Indian Journal of Clinical Anatomy and Physiology 2023;10(4):265–274

Content available at: https://www.ipinnovative.com/open-access-journals

Indian Journal of Clinical Anatomy and Physiology

Journal homepage: https://www.ijcap.org/

Case Report

Cluster of variations involving vertebral, renal, and obturator arteries in a single human body- A cadaveric case report

Sankaranarayanan Govindarajan[1], Rajasekhar SSSN[2]*, Kalaivani Kaliyamoorthy[2]

[1]*Dept. of Anatomy, Saveetha Medical College, Chennai, Tamil Nadu, India*
[2]*Dept. of Anatomy, Jawaharlal Institute of Postgraduate Medical Education and Research Institute (JIPMER), Puducherry, India*

ARTICLE INFO

Article history:
Received 07-12-2023
Accepted 12-12-2023
Available online 20-01-2024

Keywords:
Accessory renal artery
Hypoplastic vertebral artery
Obturator artery
Posterior inferior cerebellar artery
Testicular artery

ABSTRACT

We describe a unique triad of arterial variations that include vertebral, renal, and obturator arteries in a single cadaver. A combination of arterial variations was observed in a 60-year male; formalin embalmed cadaver during the routine dissection while teaching undergraduate students. The origin, course, branching pattern, and termination of the vertebral, renal, and obturator arterial systems were noted, along with the vessels' diameter close to their origin. The following variations were observed: a) Hypoplastic V4 segment of the right vertebral artery; Right Posterior Inferior Cerebellar artery had a relatively proximal origin from the V4 segment of vertebral artery and coursed in an inverted 'U' shaped manner cranially, which resembled duplicated V4 segment of the right vertebral artery, b) Right accessory renal artery originated from abdominal aorta distal to the right renal artery and the right gonadal artery originated from the right accessory renal artery, c) Right obturator artery originated from the posterior division of the right internal iliac artery, and the left obturator artery originated from the trunk of the left external iliac artery. Such a combination of variations in the anatomy of vertebral, renal, and obturator arteries was not reported previously. This case report will interest neurosurgeons and radiologists because of the possibility of concomitant arterial variations.

1. Introduction

Variations in the arterial supply of a single organ, such as the renal artery (RA), are common and are extensively reported. However, concomitant variations in the arterial supply of multiple organs are rare. Furthermore, if multiple arterial variations are noticed on the same side, the cause of such variations may be due to the initial disturbances in the arterial primordia and signalling cascades in the embryonic stage. The vertebrobasilar system is formed by two vertebral arteries (VA) branching from the first part of the subclavian artery (SCA) on each side. The vertebrobasilar system provides most of the blood supply to the posterior part of the cerebrum, cerebellum, and brainstem. And any pathology in this system results in ocular, vestibular, cerebellar, and brain stem dysfunction. The posterior inferior cerebellar artery (PICA) arises from the V4 segment of VA.

The PICA is further subdivided into five segments: (1) the anterior medullary segment, (2) the lateral medullary segment, (3) the tonsillomedullary segment, (4) the telovelotonsillar segment, (5) the cortical segment.[1]

The presence of an additional RA originating from the abdominal aorta and entering the kidney through the hilum is termed an accessory renal artery (ARA).[2] The variation in renal vasculature may be responsible for the haemorrhage during surgical procedures like nephrectomy, renal transplantation, and secondary hypertension. Variant origin and anastomosis of the obturator artery (OA)

* *Corresponding author*.
E-mail address: sekhar5883@gmail.com (Rajasekhar SSSN).

https://doi.org/10.18231/j.ijcap.2023.059

play an essential role in hernia repair surgery as it is frequently damaged. Thence, notifying the multiple arterial variations in a single body develops the knowledge base regarding concomitant arterial variations. Such a database will help the surgeons who encounter an arterial variation to anticipate concomitant arterial variations and plan the surgery accordingly to avoid compromise in arterial supply. Though individual arterial variations are not uncommon, we report a novel combination of arterial variations involving VA, RA, and OA in a single human body.

2. Case Report

Variations in multiple arteries were observed in a 60-year-old male formalin embalmed cadaver during the routine dissection for undergraduates. The origin, course, branching pattern, external diameter, and termination of the variant vessels were noted.

2.1. Vertebral artery

During the dissection of the brain, a hypoplastic V4 segment of the VA was found on the right side. At 4.5 mm above the superior border of the posterior arch of the atlas, the right PICA was found to be arising from the V4 segment of the right VA. The anterior medullary segment of right PICA ascended lateral to the V4 segment of right VA cranially for 5.6mm and had taken a 'U-turn posteroinferiorly with a convexity cranially and descended downwards and posteriorly (lateral medullary segment of PICA) towards the inferior surface of the cerebellum to supply cerebellum. The diameter of the right PICA was measured to be 1.50mm near its origin from the right VA and 1.43mm before its branching that supplied the cerebellum. The origin and initial course of the right PICA (anterior medullary segment) resembled that of the fenestrated V4 segment of the right VA near its origin owing to its ascending course adjacent to the right VA. The course of the artery was traced further and the vessel was verified to be right PICA. The diameter of the V4 segment of the right VA proximal to the origin of the right PICA was 1.67mm and distal to the origin of the right PICA was 1.51mm (Figures 2 and 1). After the origin of the right PICA, the V4 segment of the Right VA has a significant reduction in diameter (Figure 3) and passed cranially to unite with the left VA to form the basilar artery (BA) (diameter of BA: 3.82mm). The BA had an unusual course, where is passed in a curvilinear manner to the right of the midline, grooving the ventral surface of the brain. Figure 4 shows the basilar groove on the ventral surface of the pons 2mm lateral to the midline towards the right. The course and branching pattern of the V4 segment of the Left VA were normal. When measured proximal to the origin of the Left PICA, the diameter of the V4 segment of the left VA was 3.45mm and 2.38mm, when measured distal to the origin of the Left PICA. The diameter of the left PICA was measured to be 1.98mm near its origin and 1.72mm just before its branching to supply the cerebellum.

