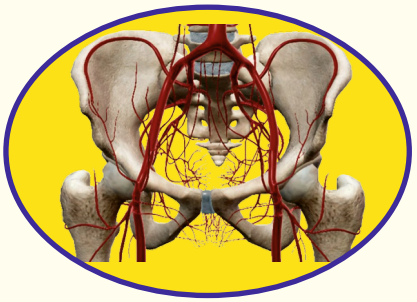
REVIEW OF LITERATURE



CHAPTER 3

REVIEW OF LITERATURE

3.1. GROSS ANATOMY

The internal iliac artery (IIA), previously called hypogastric artery, emerges from the common iliac artery (CIA) at its bifurcation into the internal iliac artery and external iliac artery (EIA). This bifurcation of common iliac artery occurs in front of the sacroiliac joint and brim of pelvis at a vertebral level between L5 and S1 (Selcuk I, 2018). The internal iliac artery supplies arterial blood to pelvic region (walls and organs), the gluteal region, the reproductive organs, the bladder and the medial compartment of the thigh. Normally, it is 3-4 cm in length and diameter not greater than 8 cm (Kahraman et al., 2006, Singh et al., 2004).

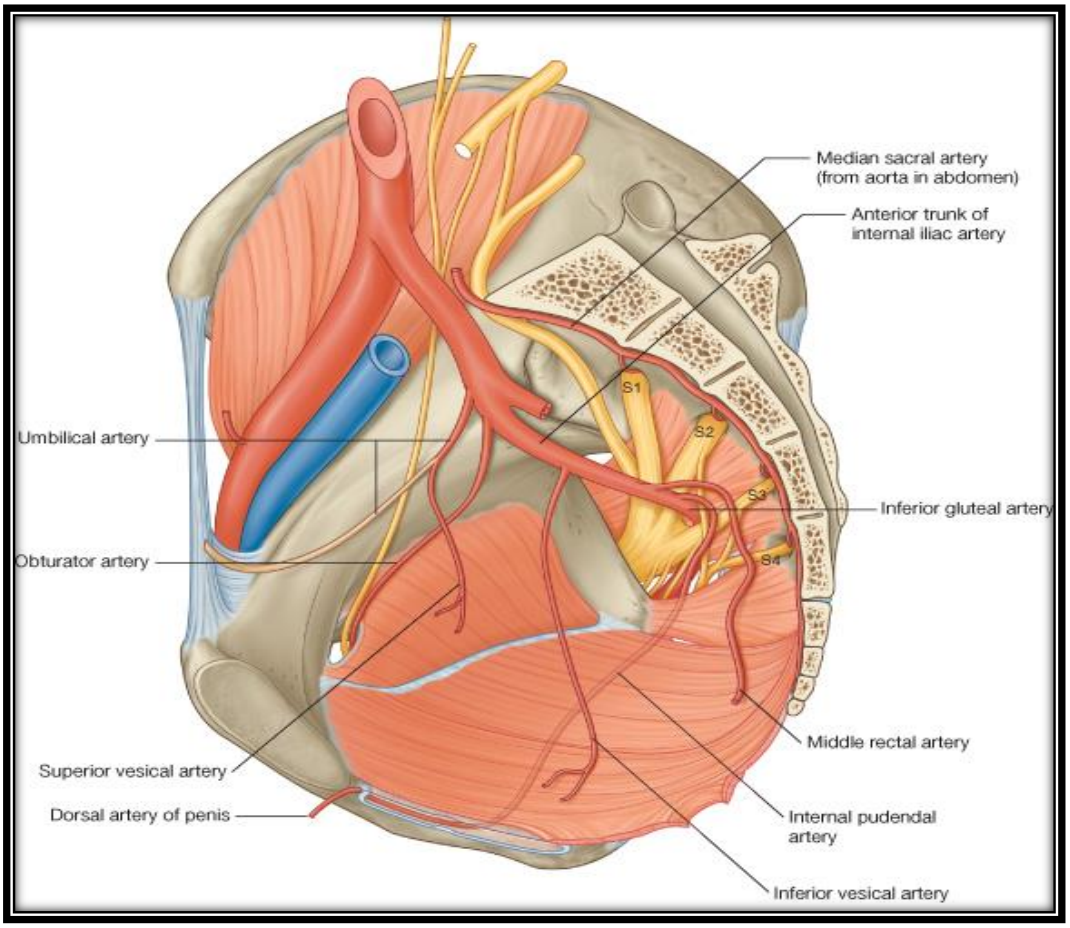


Figure 3.1: Anterior division of Internal Iliac Artery.

After the emergence of internal iliac artery, with in the pelvic cavity, it runs posteriorly towards the greater sciatic foramen and terminates at its upper border after bifurcating into anterior and posterior divisions. In the anterior division we can distinguish visceral and parietal branches; the posterior division consists of parietal branches only (Gray et al., 1995, Keith and Campbell, 1900).

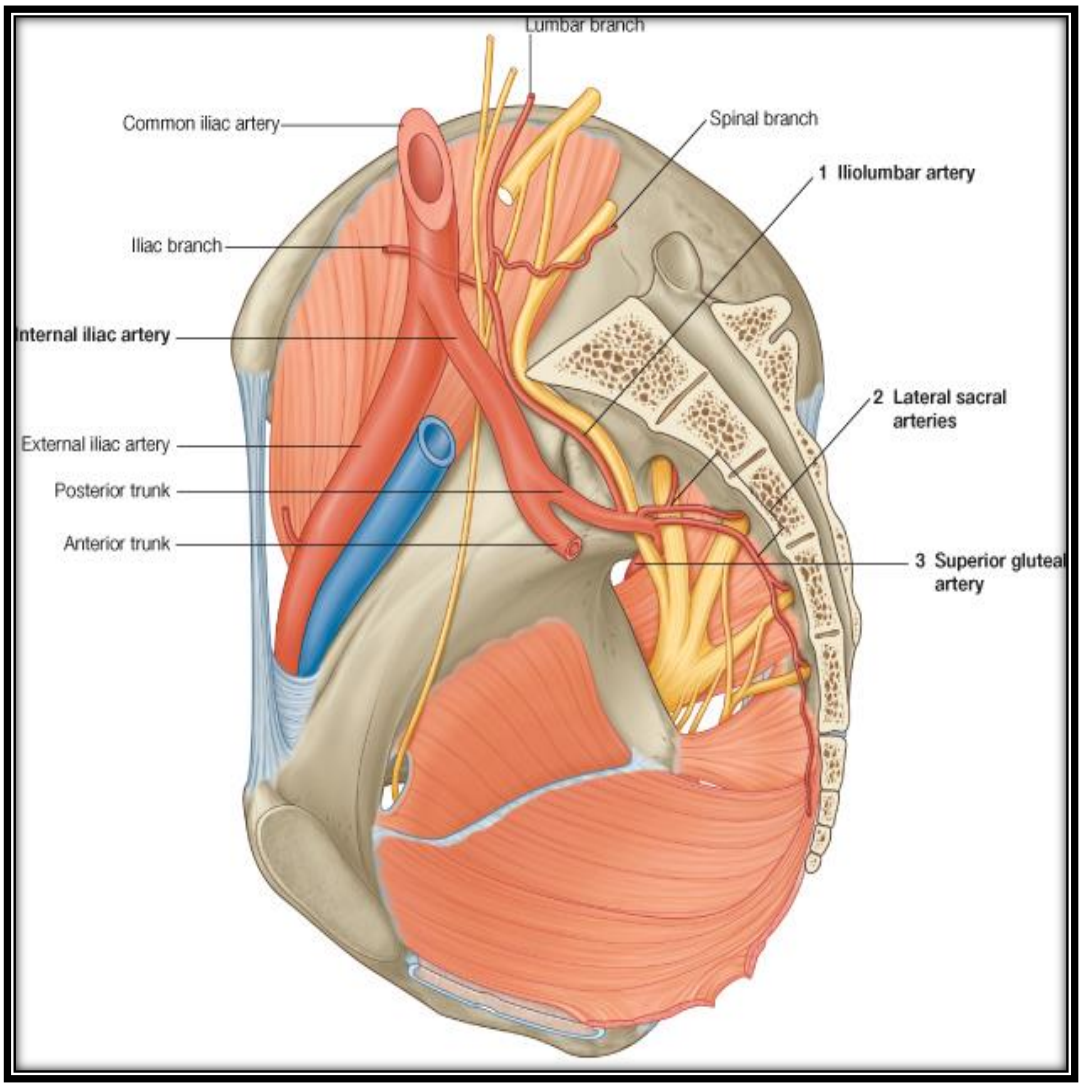


Figure 3.2: Posterior division of Internal Iliac artery.

Table 3.1: Branches of the Anterior trunk and the Posterior trunk of the Internal Iliac artery in Male & Female

Trunk of IIA		Male	Female
Anterior trunk of the IIA	Parietal branches	Internal pudendal artery	Internal pudendal artery
		Inferior gluteal artery	Inferior gluteal artery
		Obturator artery	Obturator artery
	Visceral branches	Umbilical artery	Umbilical artery
		Superior vesical artery	superior vesical artery
		Inferior vesical artery	Vaginal artery
		Middle rectal artery	Middle rectal artery
			Uterine artery (only in women)
Posterior trunk of the IIA	Parietal branches	Superior gluteal artery	Superior gluteal artery
		lateral sacral arteries	lateral sacral arteries
		Iliolumbar artery	Iliolumbar artery

The visceral branches of the anterior division are: the superior vesical artery (SVA), inferior vesical artery (IVA), middle rectal artery (MRA), uterine artery (UA) and vaginal arteries (VA). The uterine and vaginal arteries occur in females, the vaginal artery replacing the inferior vesical artery. The uterine artery is absent in males. The parietal branches of the anterior division are the obturator (OBA), internal pudendal (IPA), and inferior gluteal (IGA) arteries. There are also branches from the posterior division of the IIA, which consists of parietal branches only: the iliolumbar (ILA), lateral sacral (LSA), and superior gluteal (SGA) arteries (Gray et al., 1995, Keith and Campbell, 1900).

3.1.1 BRANCHES OF ANTERIOR DIVISION:

A. Parietal Branches: There are three parietal branches of the anterior division which leave the pelvic cavity & enter the gluteal region or medial compartment of thigh.

1. Internal pudendal artery:

The internal pudendal artery is a terminal branch of the anterior division of the internal iliac artery. It is considered to be the main artery of the perineum in both sexes. The internal pudendal artery has a relatively long course, passing through the three different regions, including the pelvis, gluteal region and the perineum where it terminates. Along its course, it provides numerous branches that supply the structures of the perineum, skin and muscles of the anal and urogenital region, inferior portion of the rectum and erectile bodies of the male and female external genitalia.

Origin and course

The internal pudendal artery is a smaller terminal branch of the anterior division of the internal iliac artery originating between the iliopectineal line and greater sciatic notch.

For didactic purposes, the course of the internal pudendal artery can be divided into three parts;

- **Pelvic part:** It has a short inferolateral course in the pelvis, crossing the piriformis muscle and the sacral plexus.
- **Gluteal part:** The artery passes from the pelvic to the gluteal region through the greater sciatic foramen, passing inferior to the piriformis muscle (infrapiriform foramen). While located in this region, the artery winds around the posterior aspect of the ischial spine and sacrospinous ligament.
- **Perineal part:** The internal pudendal artery enters the perineum through the lesser sciatic foramen. It initially traverses the ischiorectal fossa, situated in the Alcock's canal (pudendal canal) with the pudendal vein and nerve. Alcock's canal consists of the ischiopubic rami and fascia of obturator

internus, laterally and medially, respectively. The artery then runs anteromedially along the inferior pubic ramus and enters the deep perineal pouch, situated above the perineal membrane. It terminates by giving off the terminal branch called the dorsal artery of the penis/clitoris.

Branches and supply

Along its path, the internal pudendal gives off numerous branches for the vascularization of the muscles and skin of the anogenital region, as well as internal and external genital organs.

- **The inferior anorectal artery** stems from the internal pudendal artery in the pudendal canal. It then passes through the ischiorectal fossa to supply the inferior portion of the rectum (inferior to the pectinate line), anal sphincters and the adjacent skin.
- **The perineal artery** originates in the distal portion of the pudendal canal passing anteriorly and inferior to the perineal membrane. It supplies the musculature of the superficial perineal pouch. Most importantly, it gives rise to the posterior scrotal/labial artery that supplies the skin of scrotum in males or labia majora and minora in females.
- **The artery of the bulb of the penis/vestibule** arises after the internal pudendal artery enters the deep perineal pouch. In males, it supplies the bulb of penis and the adjacent part of the urethra and bulbo-urethral gland. In females, it supplies the bulb of vestibule and greater vestibular gland. This branch can also provide an additional urethral branch that supplies the external urethral sphincter.
- **The deep artery of the penis/clitoris** also originates in the deep perineal pouch. It traverses the perineal membrane and then runs through the middle of each of the corpora cavernosa of the penis/clitoris supplying them.
- **The dorsal artery of the penis/clitoris** is a terminal branch of the internal pudendal artery arising also in the deep perineal pouch. It passes between the perineal membrane and the pubic symphysis to run along the dorsal surface of the penis/clitoris. It supplies the perineal pouch, corpus spongiosum in males

and the adjacent skin and fascias of external genitalia (penis or clitoris) (Selcuk I, 2018).

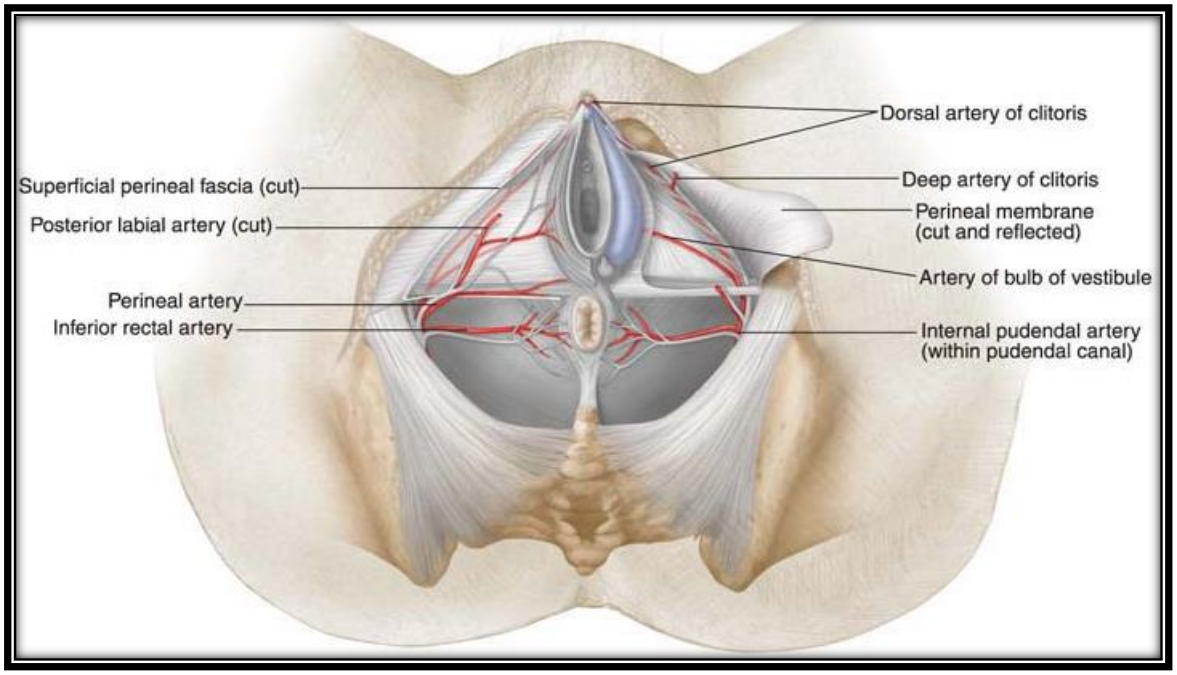


Figure 3.3: Internal pudendal artery in Females

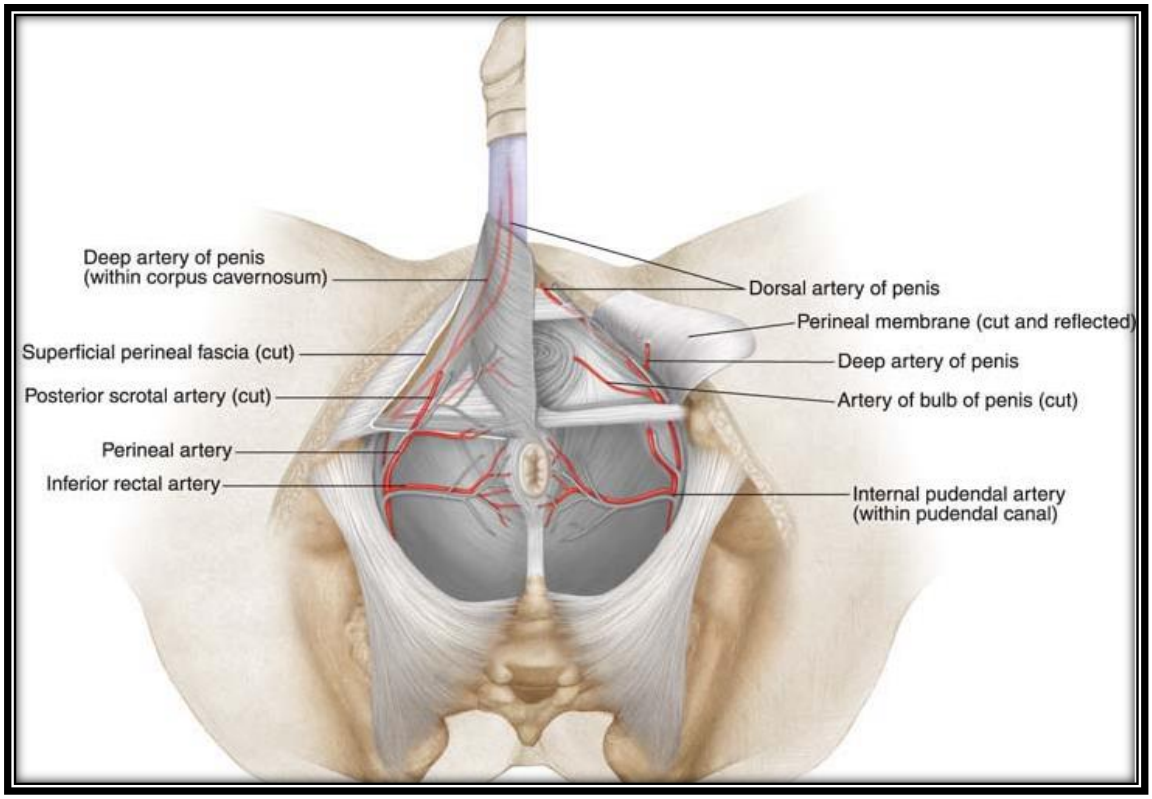


Figure 3.4: Internal pudendal artery in Males.

Anatomical variations

The internal pudendal can arise separately from the anterior division of the internal iliac artery or it can share a common origin with the inferior gluteal and obturator arteries. In some cases, an additional perineal artery can be present. It is referred to as the accessory pudendal artery and it usually arises from the pelvic segment of the internal pudendal artery. It can be unilateral or bilateral, as a single or double vessel on each side. The rates of presence of this artery vary across literature, from 10-30% (Mohammadbaigi H, 2019).

