Anatomic Study of Posterior Communicating Artery in Computed Tomographic Image

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Purpose: This study aims to provide an anatomic data of posterior communicating artery (PComA) and its anatomic relationship to the adjacent structures, so as to guide surgeons in the surgery of internal carotid artery–posterior communicating artery aneurysm clipping and sellar tumors resection without injuring the PComA.
Methods: Computer topographic angiography images of 123 individuals were reviewed, and the measurements were done on coronal, sagittal, axial, and other user-defined planes after multiplanar reconstruction. Posterior communicating artery was classified in the reconstructed three-dimensional image, measured in proper planes, and located by the structures such as anterior clinoid process (ACP), posterior clinoid process (PCP), and sagittal midline.
Results: Six types of PComA were identified in this study based on its existence and origin. The initial part of PComA can be located by ACP, PCP, and sagittal midline based on some particular angles and distances.
Conclusions: Posterior communicating artery varies in different individuals, and the radiologic study of it is an optimal way to analyze the variances. The anatomic relations between PComA and basic skull structures such as the ACP and PCP are especially important for neurosurgeons.

Key Words: ACP, classification, PComA, PCP

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Posterior communicating artery (PComA), a portion of Willis' circle, accounts for the blood supply of pars occipitalis capsulae internae, anterior part of ophthalmic tract, and abdominal cerebral ganglia.[1] Posterior communicating artery originates from the internal carotid artery–posterior communicating artery (ICA-PComA) segment, its tortuous anatomic feature leads a high occurrence rate of aneurysms. The complex shape and deep position of PComA also increase the difficulty of the surgery which requires a precise positioning of PComA such as PComA aneurysms clipping and sellar tumors resecting. Although ICA-PComA aneurysms account for >20% of all intracranial saccular aneurysms nowadays, the neurosurgical interest on these lesions is based on their high incidence.[1] Hence, the anatomic understanding of PComA is important to the neurosurgeons and interventional radiologists. Some cadaver study about PComA showed its great variety in anatomy,[2,3] but the sample volume of the specimen is too small to account for all the variance. The anatomic study in radiologic image, though difficult, can be done after multiplanar reconstruction (MPR).[4] This study used hundreds of computer topographic angiography (CTA) images to locate PComA, analyze its variances, and study its anatomic relationship with adjacent structures such as anterior clinoid process (ACP) and posterior clinoid process (PCP).[5] These data will not only benefit to the surgeons in course of ICA-PComA aneurysms related surgery, but also support the automatic image analysis system, for example, the Slicer.[6]

METHODS

Computer topographic angiography images of 123 individuals (59 men and 64 women) ranging in age from 23 to 80 years (mean 46.1 y) were reviewed. All the CTA images were obtained by the Siemens 64 row spiral computed tomography (CT) (0.625 mm between 2 pictures) in outpatients of the First Hospital of Jilin University. We collected the data in the Work Station of Radiology Department after the CT examination on patients without making any disturbance to their procedure. The electronic record system allowed us to review the image information of all the patients within the past 4 years. The data from the individuals were analyzed anonymously, and the Ethnic Committee of First Hospital of Jilin University had approved this retrospective study. Images displaying PComA aneurysms, ICA-PComA aneurysms, ICA malformations, and other disease which can shift the anatomic structure of PComA (12 of the total 135) were excluded from this study. The measurement was on coronal, sagittal, axial planes, and other user-defined plane after MPR, the user-friendly system makes it possible to view any section of the brain tissue and skull.