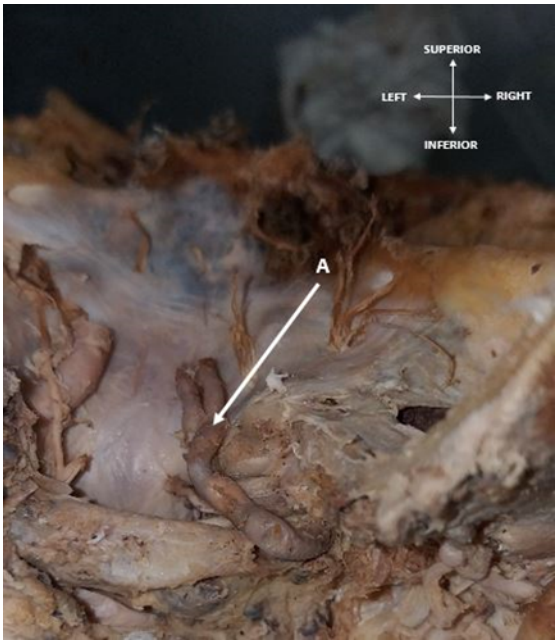

Figure 1: Shows the dissection of posterior aspect of atlas vertebra with V3 & V4 segments of right VA and normal left VA. A – R-PICA resembling duplicated V4 segment of the right VA

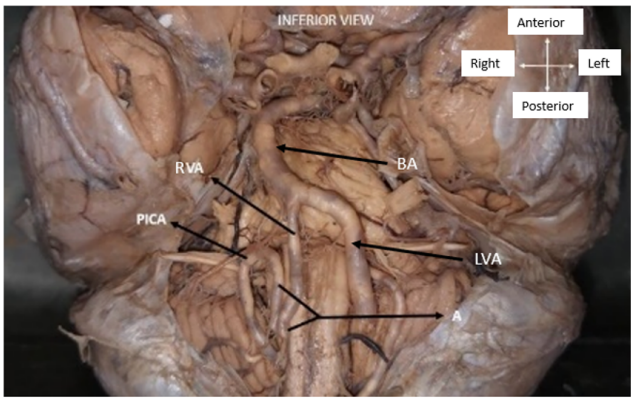

Figure 2: Shows the dissection of ventral aspect of brain stem specimen with their blood vessels. Right VA is hypoplastic above the arch of atlas vertebra and continues as VA proper and gives right PICA. A – R-PICA resembling duplicated right VA

2.2. Renal artery

During the abdominal dissection, the variation in the right renal blood supply was observed in the same cadaver. In addition to the right renal RA, an ARA was observed to be originating from the aorta on the right side. The aortic origin of RA was observed at the upper border of the L2 vertebra.

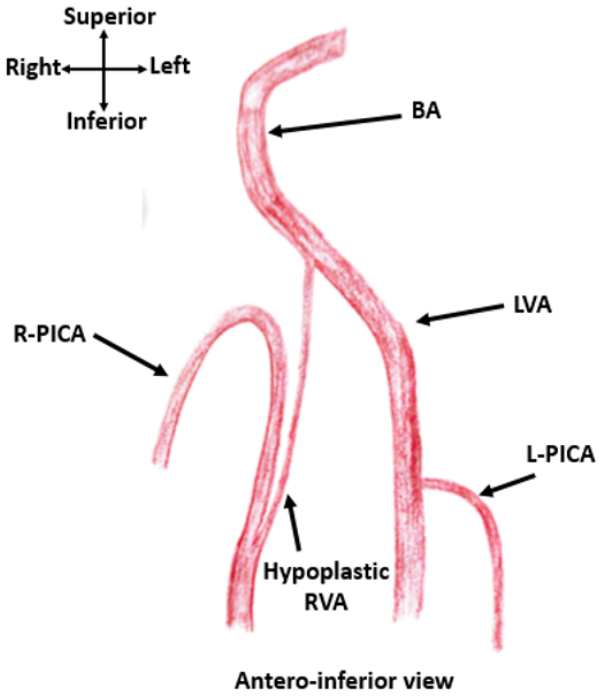

Figure 3: Shows the schematic diagram of hypoplastic V4 segment of the right VA. BA – Basilar artery, RVA – Right vertebral artery, LVA – Left vertebral artery, R-PICA –Right posterior inferior cerebellar artery, L-PICA – Left posterior inferior cerebellar artery

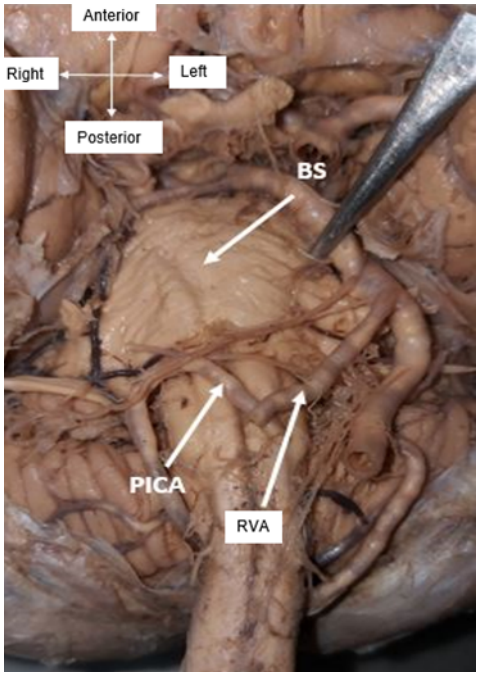

Figure 4: Shows the dissection of the ventral aspect of brain stem specimen with their blood vessels. RVA proper join with the left VA to form the BA in front of the pons. BA and its basilar sulcus are deviated towards the right side. BS – Basilar sulcus, PICA –Right posterior inferior cerebellar artery

The length of the right RA was 65.25mm measured from its aortic origin to its point of division into segmental branches. The diameter of the right RA was 5.12mm, measured near its aortic origin. After the aortic origin, the right RA had coursed anteriorly to the psoas major muscle and posterior to the inferior vena cava and the right renal vein to reach the hilum of the kidney, posterosuperior to the right renal vein (Figure 5). The ARA on the right side originated from the aorta 3.52mm distal to the origin of right RA from the aorta, at the level of the body of L2 vertebra. The ARA on the right side was 65.77mm long. The external diameter of ARA near its origin from the aorta was 4.05mm (Figure 5). After its origin the ARA coursed anteriorly to the psoas major muscle and posterior to the IVC and right renal vein to reach the hilum of the kidney, posteroinferior to the right renal vein. The right gonadal artery (GA) originated from the right ARA, 22.75mm lateral to the aortic origin of ARA. After their origin, the right GA coursed in front of the psoas major and behind the parietal peritoneum to reach the testis in the scrotum. The length of the left RA from the aortic origin to its segmental branches was 64.25mm. The external diameter of the left RA near the aortic origin was 4.95mm. The left GA originated from the left RA 28.53mm lateral to the aortic origin of the left RA and had a normal course and termination. Figure 6 shows the schematic diagram of the right ARA with the origin of the right GA.