2. Inferior gluteal artery:

The inferior gluteal artery is a terminal branch of the internal iliac artery supplying the gluteal and thigh regions. It is initially found in the pelvis after which it runs through the greater sciatic foramen to emerge into the gluteal region. Inside the pelvis, the inferior gluteal artery gives off several branches to supply the pelvic floor muscles. Upon exiting the pelvis and emerging in the gluteal region, the inferior gluteal artery gives off branches to supply the sciatic nerve and the muscles and skin of the gluteal, hip and thigh regions.

Origin and course

The inferior gluteal artery arises from the anterior division of the internal iliac artery as one of its terminal branches. From its origin, the inferior gluteal artery descends anteroposteriorly to the piriformis muscle and sacral plexus, while running posterior to the internal pudendal artery. It travels unsheathed in the parietal pelvic fascia, which runs between the S1 and S2 nerve roots, to approach the greater sciatic foramen. It passes through the lower portion of the greater sciatic foramen, running between piriformis and ischiococcygeus muscles to emerge into the gluteal region. Here, the inferior gluteal artery descends in the gap between the greater trochanter of the femur and tuberosity of the ischium, travelling deep to the gluteus maximus muscle. It continues down the posterior aspect of the thigh, supplying the skin and dividing into its terminal branches.

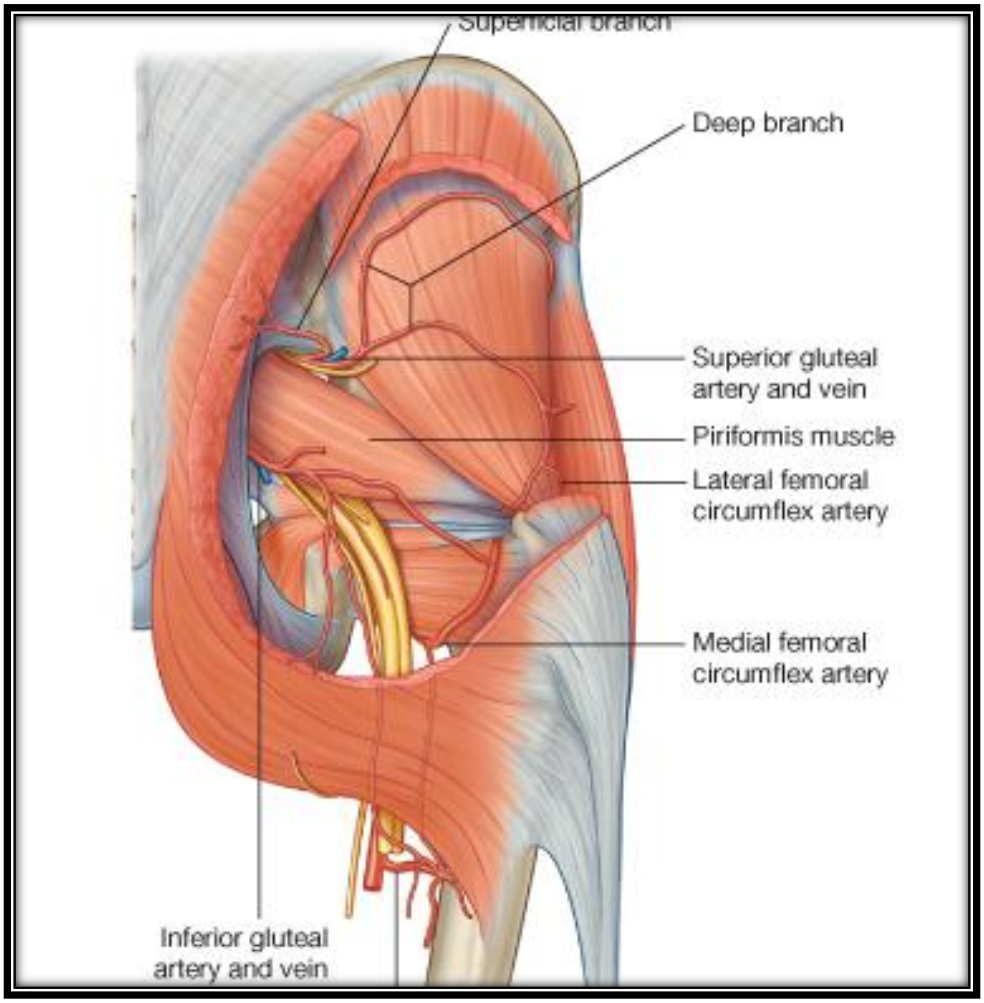


Figure 3.5: The inferior gluteal artery accompanies the sciatic nerve and escapes from pelvis through the greater sciatic foramen. In the gluteal region, the inferior gluteal artery gives sciatic branch "arteria nervi ischiadici'' to the sciatic nerve.

Branches and supply

Along its course in the pelvis, the inferior gluteal artery gives off several muscular branches that supply the muscles of the pelvic diaphragm. In the gluteal region, the artery gives off more muscular branches, the artery to the sciatic nerve and several anastomotic branches:

- **Muscular branches:** the branches that arise inside the pelvis supply the piriformis, ischiococcygeus and iliococcygeus muscles. The muscular

branches that arise in the gluteal region supply the gluteus maximus, obturator internus, superior gemellus, inferior gemellus and quadratus femoris muscles.

- **Artery to sciatic nerve:** accompanies the sciatic nerve and supplies it. This artery is a remnant of the embryonic axial artery of the limb, and was the major supplier to the posterior compartment of the thigh during embryonic life.
- **Anastomotic branches:** arise as several branches that enter the trochanteric fossa to anastomose with branches of the superior gluteal, lateral circumflex and medial circumflex artery. Together, these form the so-called trochanteric anastomosis, which supplies the head of the femur. Other branches of the inferior gluteal artery pass towards the lesser trochanter, where they anastomose with the lateral and medial circumflex artery, the posterior branch of the obturator artery and perforating branch of the deep femoral artery. These form the so-called cruciate anastomosis that supplies the upper thigh.
- **Cutaneous branches:** supply the skin of the gluteal and thigh regions (Selcuk I, 2018).

Anatomical variations

Although it most commonly arises directly from the internal iliac artery, the inferior gluteal artery may also arise as a common trunk with the superior gluteal artery or the internal pudendal artery. Additionally, the inferior gluteal artery can be duplicated (Gabrielli C, 1997).

3. Obturator artery:

The obturator artery is a branch of the anterior division of the internal iliac artery. The artery got its name as it passes through the obturator foramen in order to reach the medial compartment of the thigh.

The main function of the obturator artery is to supply the muscles of the pelvis and the adductors of the thigh; obturator externus, adductor magnus, adductor minimus, adductor longus, adductor brevis, pectineus and gracilis muscles. Additionally, it provides a branch that supplies the head of the femur.

Course

The obturator artery is a branch of the anterior division of the internal iliac artery. It originates in the pelvis, just below the umbilical artery. The artery then courses anteroinferiorly over the pelvic wall, being superior to the obturator vein and inferior to the obturator nerve.

The medial side of the artery is crossed by the ureter in both sexes, and additionally by ductus deferens in the males. The artery then reaches the superior part of the obturator foramen, via which it enters the obturator canal. After traversing the obturator canal, the obturator artery emerges in the medial compartment of the thigh.

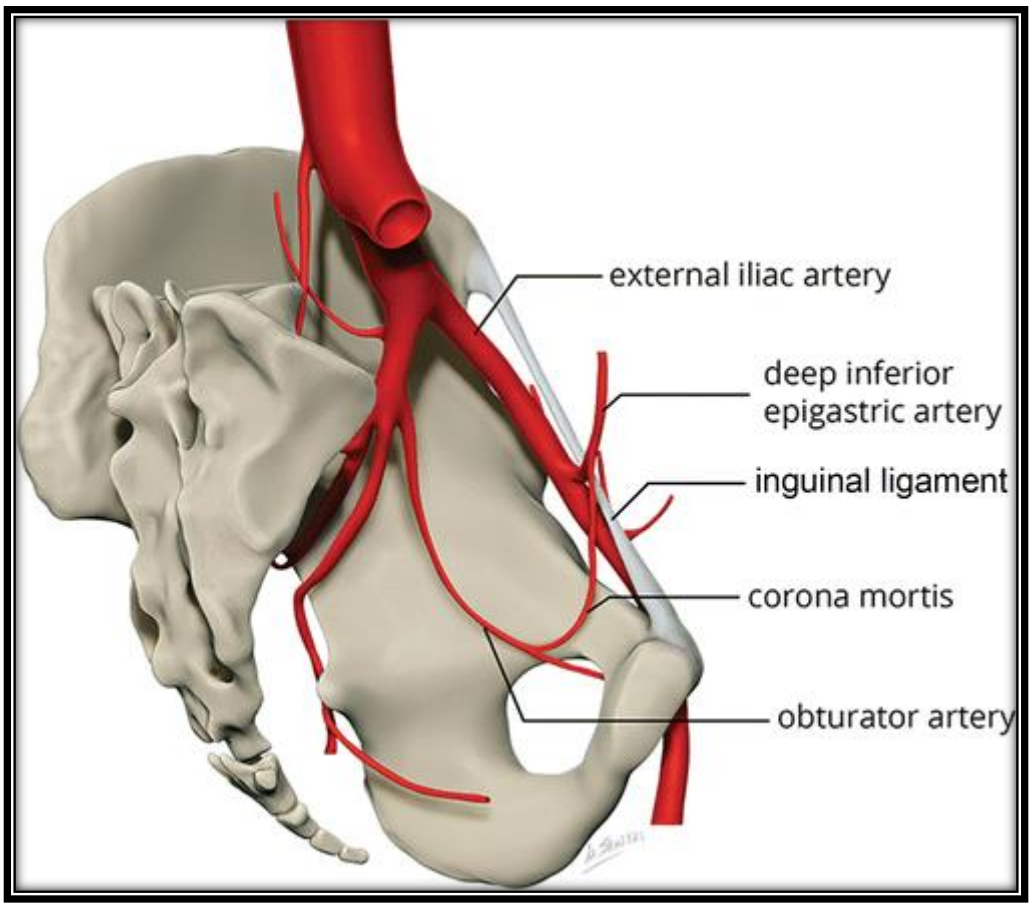


Figure 3.6: Obturator Artery

Branches and supply

Along its course, the obturator artery gives off several branches which are usually grouped as the branches within the pelvis (pelvic branches) and branches within the thigh (extrapelvic branches).

The pelvic branches of the obturator artery are the:

- **The iliac branches** supply the iliac bone and iliacus muscle and anastomose with the iliolumbar artery.
- **The vesical artery** supplies the medial part of the urinary bladder. Sometimes this branch can be large enough to replace the inferior vesical artery and supply its vascular territory as well.
- **A pubic branch** arises around the obturator canal. It runs across the pubic bone and anastomoses with its contralateral counterpart and the pubic branch of the inferior epigastric artery.

The extrapelvic branches of the obturator artery are the:

- **The anterior branch of obturator artery** follows the inner margin of the inferior pubic ramus to anastomose with the posterior branch of femoral artery and medial circumflex femoral artery. It supplies the obturator externus muscle, hip adductors and the skin over the medial thigh.
- **The posterior branch** supplies muscles attached to the ischial tuberosity such as the ischiocavernosus muscle.
- **The acetabular branch** traverses the ligament of the head of the femur and supplies the femoral head. This branch usually arises from the posterior branch (Selcuk I, 2018).

Anatomical variations

The origin of the obturator artery may significantly vary among individuals. The artery may arise from the main stem or from the posterior trunk of the internal iliac artery, from the superior gluteal artery, or from the external iliac artery.

In some cases, the obturator gives off an accessory obturator artery that forms an anastomosis with the external iliac artery. This "aberrant" obturator artery is usually referred to as the corona mortis or crown of death artery. The name of the vessel testifies to the importance of this feature; during surgical procedures, it can get accidentally injured and cause significant bleeding which is particularly difficult to stop.

In approximately 20% of the population, the enlarged pubic branch of the inferior epigastric artery may replace the obturator artery and its referred to as the replaced obturator artery (Gabrielli C, 1997).

Corona mortis

An anastomosis between the pubic rami or the vascular connections between of the inferior epigastric and obturator arteries has been referred to as crown of death or corona mortis. Black American in the South are estimated to have a higher incidence of variations of the pubic anastomosis compared to North American, European and Japanese populations (Missankov et al 1996). The distance between the corona mortis anastomotic arteries and the symphysis pubis is from 40 to 96 mm (Darmanis et al 1992) or from 45 to 90mm (mean 64) (Okcu et al 2004). There is no significant difference between gender in the incidence of corona mortis and the distance to the symphysis pubis (Okcu et al 2004).

Daeubler et al (2003) stated that an aberrant obturator artery may arise from the inferior epigastric branch of the external iliac artery, a condition known as the corona mortis. Based on morphological features, the corona mortis can be classified into three types.

- **First type** - The obturator artery arises from the external iliac artery;
- **Second type -** It originates from the inferior epigastric artery (IEA),
- **Third type** - The obturator and inferior epigastric arteries anastomose.
- **Fourth type** – Here, pubic branches of the obturator artery replaces the anastomosis with the external iliac artery.

The incidence of corona mortis with either an aberrant obturator vein or artery is 40% (Lau and Lee 2003).

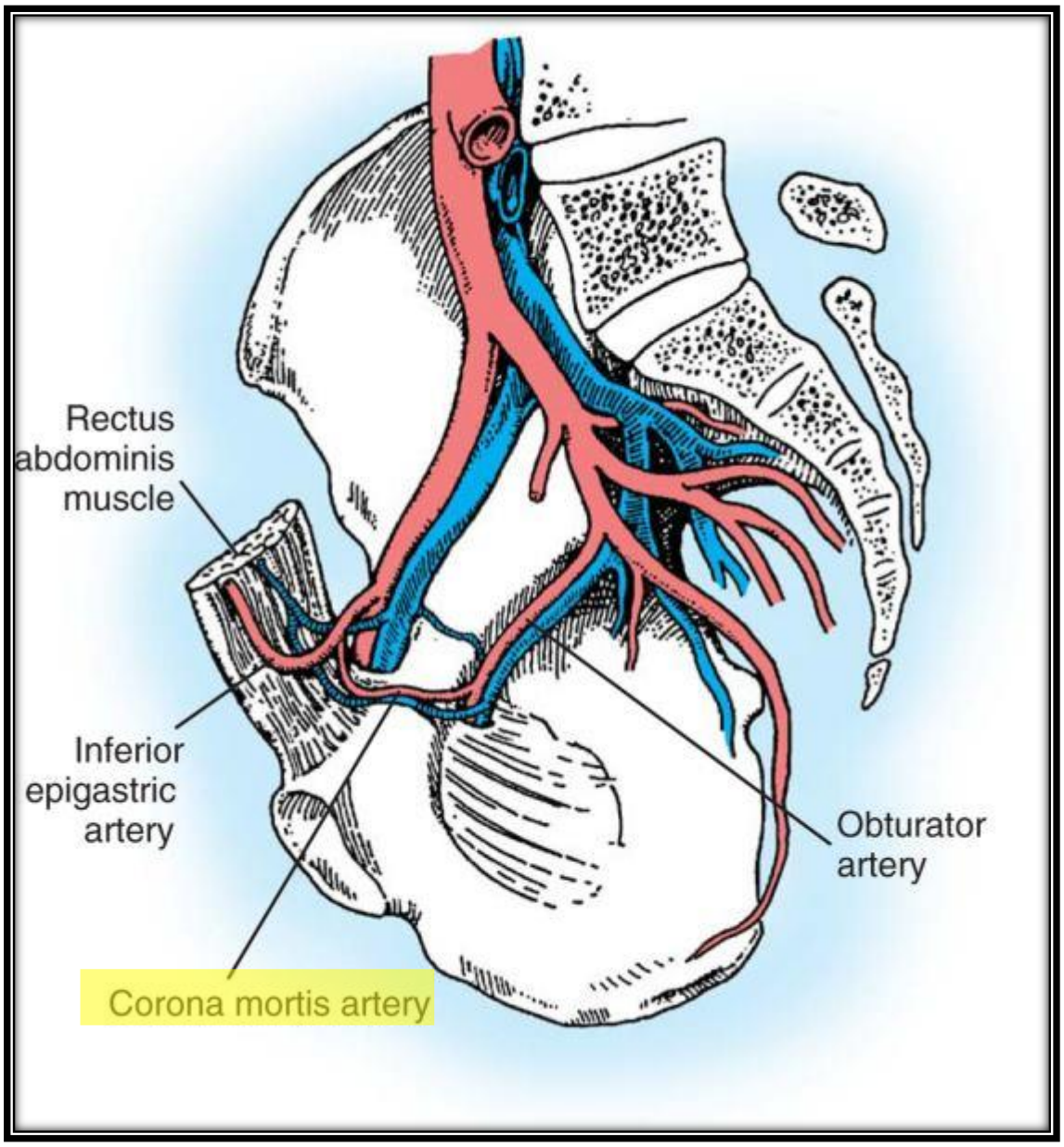


Figure 3.7: Corona mortis

B. <u>Visceral branches:</u> Anterior division gives four visceral branches in males & five visceral branches in females.

1. Umbilical Artery

The umbilical artery is a paired vessel that arises from the internal iliac artery. During the prenatal development of the foetus, it is a major part of the foetal circulation. After birth, the distal part of the artery obliterates and becomes the medial umbilical ligament. The proximal part of the artery still remains functional, providing a blood supply for the superior aspect of the urinary bladder and for ductus deferens in males. It commonly forms anastomoses with the inferior vesical, vaginal and obturator arteries.

Origin and course

The umbilical artery is a paired vessel that stems from the anterior division of the internal iliac artery. It runs anteromedially until it reaches the anterior abdominal wall. Then, it courses superiorly towards the umbilical ring, where it terminates.

During the prenatal period, the umbilical artery is the main continuation of the internal iliac artery. The two umbilical arteries run through the umbilical cord, comprising a helix around the umbilical vein. The arteries carry deoxygenated and nutrient-deficient blood from the foetus to the placenta.

After birth, when the umbilical cord is cut, a blood clot forms and occupies the distal portion of the artery. In the following months, the distal part of the umbilical artery obliterates. The obliterated umbilical artery is referred to as the medial umbilical ligament. When this ligament rises a portion of the parietal peritoneum, it is referred to as the medial umbilical fold. It's important to distinguish the medial umbilical ligament from the median umbilical ligament which is a remnant of the urachus (embryonic communication between the allantois and cloaca).

Although the distal part of the artery obliterates after birth, the proximal part remains functional. This functional segment runs anteroinferiorly and usually terminates around the urinary bladder. It generally provides blood supply for the surrounding organs, including the urinary bladder and ductus deferens in men. The umbilical artery commonly forms anastomoses with the inferior vesical, vaginal and obturator arteries.

Branches and supply

On its course, the proximal portion of the umbilical artery gives rise to the superior and middle vesical arteries. Their function is to provide abundant blood supply for the urinary bladder. In some males, the umbilical artery can also provide the artery for the ductus deferens that supplies the ductus deferens and seminal vesicles (Selcuk I, 2018).