Posterior communicating artery was classified into 6 types according its existence and origin in the reconstructed three-dimensional images (Fig. 1), the criterion of the classification was in the figure legend. The length and diameter of ICA-PComA segment of ICA can be measured in the plane through the direction of PComA (Fig. 2A, B). Proper plane was selected to measure the angle between ICA and the initial part of PComA (Fig. 2C). The distance between ACP and the initial part of PComA was measured in the plane through both of them (Fig. 2D). The distance between initial part of PComA and the sagittal midline of sellar floor was measured the coronal plane (Fig. 2E). In addition, the diameter and position of

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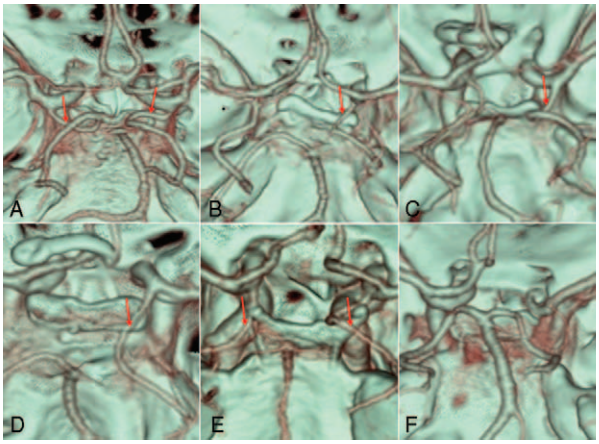

FIGURE 1. The classification of posterior communicating artery (PComA): A, the individual has bilateral PComA; B, the individual has single PComA; C, the individual has bilateral PComA one of which is directly continue to the PComA; D, the individual has single PComA which is directly continue to the PComA; E, the individual has bilateral PComA, both sides are directly continue to the PComA; F, the individual totally without PComA.

ICA-PComA segment and PComA were measured in the coronal plane through PCP (Fig. 2F).

Statistics were generated with SPSS (Version 16.0; SPSS Inc, IBM, Armonk, NY).

RESULTS

Posterior communicating artery can be seen clearly in the reconstructed three-dimensional image of CTA; the shape and the length of it vary in different individuals. Initially, the occurrence rate of PComA in single and both sides was listed in Table 1 (Fig. 1). The shapes of PComA are also various in different individuals, some people have a shape of straight whereas others curve—the percentage of each was 61.5% and 38.5%, respectively. 60.2% of PComA were straight enough for the measurement of the length, which were 11.51 ± 1.21 mm in the right and 11.53 ± 1.09 mm in the left. No significant difference was found between the right and left for $P > 0.05$. The diameter was 1.55 ± 0.46 mm in the right and 1.48 ± 0.41 mm in the left. The angle between ICA and the initial part of PComA was $74.65^\circ \pm 4.01^\circ$ in the right and $74.44^\circ \pm 4.49^\circ$ in the left. The distance between ACP and the initial part of PComA was 7.91 ± 1.23 mm in the right and 8.06 ± 1.16 mm in the left (The angle in the sagittal plane was $13.80^\circ \pm 1.35^\circ$ in the right and $13.66^\circ \pm 1.44^\circ$ in the left. The angle in the axial plane was $13.48^\circ \pm 3.87^\circ$ in the right and $13.31^\circ \pm 4.01^\circ$ in the left). The distance between the initial part of PComA and PCP was 3.15 ± 0.71 mm in the right and 3.06 ± 0.65 mm in the left. The diameter of C7 segment of ICA was 3.45 ± 0.56 mm in the right and 3.69 ± 0.51 mm in the left. The diameter of vertebral artery was 3.45 ± 0.55 mm. Parson showed no significant relations between the diameter of PComA and C7 segment of ICA, and no significant relations between the diameter of PComA and vertebral artery. The distance between the initial part of PComA and the sagittal midline was 11.41 ± 1.23 mm in the right and 11.69 ± 1.21 mm in the left.