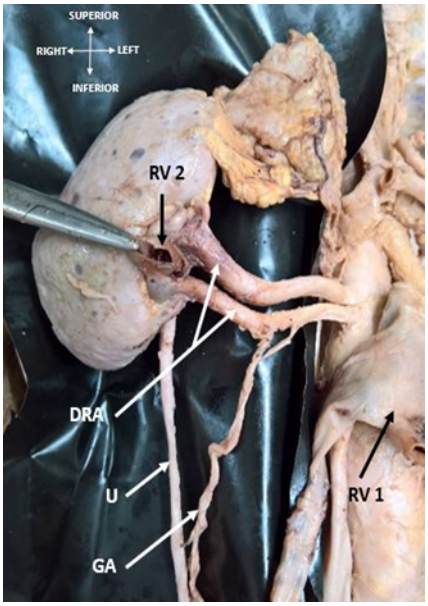

Figure 5: Shows the dissection of right-sided abdominal organs like kidney with their blood vessels, ureter, suprarenal gland, reflected renal vein, abdominal aorta, and gonadal vessels. Two renal arteries are arising from the aorta to supply the right kidney entering through their hilum (proximal and distal). Right-sided GA arising from the right distal RA. DRA – Double renal artery, GA – Gonadal artery, RV 1&2 – Reflected renal vein, U – Ureter

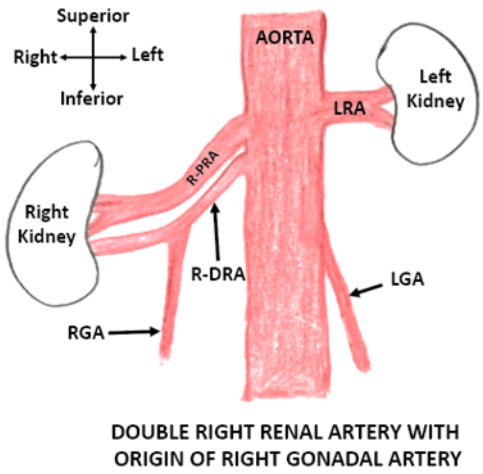

Figure 6: Shows the schematic diagram of two RA on the right side (proximal and distal) with the origin of right GA (Testicular) from the distal RA. LRA – Left renal artery, LGA – Left gonadal artery, RGA – Right gonadal artery, R-PRA – Right proximal renal artery, R-DRA – Right distal renal artery

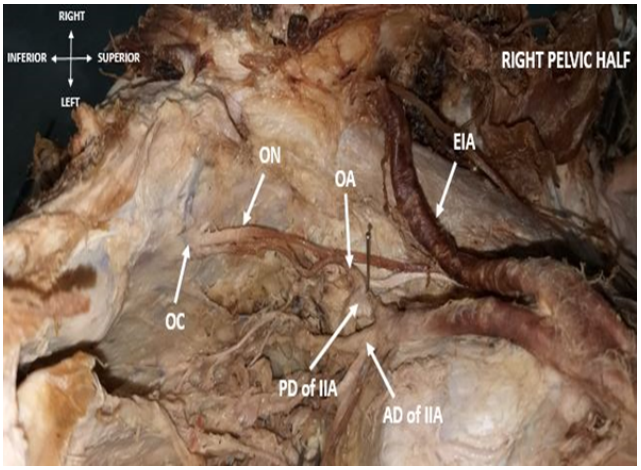

Figure 7: Shows the dissection of right pelvis with branches of IIA. OA on the right side arising from the posterior division of IIA to enter into the obturator canal along with the obturator nerve. EIA – External iliac artery, AD of IIA – Anterior division of internal iliac artery, PD of IIA – Posterior division of internal iliac artery, OA – Obturator artery, ON – Obturator nerve, OC – Obturator canal

2.3. Obturator artery

During the deep dissection of the pelvis in the same cadaver, variations in the origin of the OA were observed on both sides of the pelvis. While tracing the branches of the internal iliac artery (IIA) on the right side, the OA was found to be arising from the posterior division of IIA at 6mm distal to the division of IIA into anterior and posterior divisions (Figure 7). It passed on the right lateral pelvic wall with the accompanying obturator nerve. It entered the obturator canal to supply the muscles of the medial compartment of the right thigh. The external diameter of the right OA was measured as 2.1mm near its origin from the posterior division of IIA. Figure 8 shows the schematic diagram of the right OA arising from the posterior division of the right IIA.

On the left side, the OA arose from the trunk of the left EIA at the level of origin of the deep circumflex iliac artery (Figure 9). The left OA passed on the left lateral pelvic wall with the accompanying obturator nerve. Subsequently, the left OA entered the obturator canal to supply the muscles of the medial compartment of the left thigh. The external diameter of the left OA was measured as 2.6mm near its origin from the left EIA. Figure 10 shows the schematic diagram of the left OA originating from the trunk of the left EIA (Aberrant obturator artery, AOA). Except for the origin, there were no variations in the course, branches, and termination of the OA on both sides. And there was no enlargement of the pubic branch of the left OA after its origin from EIA.

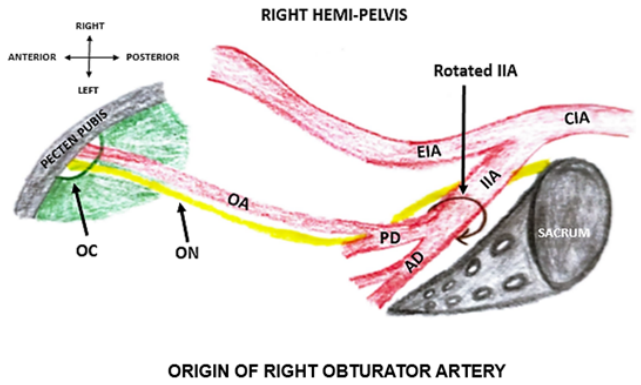

Figure 8: shows the schematic diagram of right OA originating from the posterior division of IIA. CIA - Common iliac artery, EIA – External iliac artery, IIA – Internal iliac artery, AD – Anterior division of Internal iliac artery, PD – Posterior division of Internal iliac artery, ON – Obturator nerve, OA – Obturator artery, OF – Obturator foramen