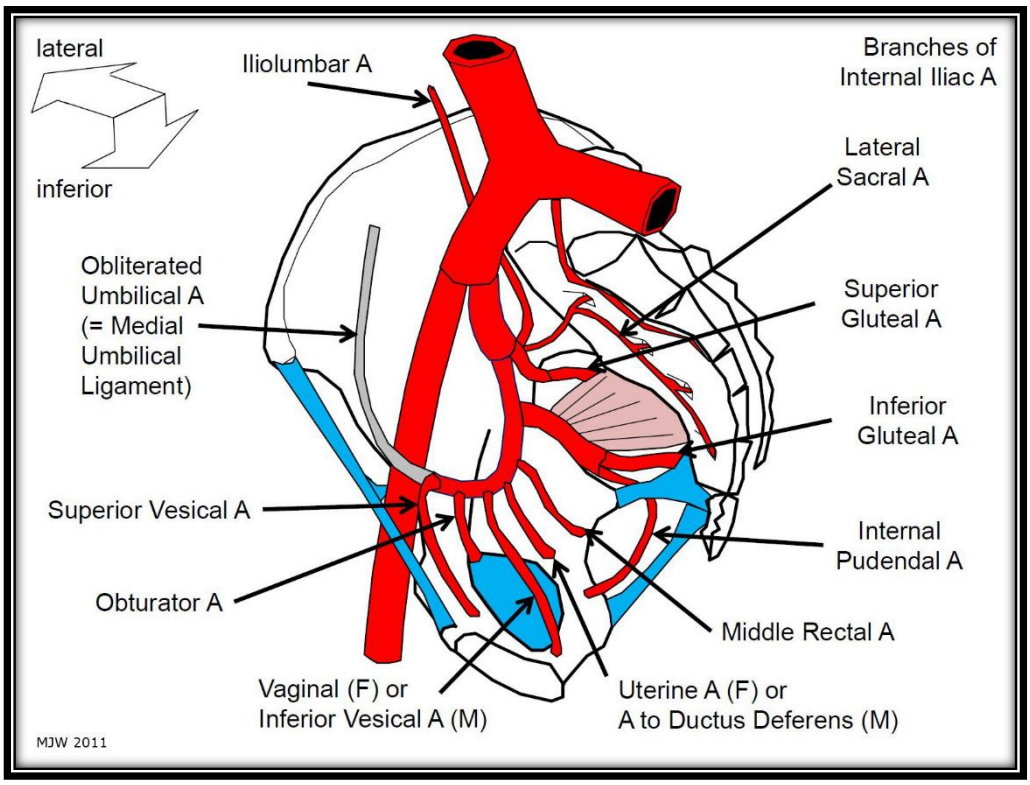


Figure 3.8: Umbilical artery

Anatomical variations

In 40% of cases, the umbilical artery gives rise to the uterine artery. In 10% of cases, it gives rise to the prostatovesical artery.

2. <u>Superior vesical artery</u>

The superior vesical artery represents the proximal, patent part of the umbilical artery, a branch of the anterior division of internal iliac artery. The artery is located within

the lesser pelvis along the posterior surface of the pubis. It supplies the ureter, urinary bladder, ductus deferens and seminal gland.

The superior vesical artery mainly provides small, visceral branches to the surrounding organs. In males, however, it also gives off the artery to ductus deferens. The superior vesical artery is continued by the occluded part of the umbilical artery (medial umbilical ligament).

Origin and course

The superior vesical artery arises as the first branch of the anterior division of internal iliac artery, inferior to the pelvic brim and on the lateral wall of the lesser pelvis. From here, the superior vesical artery travels anteroinferiorly, medial to the posterior surface of pubis. Then, it continues towards the superior surface of the urinary bladder. At this point, the superior vesical artery anastomoses with the inferior vesical artery in males and with the uterine artery in females.

The superior vesical artery is continued distally by the occluded part of the umbilical artery, commonly known as the medial umbilical ligament. Its only known function in the postnatal life is to support the urinary bladder.

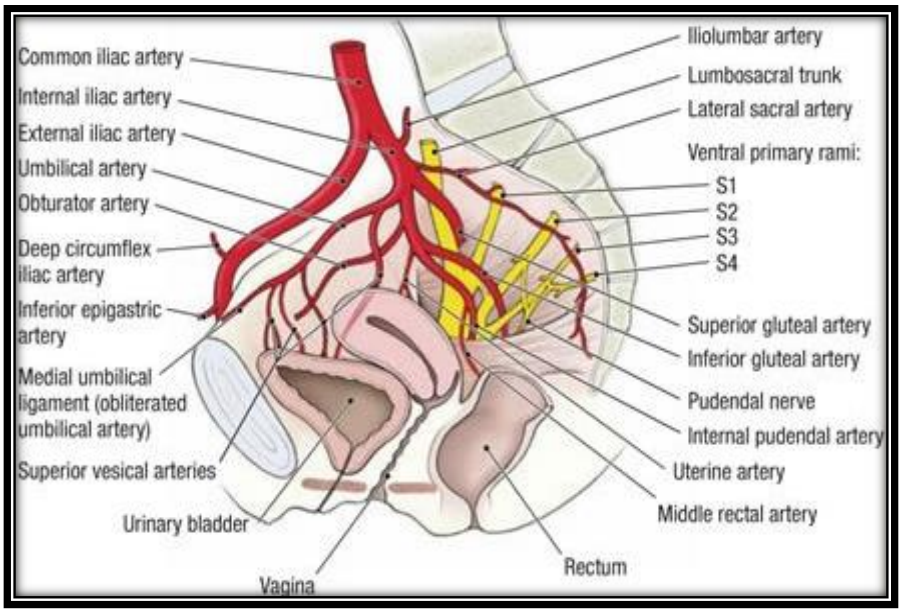


Figure 3.9: Superior Vesical Artery

Branches and supply

The superior vesical artery has several branches:

- **Visceral branches** supplying the fundus of urinary bladder and the distal end of the ureter.
- **Artery to ductus deferens** (males), which supplies the proximal end of the ductus deferens and the seminal glands.

Anatomic variation

The superior vesical artery exhibits a lot of anatomical variation in terms of occurrence and origin. According to classical anatomical textbooks, there can be up to five superior vesical arteries in total. The most common number is two, which is present in 70-74% of cases.

In terms of origin, some studies concluded that the superior vesical artery stems from the anterior trunk of internal iliac artery in 92% of cases. However, other studies have shown that it can emerge from the common trunk of the iliac artery in 75% of cases, proximal to the branching point of the latter into the anterior and posterior divisions.

3. Inferior Vesical artery

In males, the inferior vesical artery is a pelvic branch of the anterior division of the internal iliac artery, while in females it arises from the vaginal artery. It runs deep to the peritoneum (subperitoneal) to emerge on the inferior aspect of the urinary bladder.

In males, the main function of the inferior vesical artery is to supply blood for the fundus and neck of the male urinary bladder, prostate, seminal vesicles, ductus deferens, urethra and ureter. In females, when present, it supplies the urinary bladder.

Origin and course

In males, the inferior vesical artery arises from the anterior division of the internal iliac artery. It originates either as a separate vessel, or it shares a common origin with the middle rectal artery.

The inferior vesical artery courses in the subperitoneal space and emerges onto the inferoposterior aspect of the urinary bladder.

In females, the inferior vesical artery arises as a small branch from the vaginal artery.

Branches and supply

In males, the inferior vesical artery gives rise to several branches that supply the large part of the trigone of the urinary bladder, prostate, seminal vesicles, ductus deferens, urethra and the pelvic part of the ureter. It forms an anastomotic network with the superior vesical artery.

- **The prostatic branches** run in the neurovascular bundles towards the prostate. They provide small perforating branches that supply the prostate and seminal vesicles. The particularly clinically important branch is the apical perforator that supplies the prostatic urethral junction. It can form an anastomosis with the deep perineal artery. In some cases, the prostatic branch can also be supplied by the middle rectal artery.
- **The artery to ductus deferens** runs in a subperitoneal course towards the ductus deferens and supplies it. It can form anastomoses with the testicular and cremasteric arteries.
- **The urethral vessels** traverse the prostatovesical junction to supply the upper part of the urethra.

In females, it supplies the fundus of the urinary bladder and commonly forms an anastomosis with the uterine artery.

Anatomical variations

There is an ongoing debate on the presence of this artery in both sexes. One group of authors report that the inferior vesical artery exists only in the male population, while others think that it is present in both genders. The former explain that the vaginal artery is the female homologous vessel to this artery, while the latter report that the vaginal artery provides a small inferior vesical artery.

4. Vaginal Artery

The vaginal artery arises from the anterior division of the internal iliac artery. It can also arise from the uterine artery then known as a vaginal branch of the uterine artery. In some cases, the vaginal artery coming from the internal Iliac artery will anastomose with the vaginal branch of the uterine artery, if both present.

The vaginal artery is considered to be a female homologous vessel to the inferior vesical artery in males. The main function of the vaginal artery is to supply blood to the superior portion of the vaginal wall. In some cases, it can provide the inferior vesical artery which supplies the inferior portion of the urinary bladder.

Origin and course

The vaginal artery can originate from multiple sites as a single or duplicate vessel. The most common origin sites include the uterine (vaginal branch) and the internal iliac arteries. The vaginal artery then descends into the vagina and supplies its proximal aspect. In some cases, when the artery is larger in diameter, it can supply the majority of the vaginal wall.

Cervicovaginal branches of the uterine artery anastomose with the vaginal artery and create the azygos arteries of the vagina.

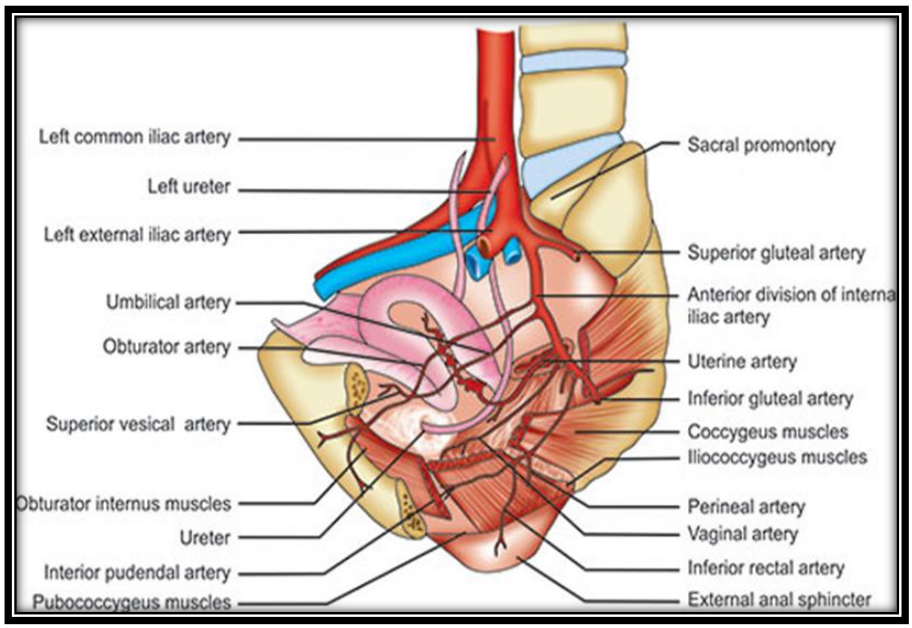


Figure 3.10: Vaginal Artery

Branches and supply

The vaginal artery provides numerous small branches that traverse the vaginal wall and provide its blood supply.

One group of authors report that the vaginal artery is a female homolog of the male inferior vesical artery, while the others report that the vaginal artery provides a small branch that carries that name. If it exists, this branch supplies the inferior portion of the urinary bladder.

Anatomical variations

In the matter of origin and supply, the vaginal artery is very variable.

- It can arise from several different vessels of the pelvis including the internal iliac, middle rectal, superior vesical, inferior vesical, inferior gluteal, obturator arteries or the ischial pudendal trunk. It has been also described that it can share a common origin with the uterine or middle rectal artery.
- It can supply either the proximal part or the majority of the vagina.

5. <u>Medial Rectal Artery</u>

The middle rectal artery, also called the middle hemorrhoidal artery, or middle anorectal artery, is an inconsistent branch of the anterior division of the internal iliac artery which supplies the rectum. It is found in the lesser pelvis, running within the lateral fascial coverings of the mesorectum.
Upon reaching the rectum, it splits into smaller branches and which supply the muscles of the middle and lower parts of the rectum.

Origin and course

The middle rectal artery usually arises from the anterior division of the internal iliac artery and courses inferiorly across the lesser pelvis, and enters the mesorectum.

They are ensheathed by fascia along with the branches of the inferior hypogastric plexus and are sometimes together referred to as the 'lateral rectal ligaments'.

The middle rectal artery then continues vertically, before taking a 90° turn to transversely approach the lower rectum, where it splits into several terminal branches.

Branches and supply

The middle rectal artery gives off terminal branches forming weak anastomoses with the superior and inferior rectal arteries, as well as the median sacral artery. The branches of the middle rectal artery supply the middle and lower portions of the rectum.

In addition, the middle rectal artery occasionally gives rise to several other arteries, such as vaginal branches in females which supply the vagina, prostatic and seminal branches in males supplying the prostate and seminal vesicles, and rarely an inferior lateral sacral branch (Kiyomatsu T et al., 2017).

Anatomical variations

The middle rectal artery is highly inconsistent. It is variably present, with studies suggesting it is more commonly present in males than females. When present, it is more often unilateral than bilateral and it often has a variable point of origin. On the other hand, it can occasionally be found in duplicates and more. The middle rectal artery can arise as a common trunk with the uterine, inferior vesical, internal pudendal, or inferior gluteal arteries (Kiyomatsu T et al., 2017).

6. Uterine Artery

The uterine artery is a paired artery that arises from the internal iliac artery. This artery is only found in females, supplying the uterus and other parts of the female reproductive system. Developmentally, the uterine artery is thought to be a female equivalent to the artery to ductus deferens in the male.

The uterine artery passes inferiorly and medially across the floor of the pelvis and above the ureter, travelling within the broad ligament of the uterus. It terminates at the cervix of the uterus, where it divides into smaller branches.

Origin and course

The uterine artery is a branch of the anterior division of the internal iliac artery, arising below the obturator artery. It runs inferiorly and medially along the lateral wall of the lesser pelvis, coursing into the inferior part of the broad ligament of uterus called the cardinal ligament.

During its initial course, the uterine artery is found lateral and superior to the ureter for about 2.5 cm and then crosses the ureter anteriorly to its medial side in order to reach the cervix of the uterus. The relationship between the uterine artery and the ureter has important clinical significance, and is remembered by the phrase “water (ureter) under the bridge (uterine artery)”.

Upon reaching the cervix of the uterus on each side, the uterine arteries give off an ascending branch, that courses superiorly alongside the uterus, and a descending branch that runs inferiorly towards the vagina.

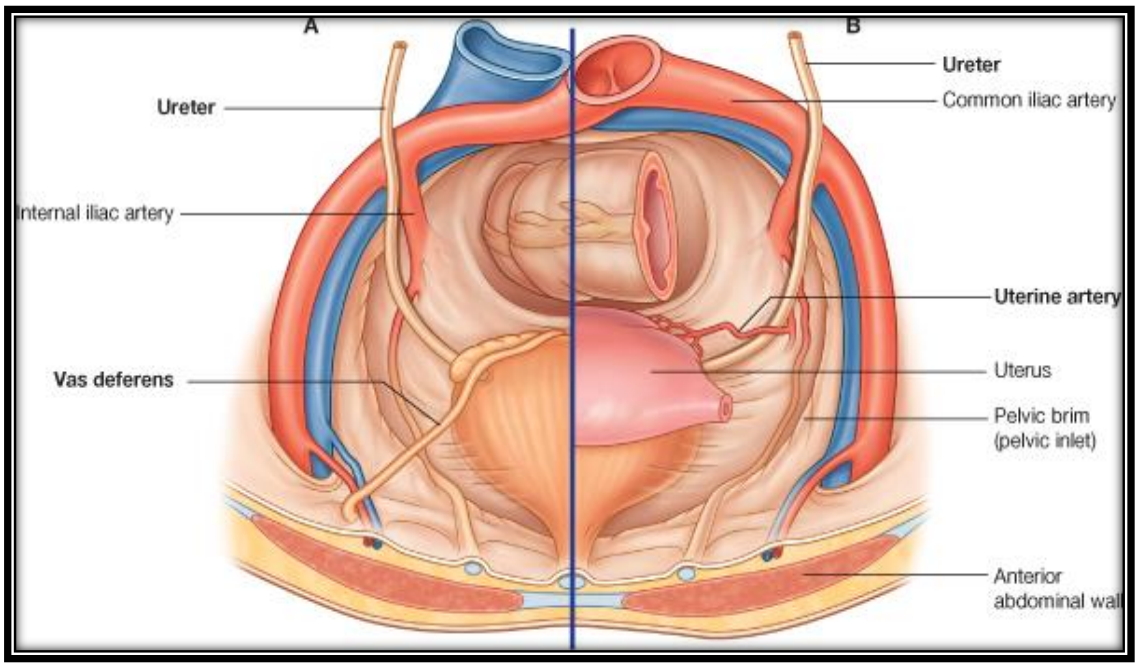


Figure 3.11: Uterine Artery

Branches and supply

At the level of the cervico-uterine junction, the uterine artery divides into an ascending and descending branch. The uterine artery and its branches constitute the majority of the blood supply of the uterus, playing an important role during processes such as the menstrual cycle and pregnancy.

- **Ascending branch:** passes superiorly in a tortuous manner along the lateral wall of the body of the uterus towards the uterine tube. Along its course, the ascending branch gives off multiple small branches entering the lateral uterine wall, and ramifies in the myometrium of the uterus into helicine, arcuate, radial, spiral, and basal arteries. The ascending branch continues superiorly until it reaches the uterine tube in the region of the ovarian hilum, where it divides into ovarian and tubal branches. These branches anastomose with the ovarian and tubal branches of the ovarian artery. In summary, the ascending branch supplies the lateral margin of the uterus, medial portion of the ovary and uterine tube.
- **Descending branch:** passes inferiorly towards the vagina. This vaginal branch anastomoses with branches of the vaginal artery forming median longitudinal arteries and the azygos arteries of the vagina, which descend along the anterior and posterior wall of the vagina. Along its course, the descending branch supplies the cervix and the vagina.

Anatomical variations

Although it most commonly arises directly from the internal iliac artery, the uterine artery can also arise from the umbilical artery. The uterine artery can also arise as a common trunk with the vaginal, internal pudendal, inferior vesical or middle rectal arteries.

3.1.2 BRANCHES OF POSTERIOR DIVISION:

1. Superior gluteal artery

The superior gluteal artery is a main artery of the gluteal region. It arises directly from the posterior trunk of the internal iliac artery as its largest branch. Along its course, it supplies muscles of the posterior pelvic region.

The superior gluteal artery gives off two terminal branches; superficial and deep. Via these branches, the artery supplies the gluteal muscles and the tensor fasciae latae, as well as some skin over the sacrum. Morever, it forms numerous arterial anastomoses with other arteries of the gluteal area.

Course

In the majority of the population, the superior gluteal artery arises from the posterior trunk of the internal iliac artery and is essentially its continuation. The artery extends posteriorly between the lumbosacral trunk of the sacral plexus and the first sacral spinal nerve, or between the first and second sacral spinal nerves.

The artery then takes a more inferior trajectory to leave the pelvis via the greater sciatic foramen, superior to piriformis muscle. Here it splits into its superficial and deep terminal branches. The superficial branch travels between the superficial surface of the gluteus medius and the deep surface of gluteus maximus, while the deep branch travels along the deep surface of the gluteus medius.

Branches and supply

After arising from the posterior trunk and before exiting the pelvis via the greater sciatic foramen, the superior gluteal artery supplies the piriformis and obturator internus muscles and gives a nutrient branch to the ilium. After leaving the greater sciatic foramen, the artery splits into two terminal branches.