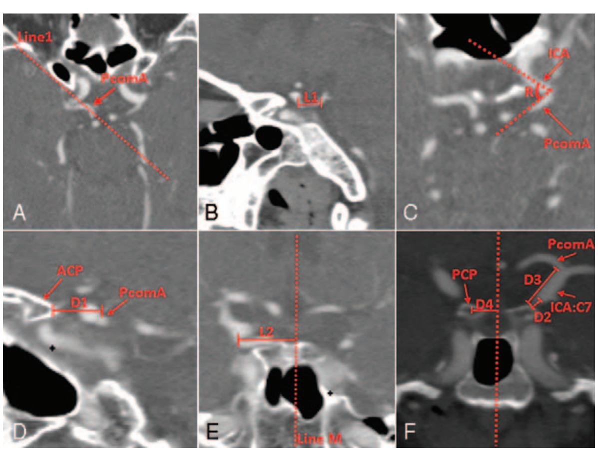

FIGURE 2. The measurement of PcomA and related structures: A, B, measurement of the length of the PComA. Line 1, the positional description of the plane in B. PComA, posterior communicating artery. B, L1: the length of the PComA; C, the angle between ICA and the initial part of PComA. ICA, internal carotid artery; PComA, posterior communicating artery; R, the angle between ICA and the initial part of PComA. D, The distance between ACP and the initial part of PComA. ACP, anterior clinoid process; PComA, posterior communicating artery; D1, the distance between ACP and the initial part of PComA. E, The distance between initial part of PComA and the sagittal midline of sella floor (SF). Line M, the midline of SF; L2, the distance between initial part of PcomA and the sagittal midline of SF. F, ICA in the position of coronal plane through PCP. Line M, the midline of sella floor; D2, distance between PCP and C7 segment of ICA; D3, distance between PCP and the initial portion of PcomA; D4, distance between PCP and sagittal midline.

TABLE 1. The Occurrence Rate and Type of PcomA

Type of Side	N (%)	In Individuals	N (%)
Have	120	Type A	38
Absence	98	Type B	41
ACP continued	18	Type C	3
		Type D	3
		Type E	6
		Type F	32

Type A: the individual has bilateral PComA.
Type B: the individual has single PComA.
Type C: the individual has bilateral PComA, one side is directly continue to the PComA.
Type D: the individual has single PComA which is directly continue to the PComA.
Type E: the individual has bilateral PComA, both side are directly continue to the PComA.
Type F: the individual totally without PComA.

DISCUSSION

The radiologic study of PComA is difficult because of the irregular position and various shape, so there is rarely report and literature about it. In our MPR image research, after the C7 segment of ICA was found in axial plane, the initial part of PComA can be seen from ICA to the direction to the inner backward, the diameter of which is nearly a quarter of ICA. Posterior communicating artery connects the blood flow of ICA and vertebral artery to balance the blood supply of the brain.[7] Its deep position in the dorsum sellae and various shape make the surgical approach difficult to neurosurgeons. The anatomic understanding of PComA hence has the clinical meanings as follows: first, guiding the surgeons in the surgical and interventional treatment of PComA aneurysm; second, avoiding the injury of PComA in the process of sellar tumor resection; and third, providing basic data for the automatic image analysis system.

The Posterior Communicating Artery Aneurysm Clipping

Posterior communicating artery aneurysm, which accounts for >20% of all intracranial saccular aneurysms, possesses complex and variable anatomic features, making the microsurgical approach hazardous and dangerous in some cases. The aneurysm is likely developed in the initial part of the PComA called ICA-PComA aneurysms.[8–10] Nowadays, the treatment includes the opening surgery and the intervention therapy.[11–13] Either method needs an accurate location of the initial part of PComA, especially in the opening surgery via extended endoscopic endonasal approaches.[14–16] Because Kassam et al[17] published the first case of cerebral aneurysm clipping via the nose, authors published cases of vertebral, basilar, and vertebral-posterior inferior cerebellar arteries aneurysms treated through endoscopic endonasal.[18,19] The endoscopic endonasal surgery applied to vascular lesions, though minimally invasive, has some disadvantages such as the limitation of the operational space, the lack of three-dimensional effect in two-dimensional image, and image distortion. So, a comprehensive anatomic study of PComA is needed. Most of the PComA was originated from the medial wall or inferior medial wall of superclinoid segment of ICA, the position is closely related to the bony structures such as the ACP and PCP—the ACP is located in the anterior part of the sellar region.[20] The anterior clinoidectomy is frequently reported in the previous literature for a better view for the operation to the paraclinoid aneurysms.[21–23] During the procedure to the PComA, the measurement of the distance between ACP and initial part of PComA is a good method to find the PComA aneurysm in visualization and in neuronavigation image. The anatomic study of ACP and adjacent structures had been done by Cheng et al.[24] According to our study, ACP can be a landmark to find the initial part of the PComA. From the tip of ACP, the initial part of PComA can be found in the direction of $13.48^\circ \pm 3.87^\circ$ in the axial plane and $13.80^\circ \pm 1.35^\circ$ in the sagittal plane; however, the direct distance is 7.91 ± 1.23 mm.