3. Discussion

Embryological basis for the multiple unilateral arterial variations in a single body: In a developing human embryo, vascular system development involves two processes, such as vasculogenesis followed by angiogenesis.[3,4] During vasculogenesis, the island of hematopoietic stem cells differentiates into primitive blood vessels. During angiogenesis, the stalk cells at the end of primitive blood vessels give rise to new cells for lengthening, further repair, and remodelling into definitive blood vessels.[3,4]

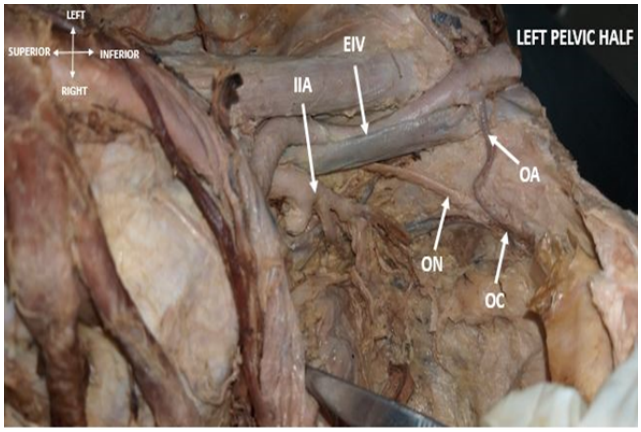

Figure 9: Shows the dissection of left pelvis with branches of left IIA. OA on the left side arising from the left external iliac artery at the level of circumflex iliac artery enters into the obturator canal along with the obturator nerve. IIA –Internal iliac artery, EIV – External iliac vein, ON – Obturator nerve, OA –Obturator artery, OC – Obturator canal

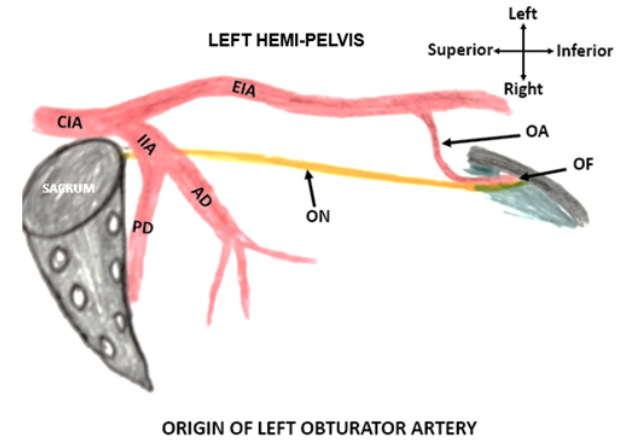

Figure 10: Shows the schematic diagram of left OA originating from the trunk of EIA. CIA –Common iliac artery, EIA – External iliac artery, IIA - Internal iliac artery, AD – Anterior division of internal iliac artery, PD – Posterior division of internal iliac artery, ON – Obturator nerve, OA – obturator artery, OF – Obturator foramen

This complex vascular development needs the sequence of signalling cascades to stimulate neural crest cells (NCC), which commit themselves to the formation of the proximal part of great vessels (e.g., derivatives of aortic arches).[5] The peripheral vascular system is mostly developed from the differentiation of local mesenchymal cells stimulated by the signalling pathway with the help of multiple growth factors and their receptors.[5,6] Any disturbances in the regulation of signalling cascades might be the reason for multiple variations in the vascular system in a single human body. Similarly, the disturbances during vasculogenesis or angiogenesis or signalling cascades, or receptor and growth factor interactions on one side of the body may influence the arterial primordia on that side of the body, which may result in multiple arterial variations on the same side of the body. This might be the reason for multiple arterial variations noticed predominantly on the right side of the body in the present case.

3.1. Vertebral artery

Embryological basis for hypoplastic arteries in the vertebrobasilar system: The primitive dorsal aorta presents plexiform and longitudinal anastomotic connections between the cervical intersegmental arteries. These connections, around the 32^{nd}- 40^{th} day of embryonic life, coalesce to form VA. Persistent vertebrobasilar anastomosis after 5th week of embryonic life is said to be a probable cause for duplication and hypoplastic VA.[7]

Normally, the V4 segment of the VA enters the cranial cavity through the foramen magnum and ascends the ventral to the anteroinferior surface of the brain stem. Here, it gives rise to PICA before joining with the VA of the opposite side, to form the BA, at the pontomedullary junction. Further, the BA ascends the ventral surface of the pons grooving its midline to form the basilar sulcus. In the present case, the right VA gave rise to PICA and subsequently became hypoplastic. The PICA ascended adjacent to the right VA for some distance before taking an inverted U-turn to course posteroinferiorly and supply the cerebellum. The variations of VA such as aneurysmal VA, fenestrated VA, hypoplastic VA, double VA, partial duplication of the VA, and looping of the VA at varying levels of cervical vertebrae have been reported earlier.[8,9] The normal diameter of VA ranges between 3 to 5mm.

The vertebral artery is designated as hypoplastic if the diameter is <2.2mm or the VA artery volume flow is <30-40mL/min in duplex ultrasound.[10] Asymmetry among right and left VA exists in about 75% of individuals. And the right VA is smaller in caliber than the left VA.[11] In the present study, we noted that the diameter of the V4 segment of the right VA measured proximal (1.67mm) and distal (1.51mm) to the origin of the PICA was lesser than 2.2mm. However, the diameter of the V4 segment of the left VA proximal (3.45mm) and distal (2.38mm) to the origin of the left PICA was above 2.2mm and within the normal range. In the present study, the diameter of the right VA proximal to the origin of PICA was smaller compared to the corresponding part on the left side. Sato et al. reported that the diameter of the hypoplastic left VA was 2.8 mm and the diameter of the right VA was 4.2 mm, with a difference of 1.4mm.[12] In the present case, the hypoplastic V4 segment of the right VA was 1.67mm which was narrower than the diameter of the hypoplastic VA reported by Sato et al., albeit on the right side.[12]