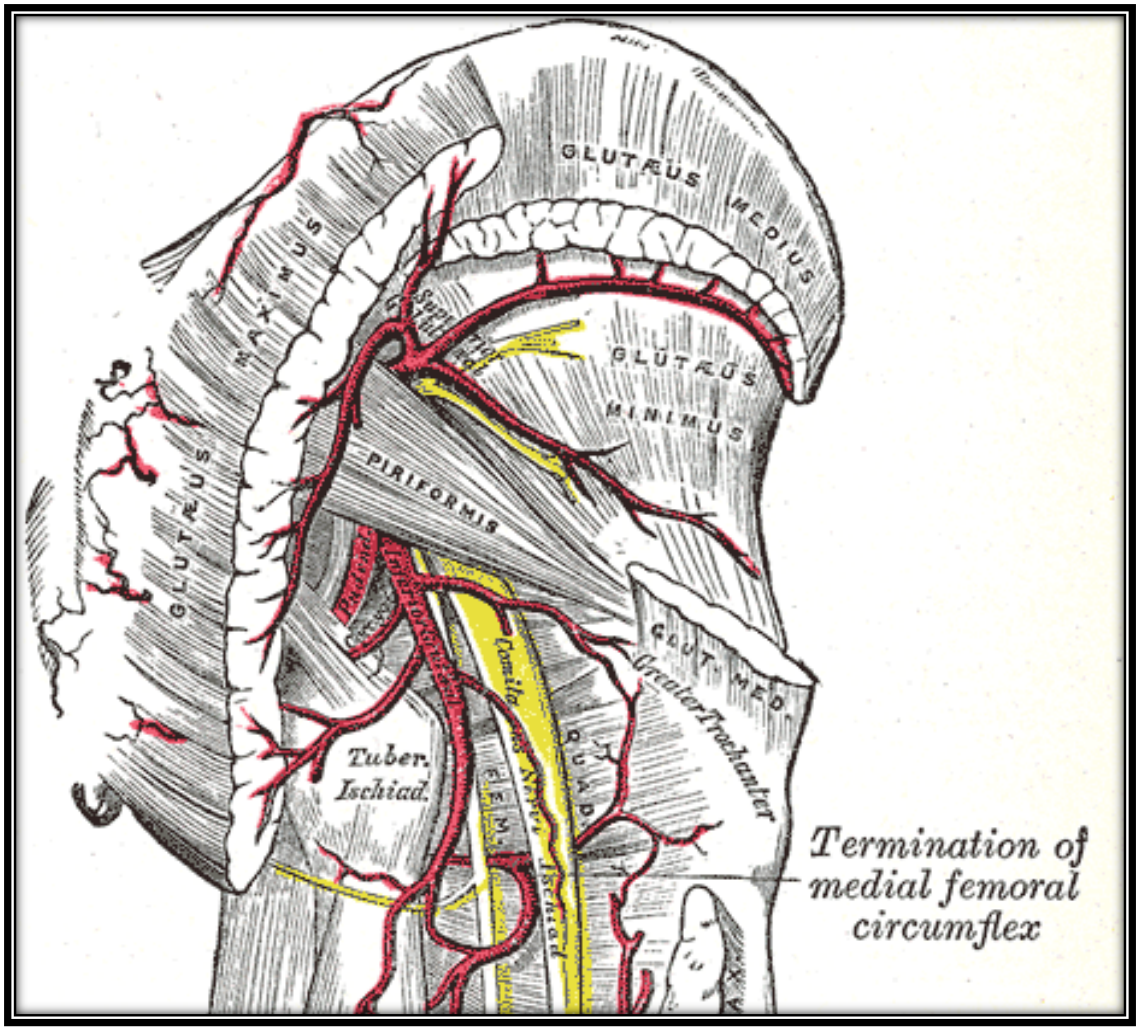


Figure 3.12: Superior gluteal artery

- **The superficial branch** gives off several branches that contribute to the blood supply to the gluteus maximus muscle by forming several anastomoses with the branches of the inferior gluteal artery. Via these anastomoses, the branches of the superior gluteal artery provide about one-third of the blood supply to the gluteus maximus, although sometimes it can be its main supplying vessel. The superficial branch also gives off several twigs that pierce the tendinous, medial, part of the gluteus maximus muscle and anastomose with branches of the lateral sacral arteries and supply the skin over the sacrum.
- **The deep branch** splits into two branches.

    - **The superior branch** travels along the pelvic attachment of the gluteus minimus to anastomose with the ascending branch of the lateral circumflex femoral artery and the deep circumflex iliac artery.

- **The inferior branch** travels between the gluteus medius and minimus muscles and supplies them both, as well as the superior part of the tensor fasciae latae. Here it anastomoses with the lateral circumflex femoral artery. It extends a branch to the trochanteric fossa, where it anastomoses with the inferior gluteal artery and ascending branch of the medial circumflex femoral artery. Some branches supply the hip joint.

The superior gluteal artery sometimes also contributes to the vascular supply of the superior gemellus muscle (Carter 1867; Wilson 1868; Fritsch and Kühnel, 2005).

Anatomical variation

Most commonly, the superior gluteal artery arises as a separate branch of the internal iliac artery. On rare occasions, it shares a common origin with other branches of the internal iliac artery; inferior gluteal, internal pudendal and umbilical arteries.

Sometimes, when the superior gluteal artery is a separate branch, it will give rise to the obturator artery, which is most commonly a branch of the internal iliac artery (Gabrielli C, 1997).

2. <u>Lateral sacral artery</u>

Origin and course

The lateral sacral artery originates from the posterior division of the internal iliac artery. It proceeds inferiorly, in close relation to the roots of the sacral plexus. It lies just lateral to the anterior sacral foramina and usually splits into superior and inferior branches, which supply 2 foramina each.

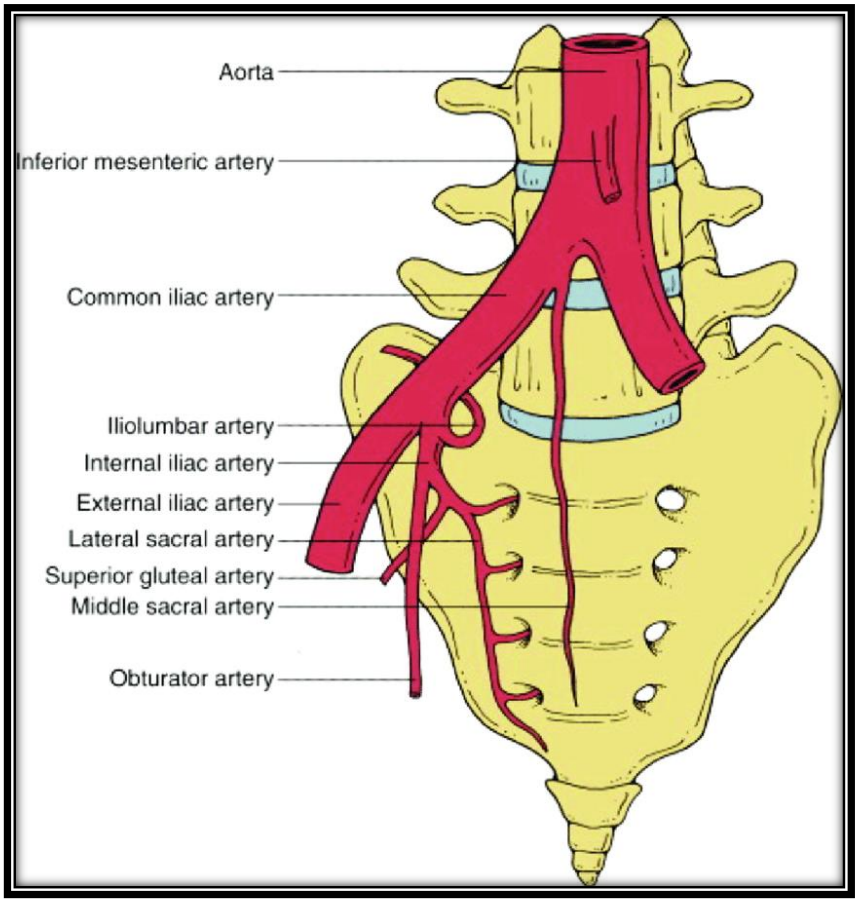


Figure 3.13: Lateral Sacral Artery

Branches and supply

- **The superior branch** passes medially, often anastomoses with the middle sacral artery and enters S1 and S2 foramina. It enters and supplies the sacral meninges and exits posteriorly to supply erector spinae and the cutaneous area over the sacrum, and anastomoses with the superior gluteal artery. It supplies the upper two sacral foramina and contents, erector spinae, and cutaneous supply over the sacrum.
- **The inferior branch** passes inferomedially over the piriformis muscle and runs down toward the coccyx, where it anastomoses with the middle sacral artery. It passes through the S3 and S4 foramina to supply spinal meninges and exits to supply muscle and overlying skin posteriorly. It supplies the lower two sacral foramina and contents as well as the piriformis muscle, coccyx, erector spinae, and skin over the sacrum (Carter 1867; Wilson et al 1868).

Anatomic variation

Occasionally the superior and inferior sacral vessels may not stem from the lateral sacral artery. Instead, they may directly come from the internal iliac artery (Gabrielli C, 1997).

3. Iliolumbar artery

The iliolumbar artery arises from the posterior division/trunk of the internal iliac artery, a branch of the common iliac artery (from the abdominal aorta). It originates within the pelvic cavity and makes its way to the iliac fossa within the greater pelvis.

The iliolumbar artery gives off two branches which contribute to the arterial supply of surrounding structures and muscles of the posterior abdominal wall.

Course

The iliolumbar artery is usually the first branch of the posterior division of the internal iliac artery. From its origin, it arches backward and ascends laterally out of the pelvic inlet toward the iliac fossa. It travels anterior to the sacroiliac joint and lumbosacral nerve trunk, passing behind the external iliac vessels to reach the medial border of the psoas major muscle.

Just posterior to the medial border of the psoas major muscle, the iliolumbar artery divides into lumbar and iliac branches.

Branches and supply

The iliolumbar artery has two main branches that contribute to the arterial supply of the posterior abdominal wall muscles and other structures in that region;

- **The lumbar branch** supplies the psoas major and quadratus lumborum muscles. It forms an anastomosis with the fourth lumbar artery. Additionally, it gives rise to a small spinal branch that travels through the intervertebral

foramen between the fifth lumbar vertebra (L5) and the first sacral vertebra (S1). This branch supplies the cauda equina.

- **The iliac branch** travels laterally into the iliac fossa to supply the iliacus muscle and the iliac bone. This branch also forms anastomoses with iliac branches of the obturator artery, the deep circumflex iliac artery, the lateral circumflex femoral artery as well as the superior gluteal artery. Through these anastomoses, the iliac branch contributes to the arterial supply of the gluteal and abdominal wall muscles (Beck et al 2003).

Anatomical variations

Although the iliolumbar artery typically arises from the posterior division of the internal iliac artery, its origin is variable. It can commonly arise directly from the main trunk of the internal iliac artery. It has also been reported to arise less commonly from the superior gluteal artery, common iliac artery or lateral sacral artery (Gabrielli C, 1997).

In summary, the anterior division of the IIA normally supplies: the urinary bladder, ureters, ductus deferens (males), rectum, uterus and cervix (females), anal canal, transversus perinei superficialis muscle, bulb of the penis (males), corpus cavernosum penis (males), and muscles of gluteal region. The supply passes through the obturator artery, anterior branch, to the obturator externus, pectineus, adductors, and gracilis muscle; and through the posterior branch of the OBA to the femoral neck and head. The posterior division supplies the psoas major, quadratus lumborum and iliacus muscles, the sacral canal, the dorsal surface of the sacrum and the gluteus maximus muscle.

3.2. EMBRYOLOGICAL BACKGROUND

Vessels as parts of the vascular system appear during embryo development around the mid-third week and originate directly from a combination of mesodermal and ectodermal angiogenic cells. There are two routes to development: angiogenesis, and in situ formation of endothelial vesicles that can coalesce with vessels that are still

elongating. Angiogenesis is characterized by growth through the building, branching and elongation of existing vessels (Noden, 1989).

Antibodies that recognize quail endothelial cells can be used to follow the movements and differentiation of endothelial cell precursors after the putative precursor populations are transplanted from quail to chick embryos (Noden, 1989). Using this method, it has been shown that all intraembryonic mesodermal tissues, except the prechordal plate, contain angiogenic precursors (Noden, 1989). Some angioblasts move in all directions away from the site of implantation, invading the surrounding mesenchyme and contributing to the formation of arteries, veins, and capillaries over a wide area. Although these invasive angioblasts, which behave unlike any other embryonic mesenchymal cell type, are found throughout the embryo, it is not known whether they represent a unique endothelial cell type in mature blood vessels (Noden, 1989).

Early embryological development of the common iliac arteries is related to fifth dorsal branches of the aorta. Initially, umbilical arteries arise from fourth ventral branches of the aorta, however their origin is mobile – longitudinal anastomotic connection between umbilical artery and fifth dorsal branch of the aorta develops in the region of expanding internal iliac artery, shifting the origin of umbilical arteries and ultimately disappears. The latter change is relevant in some anatomical classification systems, which are based on IIA branches and their origin (Tunstall, 2016).

As the primal abdominal aorta bifurcates into the common iliac arteries, which subsequently give origin to the most important lower limb vessels, it is worth noting that the bifurcation is inferior to that adults; its level rises with gestational age (Özgüner and Sulak, 2011).

The lower limb axial artery is a continuation of the fifth lumbar intersegmental artery. It is commonly accepted that it follows the course of the sciatic nerve, which conditions the final pathway of the vessel, accordingly named the sciatic artery (Khalid and Bordoni, 2021). It reaches the gluteal region, traveling to the back of

thigh, and then runs near the bone to reach the popliteus and calf muscles. The vessel ends in forming a vascular plexus on the plantar surface of the foot.

The axial artery is only observable during embryo development because it degenerates in the adult, leaving as its remnants the sciatic and inferior gluteal arteries; the latter is commonly called the primary axial artery (Grant, 1957).

During development, the IIA is derived from the umbilical artery, the proximal part of which persists postnatally while the distal part is obliterated (Mamatha et al., 2015). The embryonic umbilical artery, which subsequently becomes a regressed constituent of the IIA complex during the development of anomalous branches or variations in vascular anatomy, is considered important (Prabhu et al., 2001). After birth, the greater part of the intraabdominal portion of the umbilical artery atrophies and is converted into the medial umbilical ligament. From the portion in the pelvis, the origination of the superior vesical artery occurs.

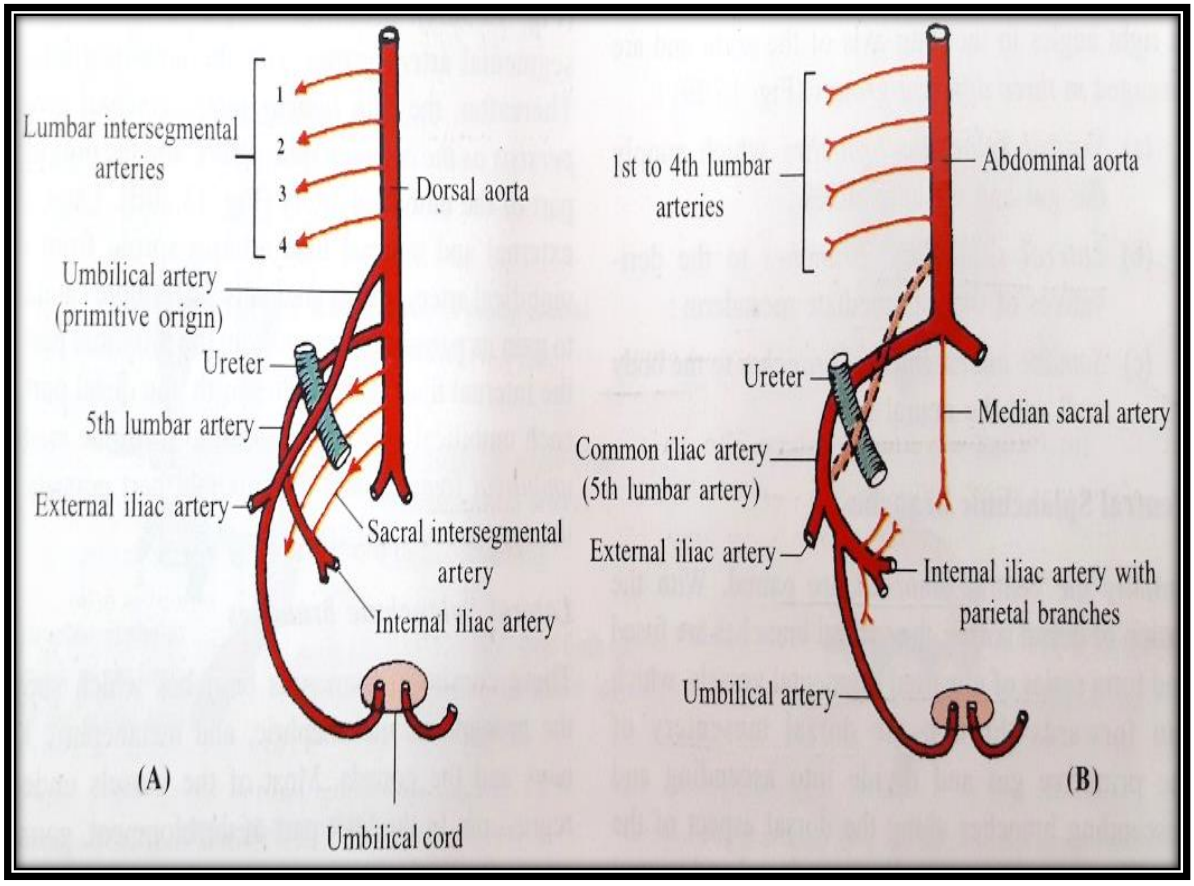


Figure 3.14: Development of Iliac Artery

3.3. HISTORY OF CLASSIFICATION

Herbert (1825)

Herbert stated that the internal iliac artery (IIA) is a branch of the common iliac artery (CIA). He, in an older description of the IIA divisions did not refer to anterior and posterior trunks, rather he described the trunk as having numerous branches classified into the internal surface of the pelvis, pelvic viscera and extra-pelvic branches.

- The first category - branches to the internal surface of pelvis are the iliolumbar artery and lateral sacral artery.
- The second category - branches to pelvic viscera are hypogastric artery or umbilical, vesical and middle rectal arteries.
- The third category - branches are the gluteal artery, sciatic artery, internal pudendal and obturator arteries.

Power (1862)

He gave a different classification, which were internal and external arteries based on whether they remain inside or were distributed outside the pelvis, respectively.

The first class

- In males - the internal arteries are iliolumbar, lateral sacral, middle rectal, vesical and umbilical arteries
- In females - the internal arteries are iliolumbar, lateral sacral, middle rectal, vesical artery umbilical artery, vaginal artery and uterine artery

The second class - external arteries are gluteal, pudendal (pudic), sciatic and obturator artery.

Testut (1948) and Williams (1995)

They classified the internal iliac artery branches into;

Visceral branches

- Male - branches supplying the urinary bladder, prostate, seminal vesicles, ejaculatory ducts and rectum
- Female - branches supplying the urinary bladder, ovaries, uterus, vagina, urethra and rectum

Fredet (1899) and Rouviere (1967)

They classified the internal iliac artery branches supplying the gluteal region, posterior and medial compartment of thigh and hip joint into the extra-pelvic branches of the internal iliac artery.

Limitations of above studies

- Some of the arteries supply both intra and extra-pelvic structures
- According to the variability of branches in males and females the vesical artery has no comprehensive description, with it also being described as giving the spermatic artery as a branch. As a result, the vesical artery could be an external or an internal artery as the spermatic artery supplies extra-pelvic structures

Carter (1967), Sharpey et al (1867), Wilson (1868)

They divided the IIA into two trunks, anterior and posterior trunks.

