA}=$ Postcommunicating artery, ICA=Internal carotid artery, ACA=Anterior cerebral artery, $\mathrm{A} 1=$ Precommunicating segment of the ACA, $\mathrm{ACoA}=$ Anterior communicating artery.
absent (Figure 1d and 1e) in 5 circles and the 2 posterior communicating arteries were absent (Figure 1c) in 4 circles. The variations of the posterior portion of the circle are shown in Figure 1 and Table 1. In this study, the adult configuration was found in 77 out of 100 sides (side means one side of one circle); the fetal configuration was found in 15 out of 100 sides and transitional configuration was found in 8 sides. In the sides which were considered as adult configurations ( 77 sides), the PCoA was absent (Figure 1c, 1d and 1e) in 13 sides (no blood reaching the PCA from the ICA), hypoplastic (Figure 1j, 1k and 11) in 33 sides (none or little if any blood reaching the PCA from the ICA) and thin (Figure 1b and 1 m ) with a diameter less than half that of the P1 segment in 31 sides (little blood reaching the PCA from the ICA). In the fetal configurations ( 15 sides), 14 sides had thin P1 segment with a diameter less than half that of the PCoA (Figure 1e, 1f and 1g). In one side that has been considered as fetal (Figure 1i), both of the PCoA and the P1 segment were hypoplastic. In this side which seems to be proper to our series, there were 2 additional thin arteries. One of these 2 thin arteries connects the PCA to the junction between the ICA and the middle cerebral artery (MCA) while the other connects the PCA to the MCA. The 2 thin arteries are most probably the
source of most of the blood in the PCA. Therefore, this side has been considered as fetal as most (or all) of the blood in the PCA seems to come either directly or indirecly from the ICA. The posterior communicating arteries were asymmetrical (Figure 1f ad 1 n ) in 12 circles out of 41 circles that have PCoA on both sides. The P1 segments were asymmetrical (Figure 1e, 1f, 1g, 1i and 1n) in 14 circles out of 50 circles. In the circles that have asymmetrical posterior communicating arteries and asymmetrical P1 segments (Figure 1e,f,g,i,n), the primary visual area of the 2 cerebral hemispheres receive blood from different sources; one mainly from the ICA through the PCoA while the other mainly from the basilar artery through the P1 segment. The variations of the anterior portion of the Circle of Willis are shown in Figure 1 and Table 2. Four of the 50 circles have hypoplastic A1 segment on one side (Figure 1 j and 1 k ) leading to A1 segments asymmetry in 4 circles out of 50 . In these 4 circles, the medial surface of the 2 cerebral hemispheres receive their blood completely (or almost completely) from one ICA through one A1 segment. In one circle (Figure 1n), the 2 A 1 segments meet each other in the midline to form a single ACA which divides more distally into 2 branches to supply the 2 cerebral hemispheres. In 3 circles, one or 2 branches arise from one ACA distal to the ACoA, cross the midline to supply the contralateral cerebral hemisphere (Figure 11 and 1 m ). This cerebral hemisphere receives blood through the ACA of both sides.

Discussion. The Circle of Willis from 50 adult Jordanians was studied for morphological variations. Fourteen types of Willis polygonals were found. One of these polygonals seems to be proper to this study. This new polygonal has 3 PCoA. One of these arteries was hypoplastic and connects the posterior cerebral artery with the ICA. The other 2 arteries were thin and connect the PCA with either the MCA or the junction of the last artery with the ICA. The remaining 13 Willis polygonals were previously described. ${ }^{12}$ Concerning the configurations of the posterior bifurcation of the PCoA, the published data shows a wide range of percentages. The percentage of the adult configuration of the posterior bifurcation of the PCoA in adults Jordanians was found in $77 \%$. These results indicate that, in $77 \%$ of cases, the blood in the PCA which supplies the occipital lobe and parts of the temporal lobe, comes from the basilar artery through the P1 segment. The percentage of the adult configuration found in this study was less than the percentage of the adult configuration reported byVan Overbeeke et al ${ }^{6}$ but it is higher than the results reported by others Stehbens et al and Zeal et al. ${ }^{3.5}$ The percentage of the fetal configuration was $15 \%$ and the transitional configuration among Jordanians was $8 \%$. The percentage of the fetal
configuration found in this study came similar or very close to the results reported by Van Overbeeke et al and Alpers et al ${ }^{6,8}$ but it is lower than the results reported by others. ${ }^{4,5,10,11}$ The percentage of the transitional configuration found in this study came close to the results reported by Riggs and Rupp ${ }^{9}$ but it is higher than the results reported by Van Overbeeke et al. ${ }^{6}$ Our results of $33 \%$ hypoplastic PCoA are similar to those reported by Pedrosa et al. ${ }^{4}$ It is interesting to note that, the same Circle of Willis may have different configurations of the posterior bifurcation of the PCoA. For example, the same circle may have adult configuration on one side and fetal configuration on the other side. Therefore, the 2 primary visual areas of the same individual may receive their blood from different sources; one from the basilar artery through the P1 segment (adult configuration) and the other from the ICA through the PCoA (fetal configuration). Thus, obstruction of the basilar artery for example, may damage the primary visual area on one side without damaging the primary visual area of the other side. The results of this study indicate that, the A1 segment of one ACA may provide blood supply to the medial surface of the 2 cerebral hemispheres. Therefore, obstruction of this segment may cause bilateral manifestations. Also bilateral manifestations may occur due to obstruction of a single ACA that provides blood to the 2 cerebral hemispheres. On the other hand, obstruction of an ACA on one side may pass without any serious manifestations if the cerebral hemisphere of that side receives blood from the contralateral ACA.

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    Received 10th December 2000. Accepted for publication in final form 10th April 2001.
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