Sarah et al. compared the PICA bilaterally between the genders(n=100), by using CT angiography. They reported that the diameter of the right PICA ranged from 1.12 to 2.4mm and the diameter of the left PICA ranged from 1.13 to 2.37 mm. The range of diameter of PICA in males was 1.13 to 2.37mm and in females was 1.11 to 2.35 mm. Of the 100 subjects studied, 16% presented unilateral aplasia of PICA, 3% bilateral aplasia of PICA, 10% presented hypoplasia of right PICA and 6% presented hypoplasia of left PICA.[11] In the present case, we observed that the diameter of the right PICA was 1.50mm near the origin and 1.43 mm near the termination of the V4 segment of the right VA. The diameter of the left PICA was 1.98 mm near the origin and 1.72 mm near the termination of the V4 segment of the left VA. In the present case, the diameters of PICA near the origin of the V4 segment of VA on both sides were found to be within the normal range and in agreement with the findings of Sarah et al.[13]

Right and left VAs fuse to form BA. The normal diameter of the basilar artery ranges from 3 to 4.5 mm.[14] In the present study, the hypoplastic V4 segment of the right VA after giving the right PICA passed cranially and united with the left VA 2mm right of the midline to form BA (diameter of 3.82mm). Although the BA was found to have a normal diameter, it coursed in the right lateral plane of the pons in a curvilinear fashion, indenting the anteroinferior surface of the pons. The probable reasons for such a curvilinear course and corresponding indentation of the subjacent pontine surface may be speculated as follows: a) the flow velocity of blood from the right VA entering into the BA will be low due to the hypoplasia; b) the majority of the blood in the BA will be filled from the left VA with a high flow velocity. Thence the flow velocity of blood from the Left VA into the BA dominates the flow velocity of blood from the right side and creates a vector of blood that pushes the right wall of BA towards the right, leading to the formation of a curvilinear BA towards the right side, as in the present case. Such a curvilinear BA may pose a risk of compression of the superficially located pontine nuclei.

Chuang YM et al studied the MRI of 158 hemispheric ischemic stroke and 33 brainstem ischemic stroke cases and reported that the incidence of unilateral hypoplastic VA is 11.51%, with right-sided predominance.[15] Sato et al. reported a hypoplastic left VA with the majority of the blood going from the left VA to the Left PICA despite the existing connections between the left VA and BA.[12]

Gaskill et al. reported a fenestrated left VA.[8] Rajasekhar et al. reported a case of hypoplastic and duplicated V4 segment of the right VA associated with a duplicated right anterior inferior cerebellar artery.[16] It was observed that, in case of duplication of the VA, one artery usually arises from the SCA; while the other artery arises either from SCA, aorta, thyrocervical trunk, or innominate trunk; or both arteries may arise from the aorta.[17] In the present case, Right PICA originated from the right VA, 4.5mm above the C1 vertebra. After its origin, the right PICA coursed alongside the right VA for some distance giving the initial impression of a fenestrated right VA. However, when traced distally, the right PICA took an inverted 'U' shaped bend with a convexity cranially and turned downwards towards the cerebellum, which resembled a large fenestration or a duplicated middle segment of the V4 segment of the right VA. However, the identity of the vessel is confirmed as right PICA, especially after tracing its course distal to the inverted 'U" shaped bend of right PICA. George et al. reported that 40% of individuals had a larger VA diameter on one side (dominant VA) compared to the other side. It was also reported that the hypoplastic VA joins with the contralateral VA to form the BA or ends as a PICA or occipital artery.[18] In the present case, the left VA was unusually large, and its caliber (diameter) was almost equal to the BA and is similar to the description by George et al.[18]

The blood flow within the VA depends on the actual stroke volume, cardiac venous return, and respiratory movements. These factors in turn are influenced by various environmental factors such as old age (> 60 years), male predominance, hypertension, and hyperlipidaemia. Hypoplastic VA with reduced caliber predisposes to a decrease in the mean blood flow in terms of volume and velocities. Thus, the hypoplastic VA is having more tendency for a prothrombotic or atherosclerotic state than the normal VA causing stenosis or occlusion.[19] In the present case, distal to the origin of the right PICA, the right VA was hypoplastic and joined with the contralateral VA to form the BA. Hypoplasia of the VA may lead to reduced blood circulation in the posterior part of the cranial fossa compared to the anterior and may serve as an independent predisposing factor for the posterior circulation stroke,[13] as in the present case. The bloodstream in PICA can aid in the differentiation between the various types of origin of PICA (i.e. whether it is dual PICA or PICA from the fenestrated intracranial VA). If the origin of PICA is from fenestrated VA, then the blood flow will be towards the basilar system; and if the PICA has duplicated origin (ie. Proximal limb and distal limb), then blood flow is towards the distal limb of PICA (PICA is getting completed by its corresponding anastomosis).[20]

The knowledge about the variant VA is vital for head positioning to avoid arterial damage during head and neck surgeries such as atlantoaxial spinal instrumentation, the dorsal approach of cervical spines, surgeries of posterior cranial fossa, and CT angiographies.[7,16,18] The VA is commonly an injured vessel during cervical spine injuries (subluxation, deceleration, and fracture transverse foramen) and may be fatal.[21] Hypoperfusion due to hypoplastic vertebral arteries cause ischemic injury to the brainstem and cerebellum.[16] The altered hemodynamics in the duplicated vessels cause turbulence, thereby increasing the risk of

cerebrovascular accidents, aneurysms, and dissection.[21] Apart from the V4 segment of VA, PICA also rarely originates from the cavernous part of the internal carotid artery (ICA) (persistent trigeminal artery), the cervical segment of ICA (persistent hypoglossal artery), and from ascending pharyngeal artery. With the latter two varieties of origin, the PICA enters the cranial cavity through the hypoglossal canal or jugular foramen, respectively. Recognition of such variations and the clinical importance of PICA is mandatory for the neurosurgeon to avoid ischemic or iatrogenic injury to the cerebellum during head & neck, neuro surgeries, and endovascular therapy.[22]

3.2. Renal artery

3.2.1. Embryological basis for the variations of renal arteries

The primitive mesonephric arteries on either side of the abdominal aorta between the C6 and L3 vertebrae form a vascular network, "rete arteriosum urogenitale".[23] The mesonephric arteries are of nine pairs, arising from the dorsal aorta, and were divided into cranial (1 & 2 pairs), middle (3 to 5 pairs), and caudal groups (6 to 9 pairs).[24] The RA usually arises from the middle group (3rd to 5th mesonephric arteries), and the accessory RA is due to the persistence of more than one RA in the middle group. The RA orifice on the right side is usually located more superior and anterolateral than the left side RA orifice. The position of the right RA may be as high as the thoracic aorta, which may be due to the persistence of cranial primitive mesonephric arteries resulting in an abnormally high origin of right RA. The RA arising from the thoracic aorta were reported on the right side so far, which might be due to the more proximal position of the right RA orifice than the left RA orifice.[23]