Jastschinski (1891)

Jastschinski classified the IIA into three groups based on size of artery.

- **First group** - large calibre arteries including the superior gluteal, inferior gluteal and internal pudendal arteries;
- **Second group** - medium calibre arteries including the obturator artery;
- **Third group** - small calibre arteries including iliolumbar and lateral sacral arteries.

Limitations

- The size of the artery varies from one cadaver to another.

Lipshutz (1918)

In 1918, Lipshutz studied 181 dissections of pelvic halves from 93 cadavers (72 males white: 11 females white; 7 males black: 3 females black) and presented an alternative five group classification system based upon the origin of the inferior gluteal, superior gluteal, internal pudendal, and obturator arteries. The ordering of the five types was based upon their frequency of observation. Lipshutz also reported that there was a tendency for types I and II to be more common on the right side with types III, IV,

and V being more common on the left. The five branching patterns were described as follows.

- **Type I (40%):** The superior gluteal artery was the largest branch and arose as the dorsal or posterior trunk of the internal iliac artery. The internal pudendal and inferior gluteal arteries arose as a common trunk caudal to superior gluteal. The obturator, vesical, middle hemorrhoidal, and uterine arteries arose as separate branches from the caudal continuation of the internal iliac artery. In 45% of this group the obturator artery arose in a common trunk with the inferior epigastric artery from the external iliac, and arose 16 times as a separate branch from the superior gluteal artery. In one subject the obturator artery was as a branch of the femoral artery.

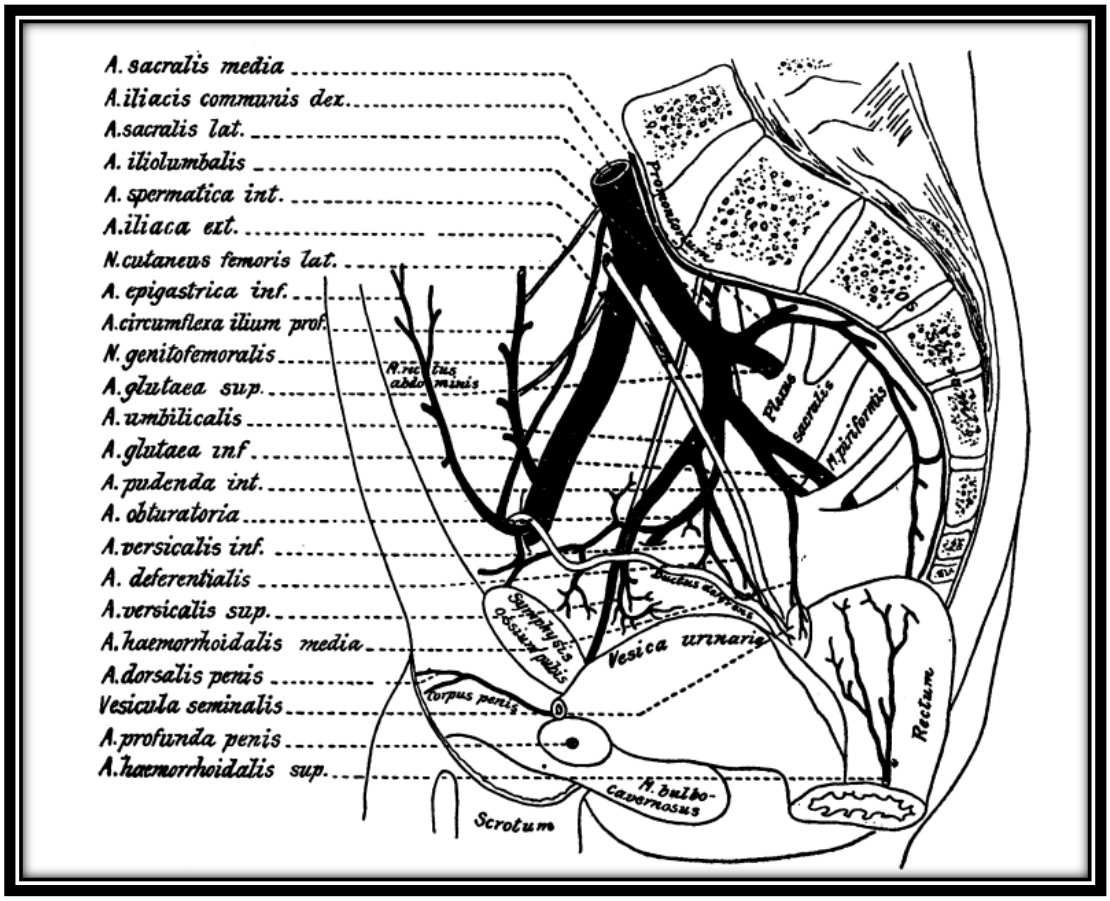


Figure 3.15: Type I, Lipshutz classification of the IIA

- **Type II (24%):** The superior and inferior gluteal arteries arose from the internal iliac artery as a common trunk. The internal pudendal, obturator, and uterine arteries arose as separate branches from the caudal continuation of the internal iliac artery. In 40% of this group the obturator artery arose as a separate branch from the common trunk of the superior and inferior gluteal arteries. It also arose via a common trunk with the inferior epigastric artery from the external iliac artery. In all cases the common trunk for the superior and inferior gluteal arteries exited the pelvis via the greater sciatic foramen superior to piriformis. In two subjects the internal pudendal artery was a separate branch of the common trunk for the superior and inferior gluteal arteries after the trunk had exited the pelvis.

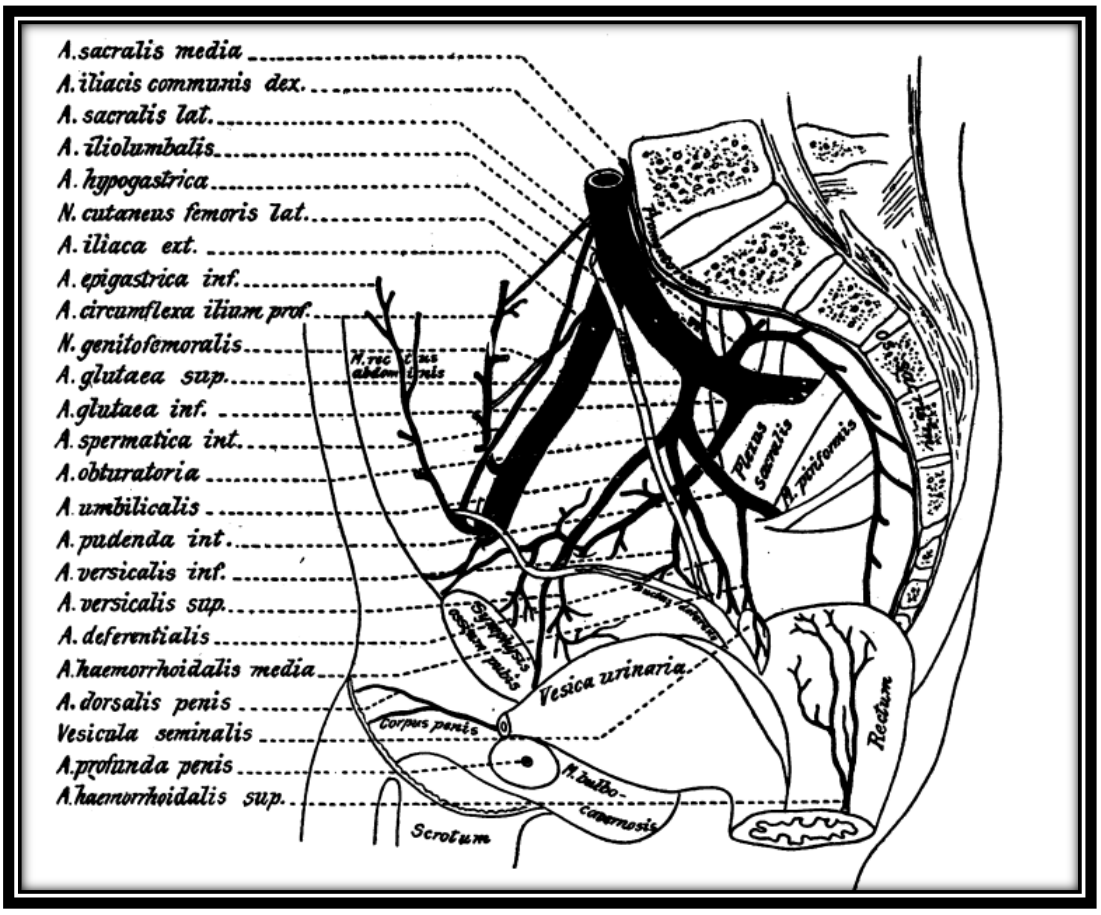


Figure 3.16: Type II, Lipshutz classification of the IIA

- **Type III (17%):** The superior gluteal, inferior gluteal and internal pudendal arteries were separate branches of the internal iliac artery. The origin of the obturator artery was variable, occurring as a branch of the internal iliac artery, inferior gluteal artery, internal pudendal artery, a common trunk with the inferior epigastric artery; and the middle rectal artery.

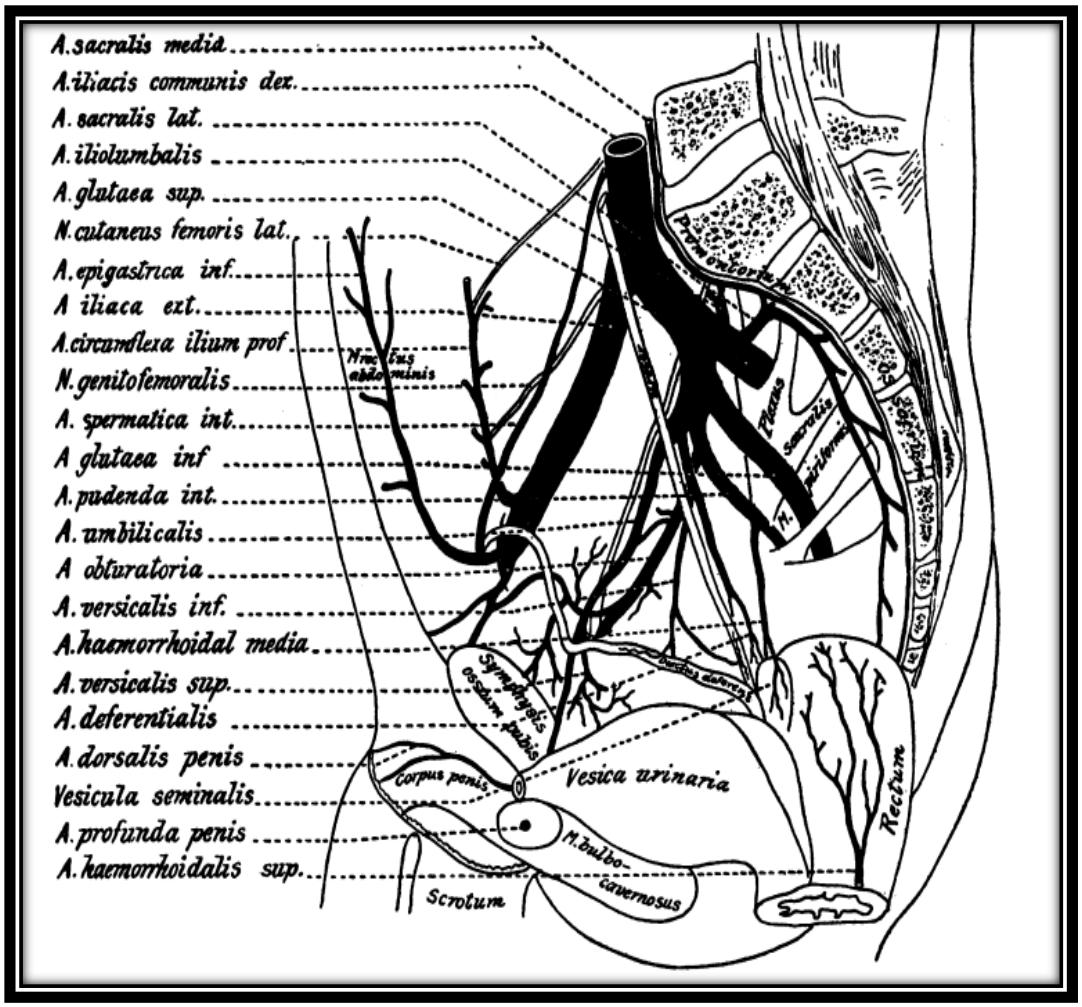


Figure 3.17: Type III, Lipshutz classification of the IIA

- **Type IV (11%):** The obturator, internal pudendal, and inferior gluteal arteries arose from the internal iliac artery as a common trunk and the superior gluteal artery arose as a separate branch dorsal to the common trunk. The superior gluteal artery was usually larger than the trunk for the inferior gluteal, obturator, and internal pudendal arteries.

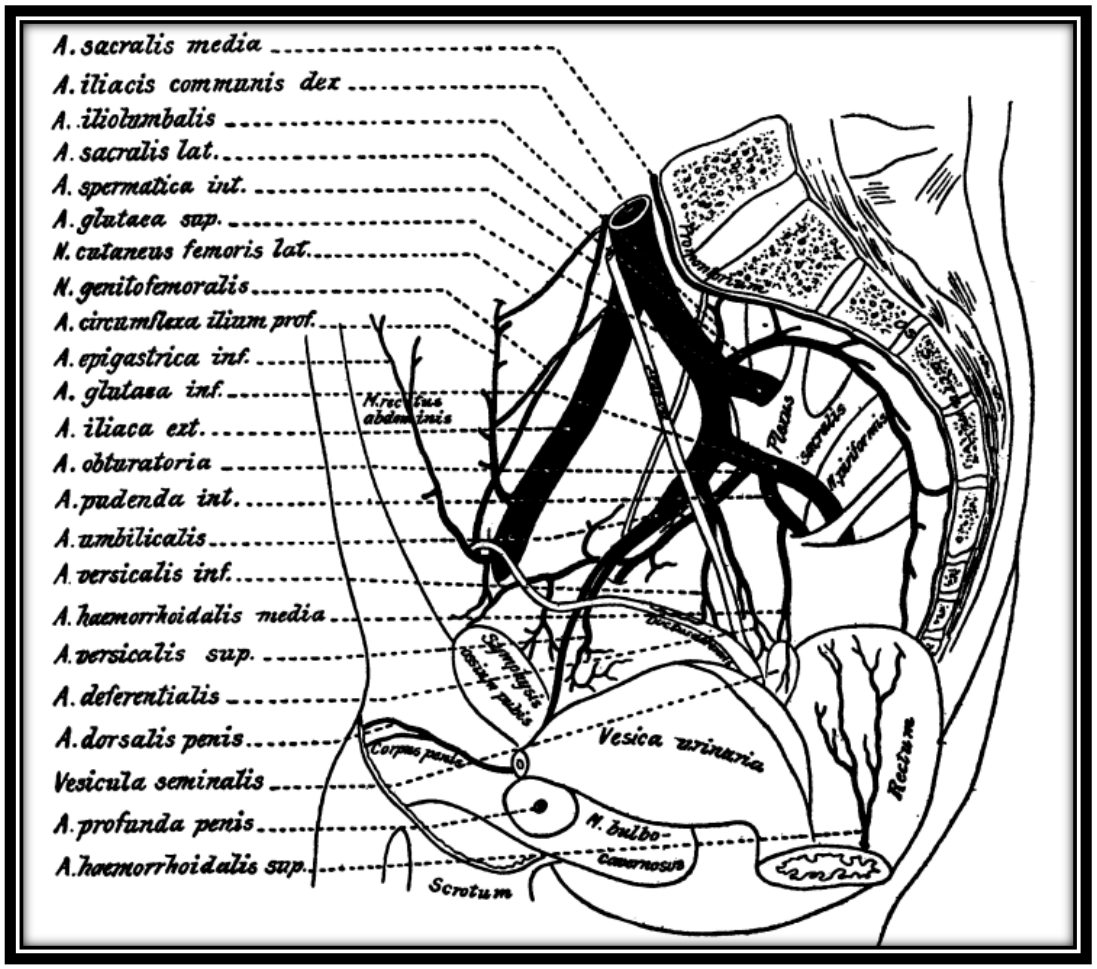


Figure 3.18: Type IV, Lipshutz classification of the IIA

- **Type V (7%):** The superior gluteal, inferior gluteal, obturator, and internal pudendal arteries arose as a common trunk from the internal iliac artery.