As for the interventional therapy, the endovascular clipping has the advantage of minimal invasion and low bleeding, but the major disadvantage is that the catheter is not easy to reach the accurate position of PComA and the catheter also cannot be changed or removed once deployed; once the stent inserted, it is not possible to pull it out again.[7] Although the digital subtraction angiography image can be used in the navigation, the image is low in resolution and poor in three-dimensional visualization. In addition, when the tip of the catheter reaching the initial part of the PComA, the direction adjusting of the catheter is another challenging[25] task to enter the PComA from ICA. Our study measured the angle between ICA and the initial part of PComA which means the direction of tip of catheter should turn in 74. $65^\circ \pm 4.01^\circ$ to adjust to enter the PComA.

The Sellar Tumor Resection

The sellar tumor, sella durosarcoma, and trigeminal neurinoma may be closely related to the PComA because of the position. During the resection of these tumors, the PComA can be injured because of its various position in different individuals.[26] Posterior communicating artery is also closely related to some basic skull structures, especially the ACP, PCP, dorsum sellae, and dural folds, that extend between the clinoid processes, sphenoid bone, and petrous apex.[1] The positioning of PComA will not only benefit to the aneurysm clipping, but also help to avoid injuring the PComA. Posterior clinoid process is a stationary structure which can be easily located in the endoscopic transsphenoidal surgery, and PComA is just in the posterior superior side of the tip of PCP. The distance was 3.45 ± 0.56 mm according to our research. During the tumor resection in sellar region, it is better to take this distance into consideration to avoid the injury of PComA. In addition, when the PComA was traced from the midline, the distance should be 11.41 ± 1.23 mm in the right and 11.69 ± 1.21 mm in the left.

Basic Data for Automatic Image Analysis System

CTA and digital subtraction angiography images are used in preoperative planning in intraoperative neuronavigation of vascular disease of neuron system. Surgeons used to design the surgical data such as the fenestration width and penetration depth by manual measurement of these images. In 2013, Egger et al[6] first describe an automatic system to tumor segmentation and surgical data computation using a software called Slicer. The volume of the pituitary gland has been successfully computed by the three-dimensional Slicer in a high efficiency than manual operation.[27] In the developing stage of this technology, the algorithm can be enhanced with statistical information about the shape and the texture of the desired object.[28] With the first report of three-dimensional image computing of the cerebral vessels,[29] the data about the PComA will be surely used in the future in the automatic imaging computing preoperatively even intraoperatively. The anatomic features of the PComA are listed as follows.

Initially, the occurrence of PComA in our study showed that 50.84% of side has the PComA. The result is similar to Yang et al's[30] result, the difference may be caused by the deviation of CTA image when the contrast agent cannot through the PComA in the case of extremely thin vessel. When considering the individuals, a person with bilateral PComA is 30.89%, the occurrence rate of PComA may be related to the congenital development and blood supply of posterior cerebral artery and the branches. The angle between ICA and PComA was measured in the plane through both ICA and initial part of PComA. The straight angle enhances the impact of blood flow which makes the formation of an aneurysms in the initial part of the PComA. The length of PComA is 11.51 ± 1.21 mm in the right side and 11.53 ± 1.09 mm in the left side, which is similar to the measurement in the cadaver reported by Yang et al[30] which means the practicability of CT image. No relationship was found between diameter of PComA and ICA or vertebral artery. Thus, the diameter of PComA may be related to the perforating branch and congenital development.

CONCLUSION

Posterior communicating artery varies in different individuals, and the radiologic study of it is an optimal way to analyze the variances. The anatomic relations between PComA and basic skull structures such as the ACP and PCP are especially important for neurosurgeons.

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