Renal arteries, normally arise from the abdominal aorta at the level of the L1-2 intervertebral disc, while the origin may range from the upper margin of L1 to the lower margin of the L2 vertebra.[25] RA variations including double and triple origin, stenosis, aneurysm, dissection of the artery, abnormal origin, course, and branching pattern were reported.[26–29] In our case, on the right side, we noted the RA and an accessory RA distal to the RA. The normal diameter of RA ranges from 3.5 mm to 6.5 mm.[30] In the present case, the diameters of the right RA (5.12mm), and Right ARA (4.05mm). The GA on the right side originated from the accessory RA. On the left side, the kidney had a solitary RA with a diameter of 4.95mm; which followed a normal anatomical course and branching pattern.

Merklin and Michels classified ARA according to their origin from vessels such as Abdominal aorta, thoracic aorta, renal, superior suprarenal, lumbar, EIA, inferior mesenteric, ovarian, spermatic, right colic, subcostal, splenic arteries.[31] However, the commonest origin of ARA is from the abdominal aorta, similar to the present case. Ozkan et al reported that the ARA was observed in 16% of the cases on the right side and 13% of cases on the left side.[32] According to Aytac et al., the diameter of the main RA is significantly reduced in the presence of ARA.[33] However, in the present case, the diameter of RA was within the normal range. It was noted that the ARA may coexist with other vascular variations such as testicular or supra-renal.[25] However, in the present case, the ARA was associated with VA and OA variations. It was observed that the conditions such as ectopic kidney and horseshoe kidney are associated with ARA.[25] In the present case, no such coexisting renal malformations were observed.

Bulic et al. reported a double and triple RA on the left side. They observed that the diameter of the proximal right RA was 6mm, and the diameter of the right ARA was 4mm, the diameter of both proximal RA and distal ARA were within the normal range. However, on the left side, one hilar artery and two polar arteries were observed. The diameter of the hilar artery was 7mm, which was more than the normal range and the diameter of the two polar arteries was 3mm which was less than the normal range.[27]

Awareness regarding variations in the origin, course, and branching pattern of RA is vital for urologists, nephrologists, and surgeons to modify surgical techniques involving anastomosis in the renal and lumbar region during renal transplantation, renal trauma, and nephrectomy. Awareness about these variations in RA would be of great help in deciding a suitable donor for renal transplantation. Although anastomoses exist at the capsular and extracapsular levels, cross-segmental intrarenal anastomoses are not well appreciated in the kidney. During renal transplantation, it is crucial to anastomose all the renal arteries. Aortic aneurysms commonly involve the proximal or distal RA with the same or a different source of origin. The loss of renal function during the postoperative period can be prevented, if the anatomy of renal arteries and aneurysms are well-defined before surgery. The variation in the diameter of the RA also helps to interpret and manage reno-vascular hypertension.[24,34,35]

3.3. Obturator artery

3.3.1. Embryological basis for the variations in the obturator artery

The umbilical arteries arise from the dorsal aorta from its ventrolateral aspect and pass medial to the primary excretory duct. As the development proceeds, a new vessel joins the proximal part of the umbilical arteries close to the termination of the dorsal aorta and passes lateral to the primary excretory duct. Thus, the original stem of the umbilical artery represents the ventral root of the umbilical artery, and the fifth lumbar intersegmental artery (i.e., new vessel) represents the dorsal root of the umbilical artery. The axial artery of the limb and branches to the pelvic viscera arise from the dorsal root. The more proximal part

of the dorsal root forms the external iliac artery (EIA). The entire ventral root of the umbilical artery disappears. The part of the umbilical artery that comes from the dorsal root distal to the EIA forms the internal iliac artery (IIA).[19] Two plexuses, the abdominal and the pelvic arise from the dorsal root of the umbilical artery. An uneven growth of the various anastomotic channels and the varying persistence and regression of channels between the developing EIA and IIA may be the reason for the varying origins and the course of OA. So, instead of arising from the IIA, the OA arises from the inferior epigastric artery or EIA. The OA may arise from the posterior division of IIA when the vascular channels related to the anterior division of IIA regress due to the unusual choice of source channels.[36,37]

Normally, the OA originates from the anterior division of IIA. In our case, the right OA originated from the posterior division of the right IIA and the left OA originated from the trunk of the left EIA, at the level of origin of the deep circumflex iliac artery. Pai et al reported that OA could arise from the posterior division of IIA as a separate branch or with the superior gluteal artery or with the iliolumbar artery.[38] Similarly, the OA was reported to arise from EIA as a separate branch or along with the inferior epigastric artery.[38] Varying origins of the OA from other sources such as the inferior epigastric artery, internal pudendal artery, and inferior gluteal artery have also been reported.[39] OA arising from EIA is termed an aberrant obturator artery (AOA) as seen in the present case, on the left side. The frequency of occurrence of AOA was reported as 33% by Zlotorowicz et al., and 31% by Sanudo et al., according to Bergma's comprehensive encyclopedia of human anatomic variations, it was said to range from 23.7 - 38.3%.[37–41] Pai et al. AOA in 19% of the cases[38]. Whereas, the variant origin of the OA from the posterior division of the IIA was found to be ranging from 0.5% to 18% of the cases.[42] Pai et al. also observed that OA can have a dual origin from both EIA and IIA, which was observed in 2% of the cases.[38] The average diameter of the OA ranges from 0.8 to 3.2 mm.[43] In the present case, the external diameter of the right OA (2.1 mm) and the left OA (2.6 mm) were within normal limits. On the right side, the OA passed along with the obturator nerve in the lateral pelvic wall to enter into the obturator canal; whereas on the left side, the OA passed anterior to the external iliac vein to reach the obturator canal, similar to the report by Pai et al.[38]