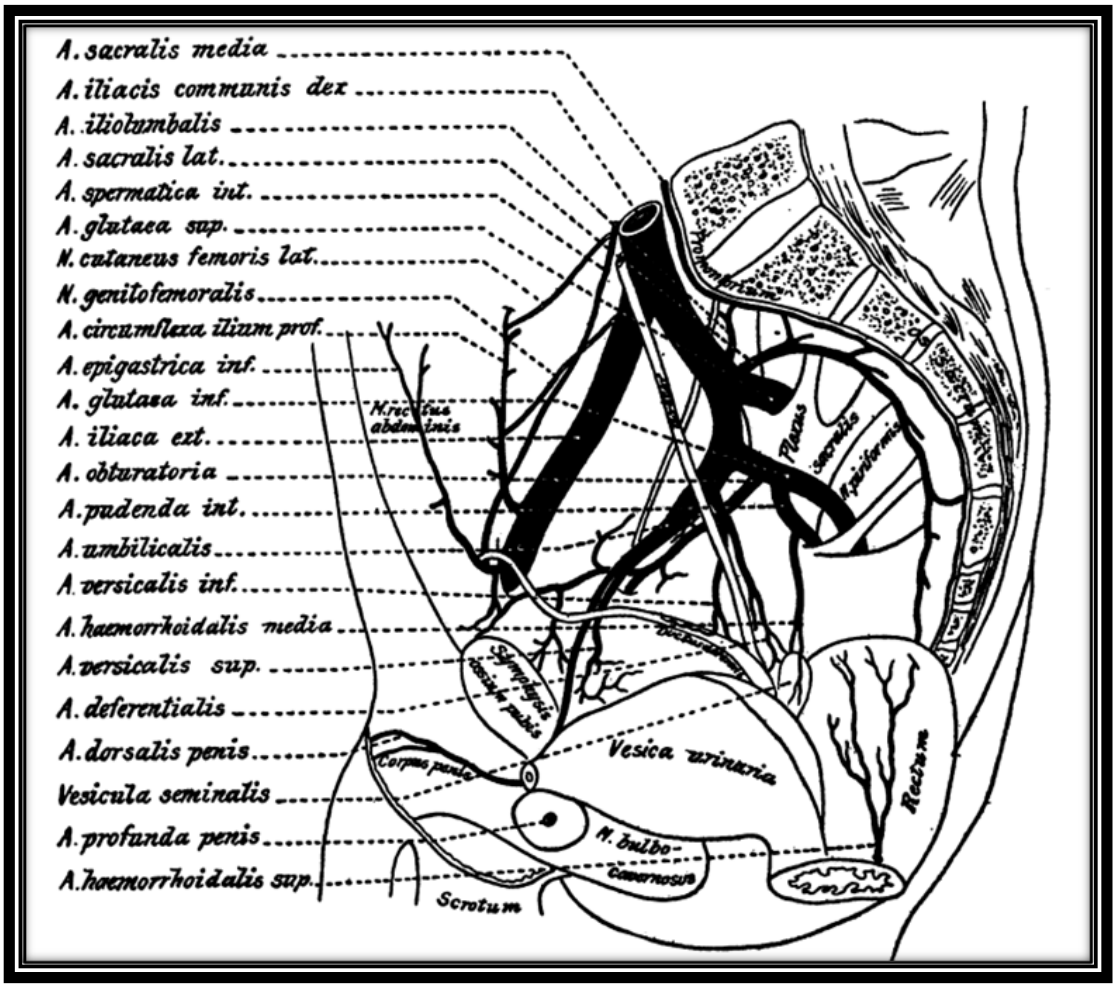


Figure 3.19: Type V, Lipshutz classification of the IIA

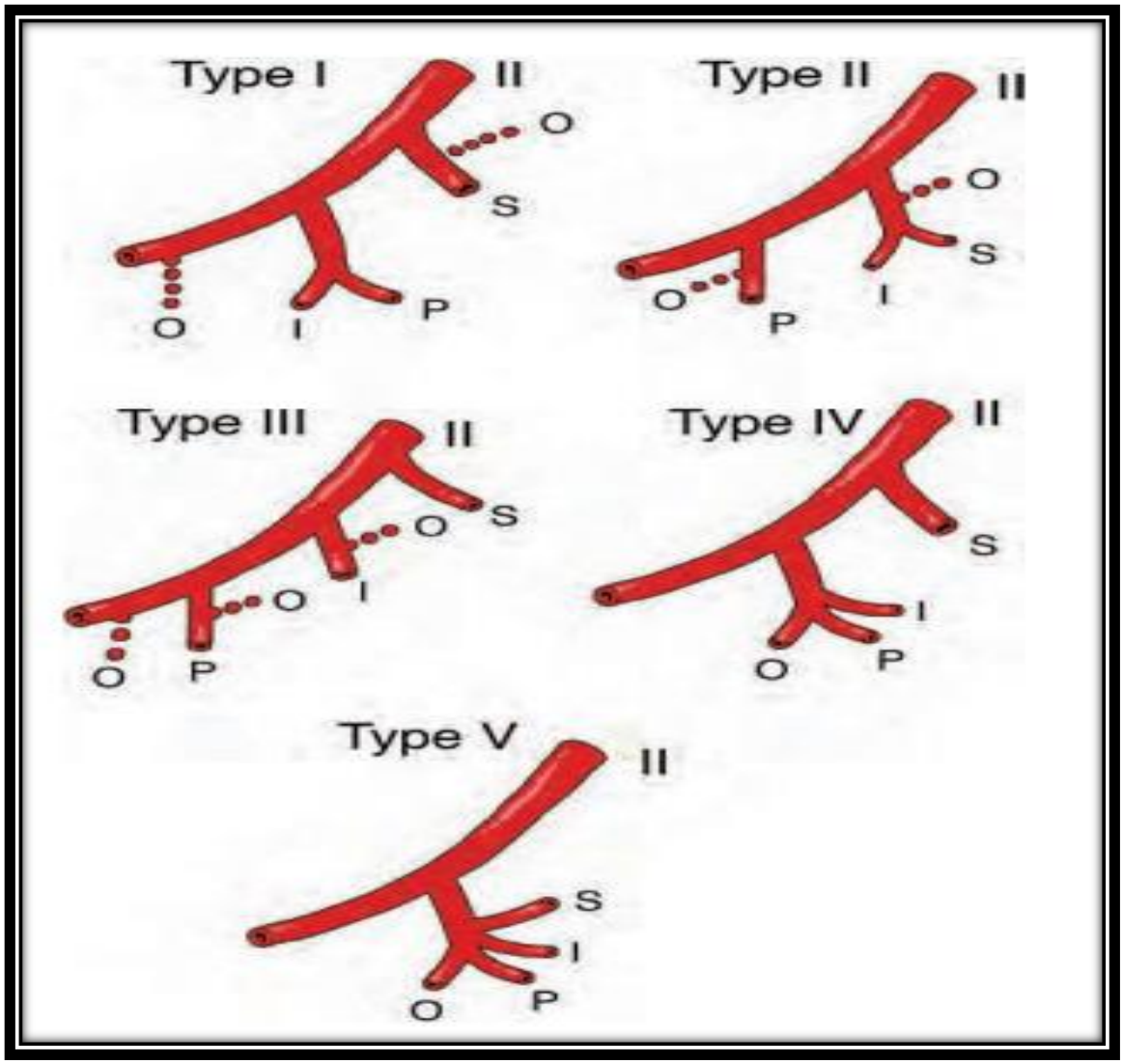


Figure 3.20: Five types of internal iliac artery branching pattern based upon a study of Lipshutz. II: internal iliac artery; I: inferior gluteal artery; S: superior gluteal artery; P: internal pudendal artery; O: obturator artery

Dubreuil-Chambardel (1925)

In 1925 Dubreuil-Chambardel conducted a study of 440 cadaveric specimens and reported ten different branching patterns of the internal iliac artery based upon the gluteal, internal pudendal and sacral arteries (Fig. 3.21) and ten different branching patterns based upon the visceral branches of the anterior division (Fig. 3.22)

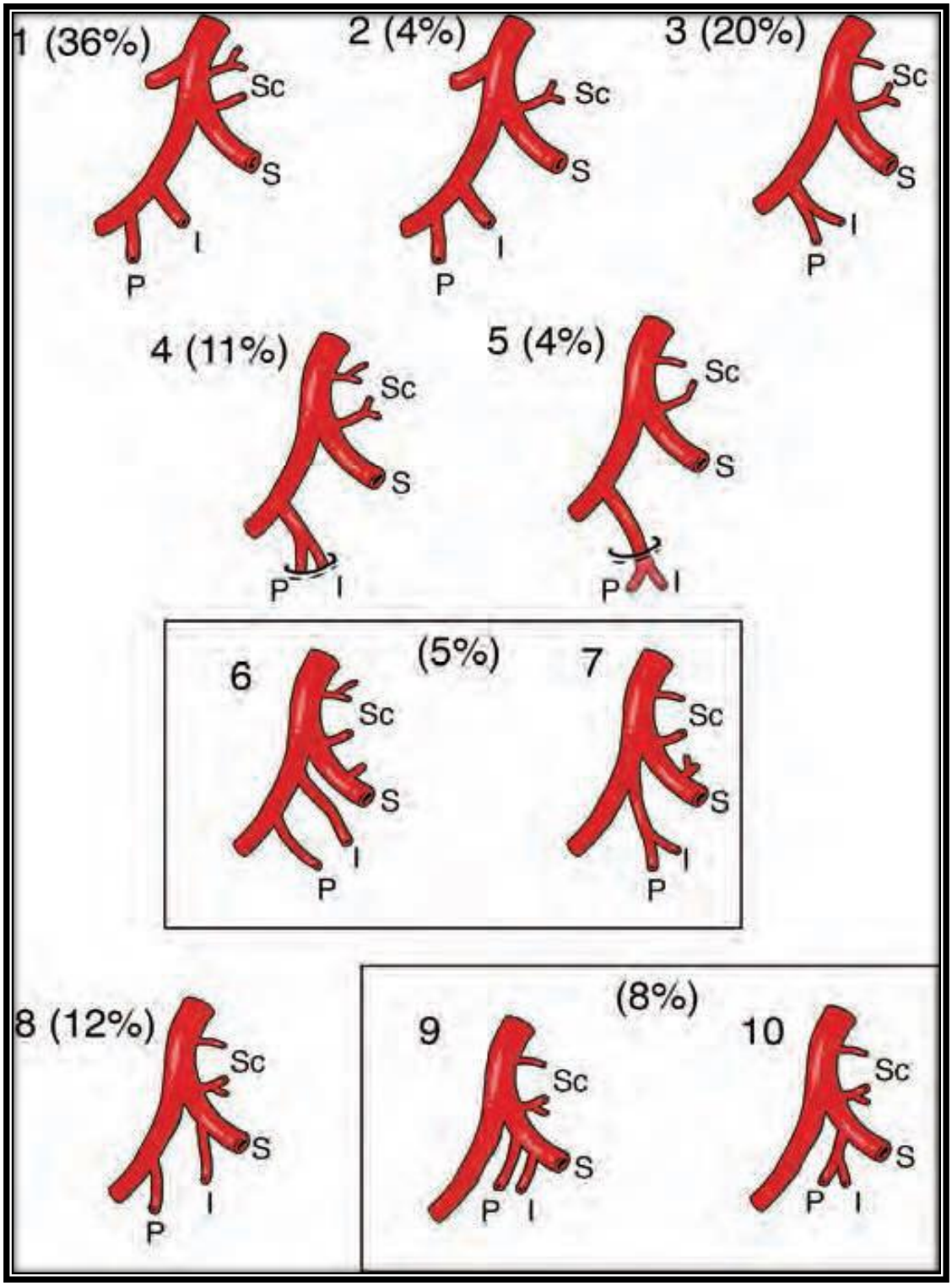


Figure 3.21: Ten types of variation in the branching pattern of the internal iliac artery based upon four main branches by Dubreuil-Chambardel. Based on 440 observations, relative frequency (%) of each type is shown. S: superior gluteal artery; I: inferior gluteal artery; p: internal pudendal artery; Sc: lateral sacral arteries.

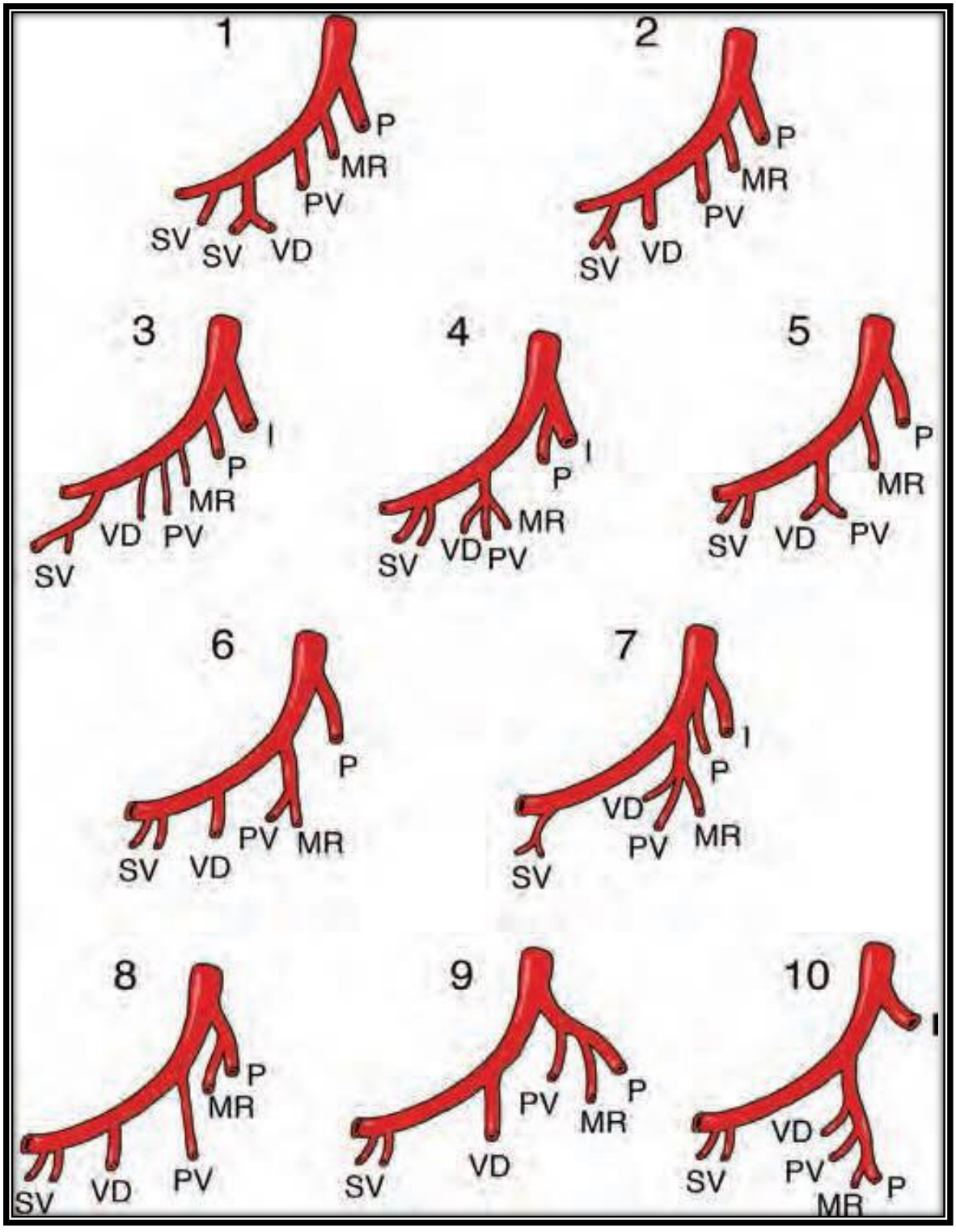


Figure 3.22: Ten types of variation in the origin of the visceral branches of the internal iliac artery by Dubreuil-Chambardel. Based on 440 observations. P: internal pudendal artery; MR: middle rectal artery; PV: prostatovesical artery; VD: vesicodeferential artery; SV: superior vesical artery; I: inferior gluteal artery.

Adachi (1928)

In 1928, Adachi published the results of a study based upon 121 Japanese cadaveric specimens. Adachi classified the distribution pattern of the IIA into five types with eight groups because only the large IIA branches – SGA, IGA and IPA – had sufficiently regular origins, the main differentiating factor. Adachi proposed that the umbilical artery was a continuation of the main stem of the IIA. Embryologically, the superior gluteal, inferior gluteal and internal pudendal arteries are principal branches of the umbilical artery.

Type I - The superior gluteal artery arose independently from the internal iliac artery whereas the inferior gluteal and internal pudendal vessels arose from a common trunk into two forms above and below the pelvic floor which are Type Ia and Type lb. respectively.

Type II - The superior and inferior gluteal arteries arise from a common trunk whereas the internal pudendal artery arises independently. The gluteal common trunk divides into two forms above and below pelvic floor which are Type IIa and Type Ilb respectively.

Type III - The superior and inferior gluteal arteries and the internal pudendal artery arises from the internal iliac artery independently.

Type IV - The superior and inferior gluteal arteries and the internal pudendal artery arise from a common trunk of the internal iliac artery. The subtyping in this latter group is based on the sites of origin of the superior gluteal and internal pudendal arteries from the parent stem. In Type IVa, the trunk first gives rise to the SG before bifurcating into the other two branches; in Type IVb the IPA is the first vessel to spring from the common trunk, which then divides into SGA and IPA.

Type V - The internal iliac artery trunk gives the internal pudendal and superior gluteal arteries from a common trunk whereas the inferior gluteal has a separate origin.

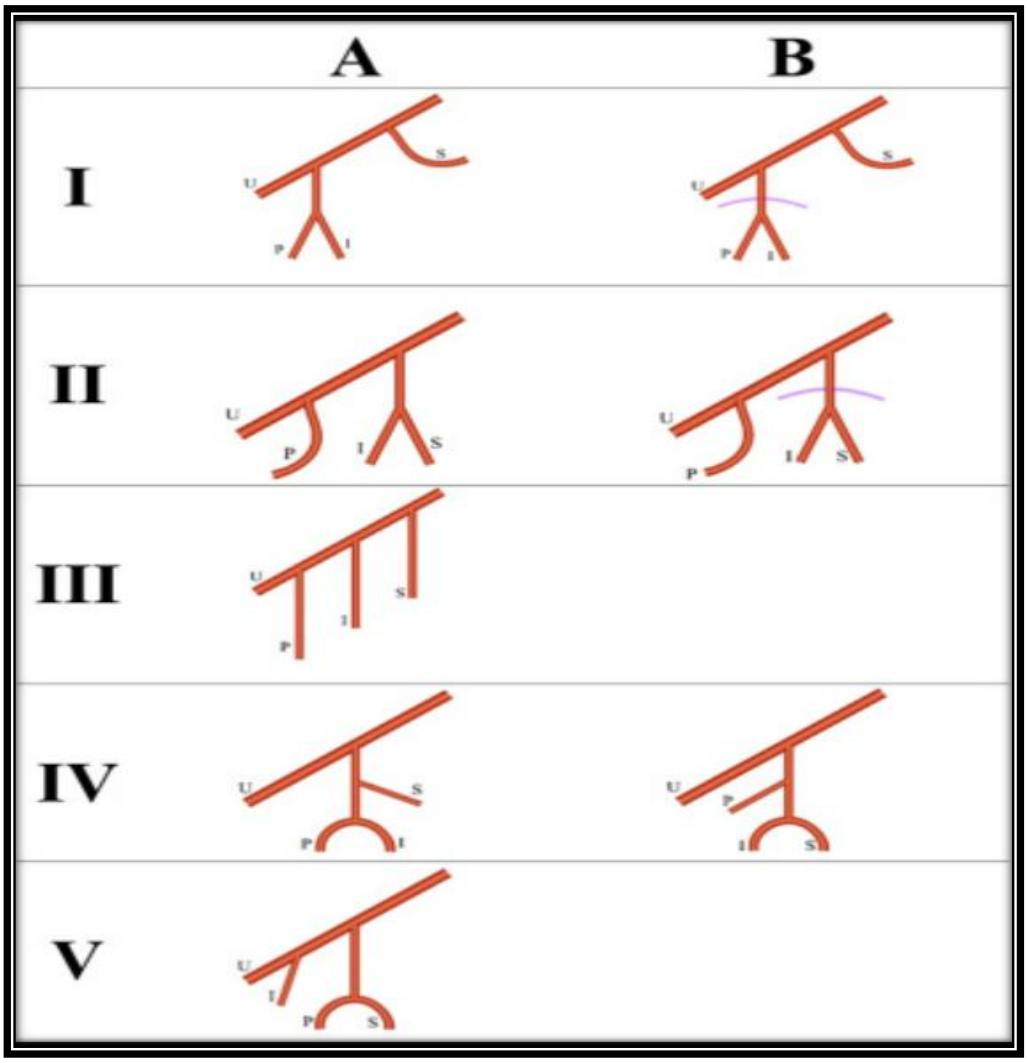


Figure 3.23: The branching pattern of the internal iliac artery, as classified by Adachi et al. (1928). U: umbilical artery, I: inferior gluteal artery, S: superior gluteal artery, P: internal pudendal artery.

Advantages –

- Widely accepted
- Many scientific papers based on it

Disadvantages –

- Concept of classification disturbed by the discovery of previously unobserved types
- Lack of assessment of coexistence of an incomplete form of sciatic artery

Modification of Adachi classification

Ashley and Anson (1941)

They updated the classification by adding the umbilical artery to the three previous arteries used in the Adachi's classification, which in turn was a modification of Lipshutz (1916) classification excluding the obturator artery.

Type I: In this rare form the superior vesical is a continuum of the main trunk

Type II: The principal branches all arise from one common trunk

Type III: Except the superior vesical artery, all other branches arise from a common trunk

Type IV: Tow common stems give off two branches each, the gluteals from one and the others from the second one

Type V: In this type, the inferior gluteal and internal pudendal arise from one common trunk, the superior gluteal and superior vesical arising as separate branches.

Type VI: The gluteals arise from a single trunk while the others arise separately

Type VII: Here all the branches arise separately but from a common level, the superior vesical giving off the internal pudendal.

Type VIII: In this type the two gluteals arise separately, the superior vesical giving off the internal pudendal. Type IX: The parent trunk becomes trifid with the superior and inferior gluteals appearing as two stems, the third stem dividing into the superior vesical and internal pudendal.

Type IX: The parent trunk becomes trifid with the superior and inferior gluteals appearing as two stems, the third stem dividing into the superior vesical and internal pudendal.

Lippert and Pabst (1985)

They presented a clinical classification and stated that it was difficult to classify the branching pattern on the basis of embryo development or practical features because the umbilical artery is the main branch during development, but after birth it ceases to be important. They therefore endorsed Yamaki's later assessment that the umbilical artery should not be considered a major differential factor.

Lippert and Pabst presented classified IIA into four types. They are as follows;

- **Type 1**: all arteries branch from a single main stem (internal iliac artery);
- **Type 2a–d**: the internal iliac artery divides into two main divisions (anterior and posterior) from which the branches arise;
    - **Type 2a**: anterior division ends as the inferior gluteal and internal pudendal arteries (posterior division ends as the superior gluteal artery);
    - **Type 2b**: anterior division ends as the internal pudendal artery; posterior division ends as the superior and inferior gluteal arteries, which leave through the supra and infrapiriform foramen, respectively;
    - **Type 2c**: same branching as 2b except the posterior division ends as a common trunk that divides into superior and inferior gluteal arteries after passing through the suprapiriform foramen;
    - **Type 2d**: the anterior division ends as the inferior gluteal artery; posterior division ends as the superior gluteal and internal pudendal arteries;
- **Type 3**: internal iliac artery divides into three stems which give off all other branches;
- **Type 4**: internal iliac artery divides into four or more stems which branch to give the other arteries.

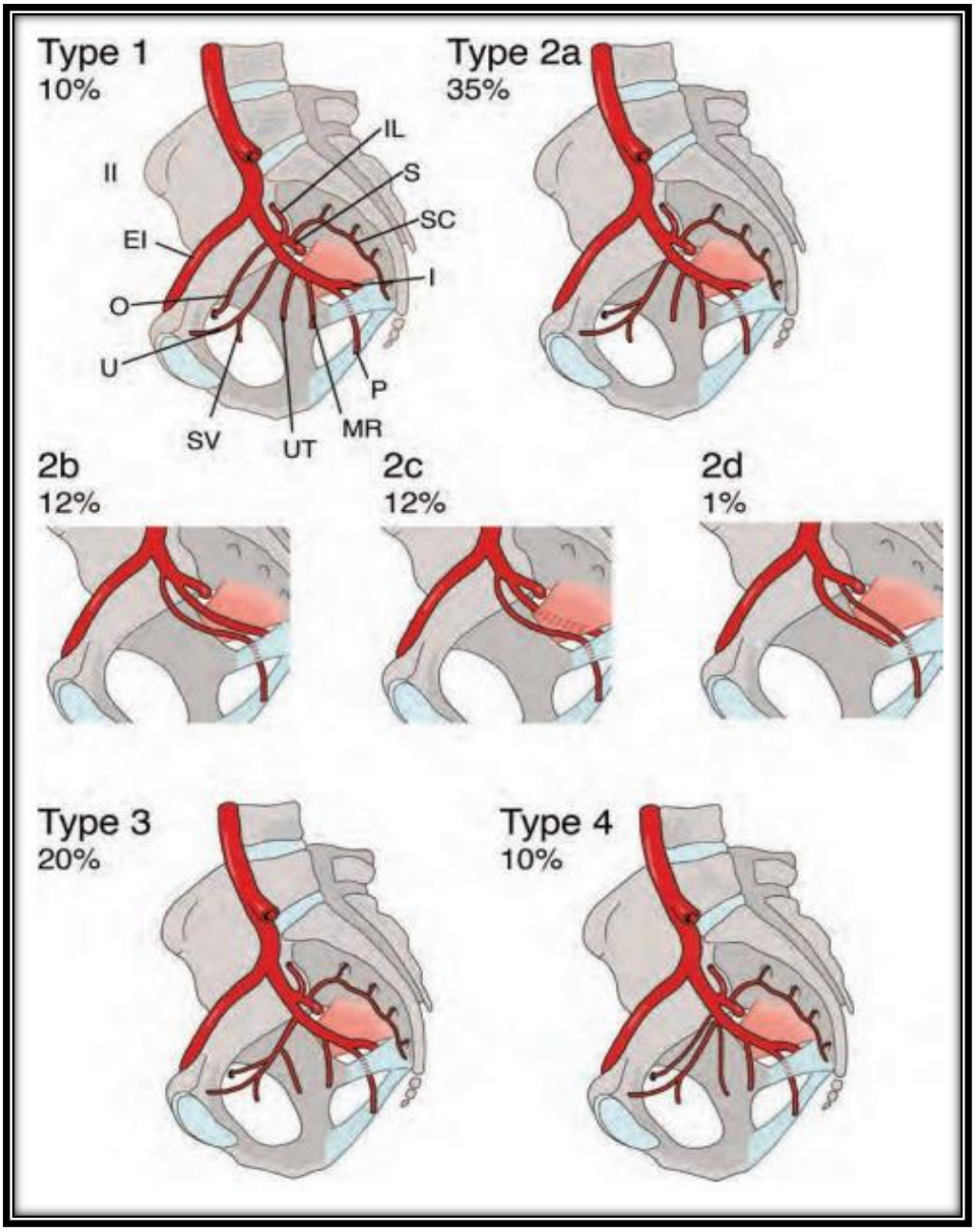


Figure 3.24: Lippert and Pabst's classification of Internal iliac artery

Yamaki et al. (1998)

In 1998, Yamaki et al. published the results of a study investigating 645 cadaveric pelvic halves from Japanese cadavers and presented a modified classification of Adachi's classification; into 5 types and 19 groups.

Type I comprises four groups;

- **Groups 1 and 2** – they are the same as Adachi's Types Ia and Ib, respectively. Here, the origins of the superior gluteal artery and the common trunk of the inferior gluteal and internal pudendal arteries are apparently separated.

- **Groups 3 and 4** - the superior gluteal artery and the common trunk of the inferior gluteal and internal pudendal arteries originate simultaneously from the main stem

Type II also comprises four groups;
Adachi's Type IIa is subdivided into Groups 1 and 3, and Type IIb into Groups 2 and 4. Three groups are added to Type III.

- **Group 1 -** It is is the same as Adachi's Type 3, but the origins of the superior gluteal, inferior gluteal and internal pudendal arteries from the main stem are apparently separate

- **Group 2** - Here, inferior gluteal and internal pudendal arteries arise from the main stem at the same point.

- **Group 3** – Here, the superior gluteal, inferior gluteal and internal pudendal arteries arise from the main stem at the same point

- **Group 4** - Here, the superior gluteal and inferior gluteal arteries arise from the main stem at the same point

Type IV comprises six groups.

- **Group 1** - It is the same as Adachi's Type IVa.
- **Group 2** - Here, the inferior gluteal and internal pudendal arteries divide outside the pelvis.
- **Group 3** - It is the same as Adachi's Type IVb.

- **Group 4** - Here, the superior and inferior gluteal arteries divide outside the pelvis
- **Group 5** - Here, all three major branches divide from the common trunk at the same point within the pelvis
- **Group 6** - Here, the division occurs outside the pelvis

Type V – It is a rare form and is the same as Adachi's Type V.

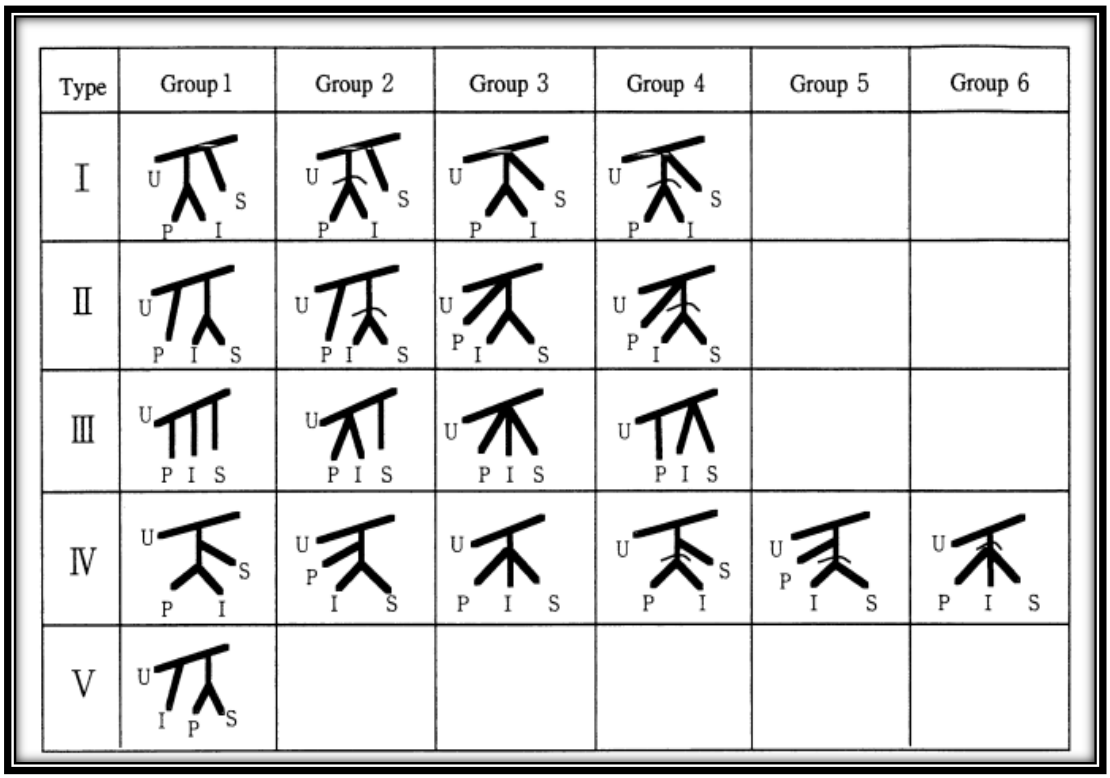


Figure 3.25: A modified Adachi classification (By Yamaki et al. 1998). U: umbilical artery, I: inferior gluteal artery, S: superior gluteal artery, P: internal pudendal artery.

Yamaki et al. noted that there are no significant differences between the numbers on the right and left sides in each group. However, females had a significantly higher rate than males for Type I, Group 1, and significantly lower rates for Type I, Group 4

Advantages-

- Addition of subdivisions of branching patterns enriched Adachi classification
- Large number of specimens used in research

Disadvantages -

- Some types and groups used to specify branching pattern look identical at origin
- Differential factor of classification complicates the recognition of origin pattern of main vessels
- Concept of classification disturbed by the discovery of previously unobserved types
- Lack of assessment of coexistence of an incomplete form of sciatic artery

Yamaki et al. classification

Yamaki and colleagues upgraded their morphological account of the IIA with a new classification in which the umbilical artery was excluded from the pattern of IIA branching. They proposed that the superior gluteal, inferior gluteal, and internal pudendal arteries were the principal branches of the IIA, so the IIA was classified into four groups (Fig. 3.26) as follows

- **Group A**: The IIA divides into two branches, the superior gluteal artery and the common trunk of the inferior gluteal and internal pudendal arteries. Group A includes Type I Groups 1–4, Type III Groups 1 and 2, and Type IV Groups 1 and 2 of the modified Adachi classification presented above.

- **Group B**: The IIA divides into two branches, the internal pudendal artery and the common trunk of the superior gluteal and inferior gluteal arteries. Type II Groups 1–4 and Type IV Groups 3 and 4 of the modified Adachi classification are included in Group B.

- **Group C**: The IIA trifurcates into three major branches. This group includes Type III Groups 3 and 4 and Type IV Groups 5 and 6 of the modified Adachi classification.

- **Group D**: The IIA divides into the common trunk for the superior gluteal and internal pudendal arteries and the inferior gluteal artery. This group includes Type V of the modified Adachi classification

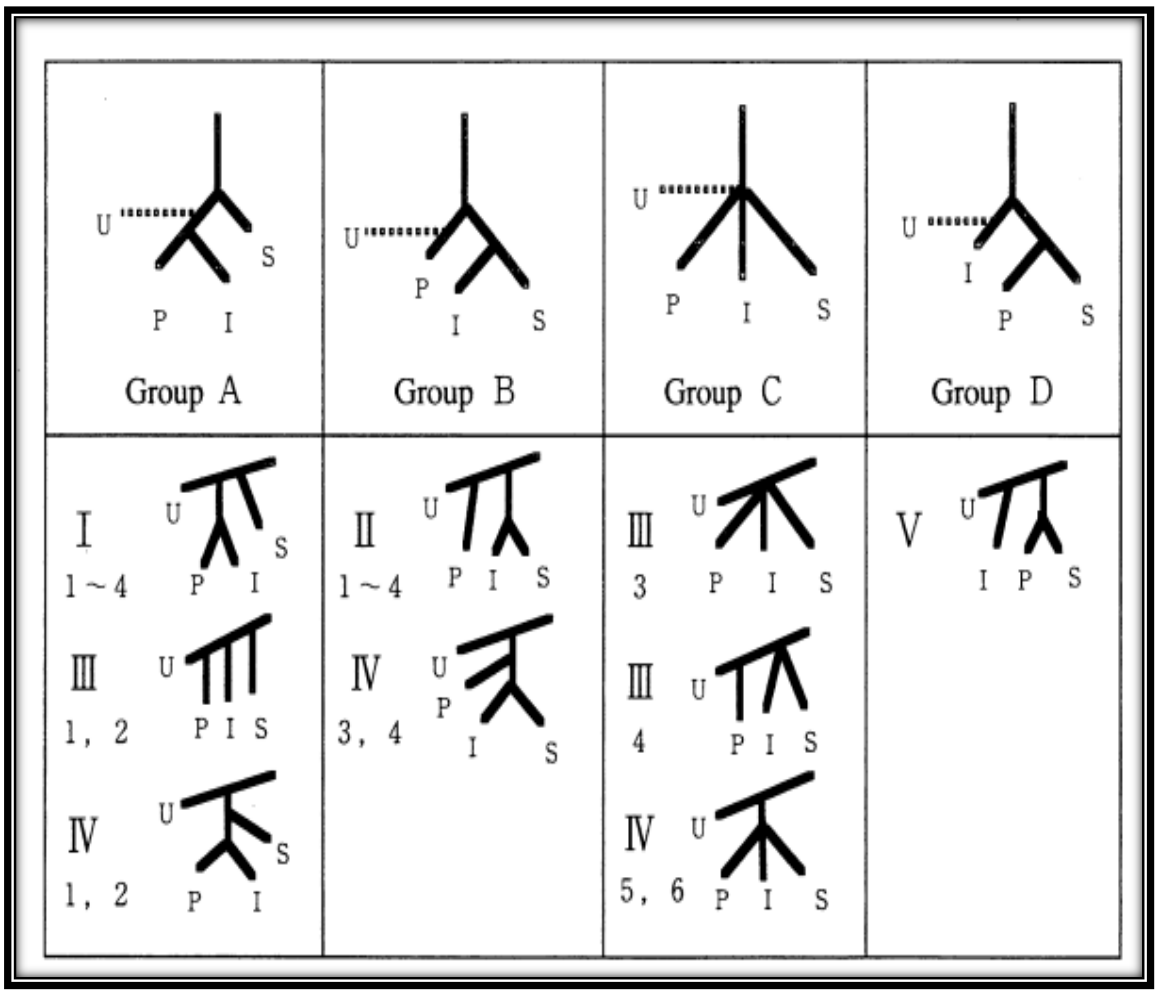


Figure 3.26: The branching pattern of the IIA classified without the umbilical artery by Yamaki et al. U: umbilical artery, I: inferior gluteal artery, S: superior gluteal artery, P: internal pudendal artery.

Advantages-

- Unification of types of branching patterns

Disadvantages -

- Some types can be placed in wrong group, resulting in misidentification
- Concept of classification disturbed by the discovery of previously unobserved types
- Lack of assessment of coexistence of an incomplete form of sciatic artery

Pelage et al (1999)

Pelage et al. established a classification of the internal iliac artery, based on a radiological review of 197 cases, that it terminated as two main trunks (anterior and posterior) in 77% of cases and into three main trunks in 14% of cases including posterior branches a common trunk of the internal pudendal and inferior gluteal artery and genitourinary branches. In addition, Pelage also stated that in 3% of cases the internal iliac artery has four or more terminal divisions, in 4% of cases the internal iliac artery remains as a single main trunk, while in 2% of cases the internal iliac artery had no systematic termination.

Naguib et al. (2008)

They used MRI to study 98 pelvic halves and determine origin of UA, SGA, IGA, LSA, ILA, SVA, MRA, IPA and OA. Results were categorized into groups and instead of classifying the entire branching pattern, the focus was on determining the exact point of origin of individual vessels – whether it was anterior division, posterior division, main stem or bifurcation point of IIA.

Advantages-

- Provides insight into anatomy and morphology of individual branches of IIA

Disadvantages -

- Lack of connection between variabilities of the origin of individuals vessels and branching pattern they are part of
- Limited clinical and statistical use

Al Talalwah and Soames (2014)

They suggested potential misclassifications that could have occurred in previous studies owing to the coexistence of an incomplete form of the sciatic artery when the inferior gluteal artery
was either absent or raised in the gluteal region. They noted that Adachi's classification system does not take such cases into account, so they supplemented it with new divisions: atypical Type I SA2, typical Type III SA, atypical Type IV SA, and also atypical substitutive Types IA, IB, IIA and III, where SA stands for the sciatic artery.

Type I – Here, the superior gluteal artery (SGA) arises independently from the IIA, the inferior gluteal and internal pudendal arteries arising from a gluteopudendal trunk that divides into Type IA above or Type lB below the pelvic floor. Type I has further subdivisions into three atypical (SA1–SA3) and two substitutive types.

- **SA1** –
  - The SGA and SA arise from the IIA.
  - The inferior gluteal and internal pudendal arteries arise from a gluteopudendal trunk dividing into one of three different forms:
    - Type IA above the pelvic floor
    - Type IB below the pelvic floor
    - Type IC – the inferior gluteal and internal pudendal vessels arise independently.
- **SA2** –
  - The SGA arises independently from the IIA

- ❖ The inferior gluteal and internal pudendal arteries arise from a gluteopudendal trunk originating from the SA, which can appear in three forms:
    - Type IA above the pelvic floor
    - Type IB below the pelvic floor
    - Type IC – the inferior gluteal and internal pudendal vessels arise independently.

- ➢ **SA3 –**
    - The SGA arises independently from the IIA
    - The SA, inferior gluteal and internal pudendal arteries arise from a common trunk dividing inside the pelvis.

Atypical substitutive Type IA –

- The SGA is replaced by the SA arising independently from the IIA
- The inferior gluteal and internal pudendal arteries arise from a gluteopudendal trunk in one of two forms:
    - substitutive Type I A1 above the pelvic floor
    - substitutive Type I A2 below the pelvic floor

Atypical substitutive Type IB –

- The SGA arises independently from the IIA
- The inferior gluteal is replaced by the SA arising with the internal pudendal artery from a common trunk in one of two forms:
    - Type I B1 above the pelvic floor.
    - Type I B2 below the pelvic floor
    - Type I B3 is the internal pudendal artery arising from the SA.

Type II – Here, the superior and inferior gluteal arteries arise from a common trunk and the IPA arises independently. The common gluteal trunk divides into one of two forms: Type IIA above or Type IIB below the pelvic floor.

Atypical substitutive Type II

- The SA replaces either the superior or inferior gluteal artery, both of which arise from a common trunk
- The IPA again arises independently.
- The common gluteal trunk divides into one of two forms:
  - Type II A1 above the pelvic floor
  - Type II A2 below the pelvic floor.

Type III – Here, the superior and inferior gluteal and internal pudendal arteries arise independently from the IIA.

Atypical Type III SA

- The superior and inferior gluteal and internal pudendal arteries all coexist with a SA, which arises independently from the IIA.

Atypical substitutive Type III

- The SA replaces either the superior or the inferior gluteal artery, the internal pudendal artery arising (directly or indirectly) from the IIA independently.