In aortic, iliac, and femoral vessel occlusive diseases, the parietal branches of OA form an important collateral pathway.[38] The variant origin of OA from the posterior division of IIA confers a unique advantage. In avascular necrosis of the head of the femur particularly due to the obstruction of OA, a bypass graft can be used to connect the posterior division of IIA with the OA distal to its obstruction. Furthermore, OA will be preferred for grafting due to its longer length, especially when arising from the posterior division of IIA.[44] Surgeons dealing with laparoscopic herniorrhaphies must be aware of the various origins of the OA, which lies behind pubic rami, to avoid injury to it while anchoring the mesh to Cooper's ligament.[45] During the anterior approach of the acetabulum during hip replacement surgery, care should be taken not to injure the AOA.[45] It is also essential for surgeons to be aware of the vascular anatomy of the abdomen and pelvis since obstetric manoeuvre and urogenital interventions are rapidly advancing and challenging.[36]

The knowledge of VA, RA, and OA variations is vital before performing any surgery involving these arteries. Multiple arterial anatomy variations must be anticipated by physicians, neurosurgeons, and radiologists as they may coexist. Duplicated VA /PICA are common variations noted, and care should be taken as any injury to these vessels causes alarming haemorrhage/ischemia to the cerebellum and brainstem during surgeries of the posterior cranial fossa. The ARA is not unlikely; transplant surgeons must be cautious enough during renal transplantation while performing anastomosis of RA when the kidney is procured from the donor with RA variation. Corona mortis is a variation noted frequently, which should be foreseen while performing hernioplasty and herniorrhaphy for an inguinal and femoral hernia. A safe treatment protocol can be planned if these variations are defined priorly, which helps surgeons to circumvent the iatrogenic complications.

4. Ethical Approval

This study involves human cadavers that are routinely dissected for teaching undergraduate students. All cadavers are procured on the basis of the Anatomical Act which caters to the supply of human cadavers meant for teaching and research. The human cadavers are sourced from voluntary whole-body donations and unclaimed bodies. Hence, all cadaveric studies have implied consent for research in their manner of procurement itself and do not need additional consent. This procedure is currently followed in our institution and we have followed the same. All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

5. Source of Funding

Not applicable.

6. Competing Interests

We declare that the authors have no competing interests or other interests that might be perceived to influence the results and/or discussion reported in this paper.

7. Author Contribution

1. Sankaranarayanan G: Data Collection, Manuscript Writing
2. Rajasekhar S.S.S.N.: Manuscript writing, Manuscript editing
3. Kalaivani K: Manuscript editing.

8. Availability of Data and Materials

The arterial variations were observed in the cadaver during dissection for undergraduates. After the documentation of the variant anatomy, the cadaver was subsequently dissected further in accordance with the anatomy curriculum. Hence, the cadaver could not be preserved to retain the anatomical variants.

9. Acknowledgements

The authors sincerely thank those who donated their bodies to science so that anatomical research could be performed. Results from such research can potentially increase mankind's overall knowledge which can then improve patient care. Therefore, these donors and their families deserve our highest gratitude.

References

1. Rodriguez-Hernandez A, Rhoton AL, Lawton MT. Segmental anatomy of cerebellar arteries: a proposed nomenclature. Laboratory investigation. *J Neurosurg*. 2011;115(2):387–97.
2. Parimala NB. Bilateral aberrant renal arteries with abnormal left renal vein: a case report. *J Clin Diagn Res*. 2013;7(7):1425–6.
3. Olry R, Lellouch A. The arterial system of the Japanese anatomist Buntaro Adachi. *Hist Sci Med*. 2003;37(1):89–94.
4. Yancopoulos GD, Davis S, Gale NW, Rudge JS, Wiegand SJ, Holash J. Vascular-specific growth factors and blood vessel formation. *Nature*. 2000;407(6801):242–8.
5. Kleinstreuer N, Dix D, Rountree M, Baker N, Sipes N, Reif D, et al. A computational model predicting disruption of blood vessel development. *PLoS Comput Biol*. 2013;9(4):e1002996.
6. Kubis N, Levy BI. Vasculogenesis and Angiogenesis: Molecular and Cellular Controls. *Interv Neuroradiol*. 2003;9(3):227–37.
7. Uchino A, Sawada A, Takase Y, Kudo S. Extreme fenestration of the right vertebral artery: magnetic resonance angiographic demonstration. *Eur Radiol*. 2002;12(Suppl 3):32–4.
8. Gaskill SJ, Heinz ER, Kandt R, Oakes WJ. Bilateral congenital anomalies of the extracranial vertebral artery: management with balloon therapy. *Pediatr Neurosurg*. 1996;25(3):147–50.
9. Polguj M, Podgórski M, Jędrzejewski K, Topol M, Majos A. Fenestration and duplication of the vertebral artery: the anatomical and clinical points of view. *Clin Anat*. 2013;26(8):933–43.
10. Park JH, Kim JM, Roh JK. Hypoplastic vertebral artery: frequency and associations with ischaemic stroke territory. *J Neurol Neurosurg Psychiatry*. 2007;78(9):954–58.
11. Tarnoki AD, Fejer B, Tarnoki DL, Littvay L, Lucatelli P, Cirelli C, et al. Vertebral artery diameter and flow: nature or nurture. *J Neuroimaging*. 2017;27(5):499–504.
12. Sato K, Emura S, Tomiyoshi H, Morita S. Endovascular repair of an aortic arch aneurysm in a patient with a hypoplastic left vertebral artery terminating into the posterior inferior cerebellar artery. *Ann Vasc Dis*. 2019;12(4):555–8.
13. Sarah S, Garima S, Jyoti C, Pankaj AK, Vandana L. Variations in posterior inferior cerebellar artery and its clinical significance in Uttar Pradesh region: A 64-slice CT angiographic study. *Int J Anat Res*. 2018;6:5261–67.
14. Smoker WR, Price MJ, Keyes WD, Corbett JJ, Gentry LR. High-resolution computed tomography of the basilar artery: 1. Normal size and position. *AJNR Am J Neuroradiol*. 1986;7(1):55–60.
15. Chuang YM, Chan L, Wu HM, Lee SP, Chu YT. The clinical relevance of vertebral artery hypoplasia. *Acta Neurol Taiwan*. 2012;21(1):1–7.
16. Rajasekhar S, Aravindhan K, Tamgire DW. Duplicated and hypoplastic V4 segment of vertebral artery along with duplication of anterior inferior cerebellar artery: A case report. *J Clin Diagn Res*. 2017;11(8):3–5.
17. Kim MS. Duplicated Vertebral Artery : Literature Review and Clinical Significance. *J Korean Neurosurg Soc*. 2018;61(1):28–34.
18. George B, Cornelius J. Vertebral artery: surgical anatomy. *Oper Tech Neurosurg*. 2001;4(4):168–81.
19. Tickle C. Development of the limbs. In: Stranding S, editor. Gray's Anatomy – The anatomical basis of clinical practice. Edinburg; Churchill Living Stone: Elsevier; 2020. p. 303–14.
20. Uchino A, Saito N, Ishihara S. Double origin of the posterior inferior cerebellar artery diagnosed by MR angiography: a report of two cases. *The Neuroradiol J*. 2015;28:187–89.
21. Satti SR, Cerniglia CA, Koenigsberg RA. Cervical vertebral artery variations: an anatomic study. *AJNR Am J Neuroradiol*. 2007;28(5):976–80.
22. Uchino A, Ohno H, Kondo R, Ishihara S. Ascending pharyngeal artery-posterior inferior cerebellar artery anastomosis via the jugular foramen: a case report and literature review. *Surg Radiol Anat*. 2021;43(6):1019–22.
23. Ichikawa T, Iino M, Koizumi J, Hara T, Kazama T, Sekiguchi T, et al. A case of right renal artery originating from the thoracic aorta. *Jpn J Radiol*. 2014;32(12):716–20.
24. Budhiraja V, Rastogi R, Asthana AK. Variant origin of the superior polar artery and unusual hilar branching pattern of renal artery with clinical correlation. *Folia Morphol (Warsz)*. 2011;70:24–8.
25. Gulas E, Wysiadecki G, Cecot T, Majos A, Stefańczyk L, Topol M, et al. Accessory (multiple) renal arteries - differences in frequency according to population, visualizing techniques and stage of morphological development. *Vascular*. 2016;24(5):531–7.
26. Benedetti E, Troppmann C, Gillingham K, Sutherland DE, Payne WD, Dunn DL, et al. Short- and long-term outcomes of kidney transplants with multiple renal arteries. *Ann Surg*. 1995;221(4):406–14.
27. Bulić K, Ivkić G, Pavić T. A case of duplicated right renal artery and triplicated left renal artery. *Ann Anat*. 1996;178(3):281–3.
28. Delasotta LA, Olivieri B, Malik A, Nguyen C, Bhatia V, Burke W. Thoracic renal artery: a rare variant. A case study and literature review. *Surg Radiol Anat*. 2015;37(5):561–4.
29. Shoja MM, Tubbs RS, Shakeri A, Loukas M, Ardalan MR, Khosroshahi HT, et al. Peri-hilar branching patterns and morphologies of the renal artery: a review and anatomical study. *Surg Radiol Anat*. 2008;30(5):375–82.
30. Kesavan A, Tai BC, Goh B, Raman L, Anantharaman V, Tiong HY. Renal artery diameter is a surrogate marker for kidney volume in living kidney donors. *Transplant Proc*. 2018;50(8):2342–5.
31. Merklin RJ, Michels NA. The variant renal and suprarenal blood supply with data on the inferior phrenic, ureteral and gonadal arteries: a statistical analysis based on 185 dissections and review of the literature. *J Int Coll Surg*. 1958;29(1 Pt 1):41–76.
32. Ozkan U, Oğuzkurt L, Tercan F, Kizilkiliç O, Koç Z, Koca N, et al. Renal artery origins and variations: angiographic evaluation of 855 consecutive patients. *Diagn Interv Radiol*. 2006;12(4):183–6.
33. Aytac SK, Yigit H, Sancak T, Ozcan H. Correlation between the diameter of the main renal artery and the presence of accessory renal artery. *J Ultrasound Med*. 2003;22(5):433–9.
34. Mir NS, Hassan A, Rangrez R, Hamid S. Bilateral duplication of renal vessels: anatomical, medical and surgical perspective. *Int J Health Sci (Qassim)*. 2008;2(2):179–85.
35. Satyapal KS, Haffejee AA, Singh B, Ramsaroop L, Robbs JV, Kalideen JM. Additional renal arteries incidence and morphometry. *Surg Radiol Anat*. 2001;23(1):33–8.

36. Rajive AV, Pillay M. A study of variations in the origin of obturator artery and its clinical significance. *J Clin Diagn Res*. 2015;9(8):12–5.
37. Sanudo JR, Roig M, Rodriguez-Aferreira B, Domenech JM. Rare origin of the obturator artery, inferior epigastric and femoral arteries from a common trunk. *J Anat*. 1993;183:161–3.
38. Pai MM, Krishnamurthy A, Prabhu LV, Pai MV, Kumar SA, Hadimani GA. Variability in the origin of the obturator artery. *Clinics (Sao Paulo)*. 2009;64(9):897–901.
39. Biswas S, Bandopadhyay M, Adhikari A, Kundu P, Roy R. Variation of origin of obturator artery in eastern Indian population-A study. *J Anat Soc India*. 2010;59(2):168–72.
40. Tubbs RS, Shoja MM, Loukas M. Bergman's Comprehensive Encyclopedia of Human Anatomic Variation. United States: John Wiley & Sons; 2016. p. 694–740.
41. Zlotorowicz M, Czubak-Wrzosek M, Wrzosek P, Czubak J. The origin of the medial femoral circumflex artery, lateral femoral circumflex artery and obturator artery. *Surg Radiol Anat*. 2018;40(5):515–20.
42. Chua PT, Huang KG. Rare Variant of Obturator Artery Branching from Posterior Division of Internal Iliac Artery. *J Gynecol Surg*. 2020;36(3):149–50.
43. Perandini S, Perandini A, Puntel G, Puppini G, Montemezzi S. Corona mortis variant of the obturator artery: a systematic study of 300 hemipelvises by means of computed tomography angiography. *Pol J Radiol*. 2018;83:519–23.
44. Dinesh K, Gayatri R. Anomalous origin of obturator artery from the internal iliac artery. *Int J Morphol*. 2007;25:639–41.
45. Lau H, Lee F. A prospective endoscopic study of retropubic vascular anatomy in 121 patients undergoing endoscopic extraperitoneal inguinal hernioplasty. *Surg Endosc*. 2003;17:1376–79.

Author biography

Sankaranarayanan Govindarajan, Assistant Professor

Rajasekhar SSSN, Additional Professor

Kalaivani Kaliyamoorthy, Junior Resident

Cite this article: Govindarajan S, Rajasekhar SSSN, Kaliyamoorthy K. Cluster of variations involving vertebral, renal, and obturator arteries in a single human body- A cadaveric case report. *Indian J Clin Anat Physiol* 2023;10(4):265-274.