Type IV – Here, the superior and inferior gluteal and internal pudendal arteries arise from a common trunk of the IIA.

Atypical Type IV

- SA, the superior and inferior gluteal and internal pudendal arteries coexist with a SA, all arising from a common trunk of the IIA.

Atypical substitutive Type IV

- The SA replaces either the SGA or the IGA (Inferior Gluteal Artery) and arises with the internal pudendal artery from a common trunk of the IIA.

Type V – Here, the internal pudendal and superior gluteal arteries arise from a common trunk, the IGA having a separate origin.

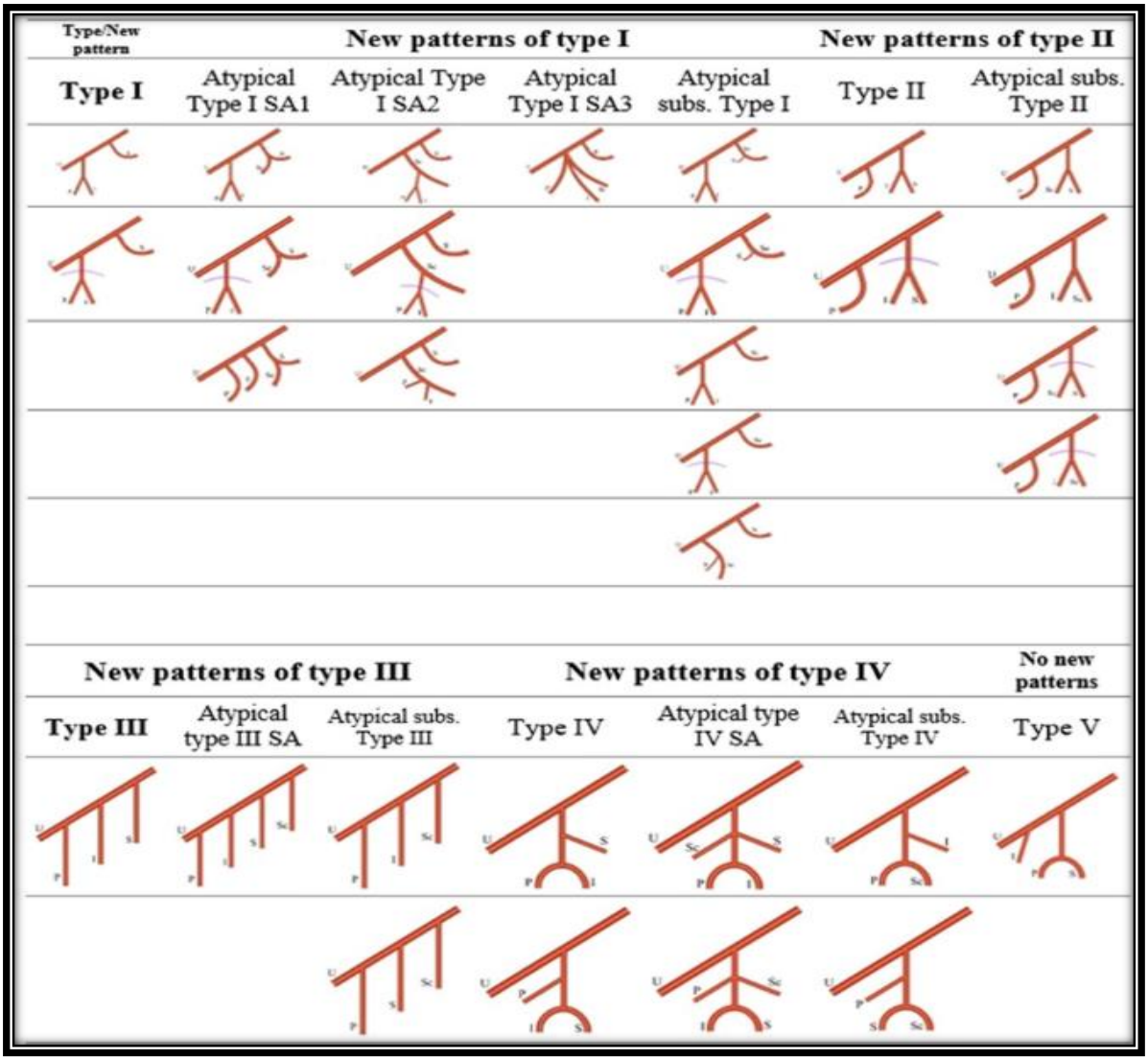


Figure 3.27: Al Talalwah classification. U: umbilical artery, I: inferior gluteal artery, S: superior gluteal artery, P: internal pudendal artery

Advantages-

- Highly detailed anatomical classification
- Refinement of Adachi widely used classification

Disadvantages -

- Lack of connection between variabilities of the origin of individuals vessels and branching pattern they are part of
- Limited clinical and statistical use

Balcerzak A et al. (2021)

They proposed a new system of classification based on;

- The image of the origins of the main arterial branches (superior gluteal artery, inferior gluteal artery, interior pudendal artery, sciatic artery) from the IIA
- The presence of an umbilical artery

Group I - This group includes all types characterized by two points of origin of the main vessels (superior gluteal artery, inferior gluteal artery, internal pudendal artery) from the IMA, not including the umbilical artery, which is its extension.

- The first origin point is a single branch;
- The second origin point is a common trunk dividing into two arteries.
    - Subgroup A – Common trunk divides inside the pelvic cavity.
    - Subgroup B – Common trunk divides outside the pelvic cavity.

Group II -This group includes all types also characterized by two points of origin of the main vessels (superior gluteal artery, inferior gluteal artery, internal pudendal artery) from the IMA, not including the umbilical artery, which is its extension.

- The first origin point is a common trunk dividing into two arteries
- The second origin point is a single branch.
    - Subgroup A – Common trunk divides inside the pelvic cavity.
    - Subgroup B – Common trunk divides outside the pelvic cavity.

Group III - This group includes all types characterized by three points of origin of the main vessels (superior gluteal artery, inferior gluteal artery, internal pudendal artery) from the IMA, excluding the umbilical artery, which is its extension, regardless of the order of origin of the individual vessels.

Group IV - This group includes all types characterized by a single point of origin of the main vessels (superior gluteal artery, inferior gluteal artery, internal pudendal artery) from the IMA, except for the umbilical artery, which is its extension. Individual vessels subsequently depart from that single origin. However, their order does not affect the classification.

Group V - This group includes all types characterized by four points of origin of the superior gluteal artery, inferior gluteal artery, Internal pudendal artery and also the SA, which in these types departs directly from the IMA. The umbilical artery is an extension of the IIA and does not count as an independent origin.

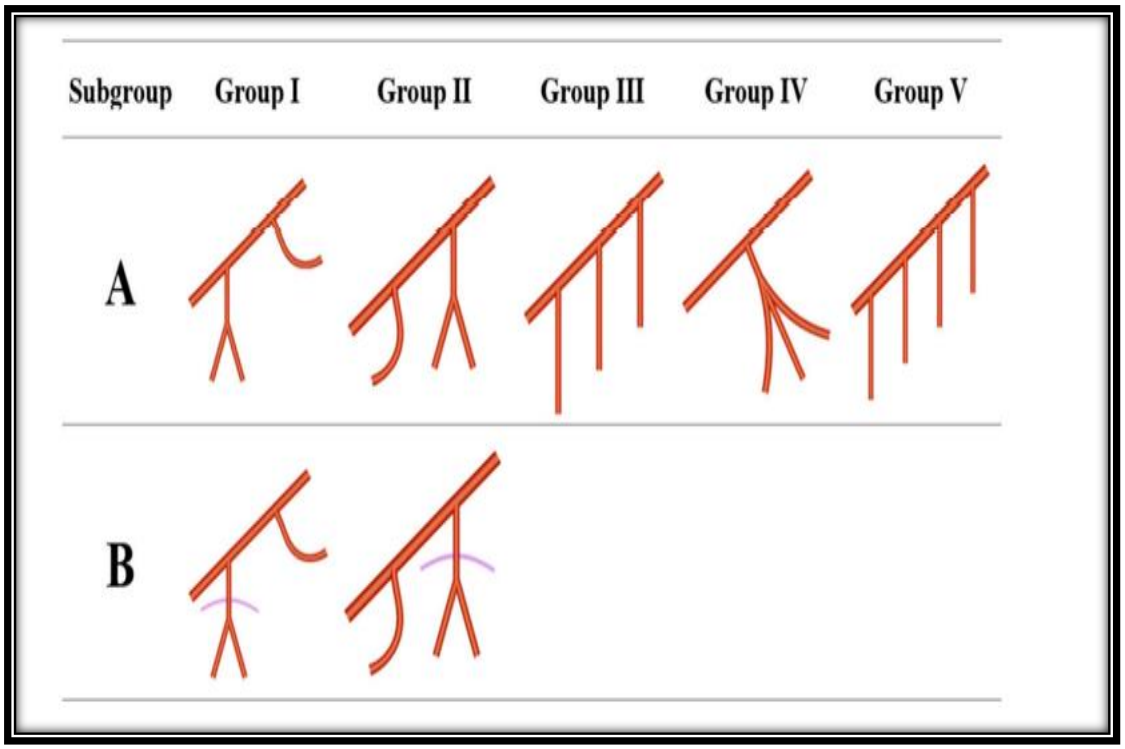


Figure 3.28: Balcerzak A et al. (2021) - new classification.

Advantages-

- Unified classification based on widely used Adachi system
- One clinically extremely important factor of differentiation
- Minimizing the possibility of incorrect branching pattern assignment
- Maximizing clinical utility
- Useful both in small and large research groups for statistical analysis

Disadvantages -

- Requires further stress testing in future studies
- Provides limited insight into anatomy and morphology of individual branches of internal iliac artery.

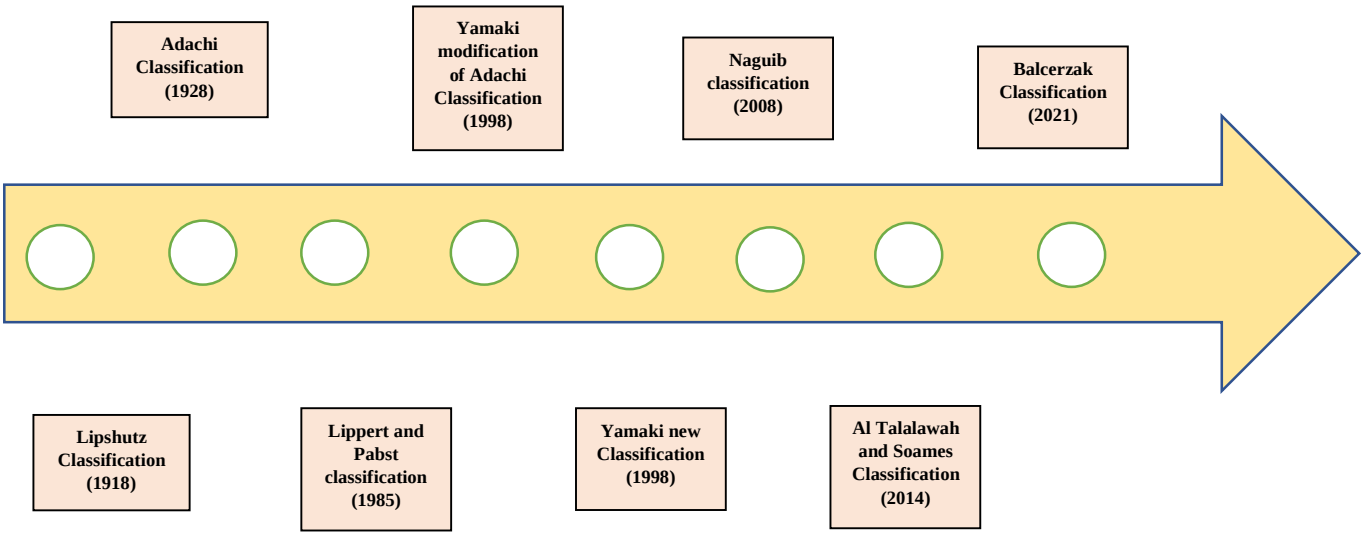


Chart 3.1: Evolution of the classification of IIA created over the years

3.4 CLINICAL SIGNIFICANCE

Vessels supplying the pelvic organs, walls and surrounding tissues originating from the IIA and other branches often anastomose with each other, resulting in the formation of a collateral circulation within the described area. This can supply the tissues if the main nourishing angiological path is closed (Chait et al., 1968). However, the form of the net of collateral vessels can depend directly on the IIA branching pattern and its morphological aspects. Certain vessels should be ligated with caution and only after precise examination in order to preclude all predictable complications. Surgical procedures such as correction of hernia can proceed by laparoscopic or open surgery, in which surgeons should be aware of possible variations of the obturator artery (Rajive and Pillay, 2015). Its variability mostly depends on an IIA branching pattern in which the obturator artery arises from the inferior epigastric artery, not the anterior division of the IIA, and runs on the superior pubic ramus close to the inguinal canal (Brick et al., 1995; Hong et al., 2004; Kawai et al., 2008; Missankov et al., 1996; Pai et al., 2009; Ten Broek et al., 2014). An OA originating from the inferior epigastric artery is also known as corona mortis (crown of death). It is an anatomical variant of anastomosis between these two structures, either OA with external iliac artery (Ates et al., 2016; Berberoğlu et al., 2001). During dissection, the aberrant OA could be cut and removed with the weakened section of tissue, potentially leading to hemorrhage in which hemostasis could be difficult to maintain (Ates et al., 2016; Lau and Lee, 2003). Moreover, there is a high risk of ischemic necrosis of the femoral head. An anterior approach to the acetabulum, including the iliolinguinal and the intrapelvic approaches, can have similar outcomes; and in pelvic fractures, an injured OA could be a source of unidentified hemorrhage (Kachlik et al., 2019; Nayak et al., 2016). Due to the fact, that there is a possibility of angiolipoma located inside the obturator canal, which can be supplied by the umbilical artery, diagnostics and surgeons should pay additional attention to this region (Sarikcioglu et al., 2007). Surgeons' awareness of possible variations of the IIA, including those affecting the vessel's length, different levels of bifurcation or variable terminations of its main branches, is important for preventing unnecessary complications that can arise during procedures such as ligation of the IIA (Bleich et al., 2007; Mamatha et al., 2015; Mohammadbaigi et al., 2019). The IIA can be ligated in cases of postpartum hemorrhage, continuous bleeding from the base of the broad

ligament, post-abortion bleeding or dispersed bleeding where the vascular bed of origin is unknown (Satheesha Nayak B et al., 2012; Selçuk et al., 2019). The primary purpose of this procedure is to reduce the pulse pressure and blood flow to ensure hemostasis. Successful ligation should be performed at the beginning of the anterior division, with particular attention to the possible variations of the SGA, IGA and IPA identified in the classifications presented in this paper. Accidental inclusion of the posterior division owing to a low bifurcation of IIA can lead to gluteal, hip or thigh necrosis (Francis et al., 2018; V et al., 2009).

In the region of the sacrospinous ligament and buttocks there are multiple collateral supplies and anastomoses consisting of the superior gluteal, inferior gluteal, internal pudendal, middle and lateral sacral arteries (Hammer et al., 2009). Therefore, any medical procedures in this area should be performed with caution. It has been reported that during sacrospinous ligament fixation, particularly in applying sutures, there is a high rate of injury to the IGA and also in some cases the IPA, which both descend behind the ligament (Barksdale et al., 1998; Thompson et al., 1999). The IGA, no matter whether it originates from the anterior or the posterior division of the IIA, passes posterior to the upper edge of the ligament and can easily be injured. However, there is no direct information to determine whether an IPA arising from the common trunk with the IGA has a higher risk of injury than one arising separately (Petri and Ashok, 2011; Roshanravan et al., 2007).

In ischemia caused by stenosis of the vessels' lumina, claudication and severe pain can occur. For instance, narrowing of the posterior division of the IIA can cause thigh and buttock claudication. Treatment that results in symptomatic improvement involves removing the blockage by inserting stents or by angioplasty (Donas et al., 2009; Thompson et al., 2010). Knowledge of the vessels' spectrum of supply and their courses, in particular referring to the IIA branching pattern, is valuable for restoring proper circulation as effectively as possible. Several vessels can be problematic, especially if they have unusual origins, so it is important to establish their course and possible variations in bifurcation so that none of them are overlooked during reopening (Michalak et al., 2003). During a hysterectomy procedure it is important to remember that the vaginal artery can be a separate branch of the IIA rather than a branch of the uterine artery. A mistake can make the surgical operation ineffective or potentially endanger the patient, for example by internal bleeding. The uterine artery

crosses the ureter, so special attention is needed to avoid confusing those two structures in ligation (Boswell et al., 2008; Gerema et al., 2020). Uncertainties arising from the diverse divisions of the IIA can appear not only in the operating room but also during analysis of the angiographic image (Thompson et al., 2010). In common bifurcations including the various divisions and courses of the internal pudendal, superior gluteal or inferior gluteal arteries, there is no great concern in identifying the vessels. However, difficulties can arise if there are unusual bifurcations, for instance an abnormal obturator artery arising from the inferior epigastric artery (Missankov et al., 1996; Pai et al., 2009; Ten Broek et al., 2014) or an iliolumbar artery arising from a main stem of the IIA (Al Talalwah et al., 2015). Additionally, with reference to the Talalwah and Soames classification of the IIA, the presence of a SA, especially if it arises separately from the IIA and not as a branch of the IGA, or is a replacement for either the SGA or the IGA, could also create difficulties (Al Talalwah and Soames, 2014; Bergman et al., 2015; Selçuk et al., 2018). The variability in branching of the IIA originates during embryo development (Ongidi et al., 2021). Primitive vessels, and their growth or regression, depend on factors such as genetics, race, and the vascular demands of tissues (Ribatti, 2006). Therefore, any radiological and surgical interventions, especially operations by general surgeons, orthopaedic surgeons, gynecologists, obstetricians and urologists, should be preceded by revision of the IIA branches. Understanding the anatomy of the branching pattern of the IIA is highly important in medical practice and can help to reduce unnecessary complications.

3.5 OTHER RELATED STUDIES ON ORIGIN, MORPHOMETRY, BRANCHING PATTERN OF INTERNAL ILIAC ARTERY

- **Fatu C, Puisoru M and Fatu IC (2006)** analysed 100 internal iliac arteries, 50 on the right side and 50 on the left side from 50 Romanian bodies, 30 males and 20 females. They determined the origin of the IIA according to the relationship with the osteoarticular elements in its proximity and the distance to the midsagittal plane represented by the line connecting the middle of the symphysis pubis with the middle of the lumbo-saccral promontorium. They also measured the length of the internal iliac artery from its origin to the emergence of its terminal branch, the gluteal artery and as well as the caliber of the artery. They noted that when related to the osteoarticular elements in its proximity, the origin of the internal iliac artery is at the level of the sacro-iliac joint with insignificant differences to the right or left. However, in males the origin is internal to the sacro-iliac joint, while in females it is at the same level. Moreover, they observed that the distance from the midsagittal plane to the origin of the internal iliac artery ranged between 29 and 36 mm on the right side and between 40 and 50 mm on the left side, with variations between sexes. They stated that length ranged between 20 and 90 mm, mean value 49 mm, without major differences between the two sexes or between left and right. In case of the caliber of the IIA, they observed between 4 and 11mm.

- **Naveen NS, Murlimanju BV, Vishal K, Jayanthi KS, Krishna R and Thejodhar P (2011)** conducted the morphological analysis of the human Internal Iliac Artery in South Indian population. The study included 60 human bisected pelvises irrespective of their side and sex. They observed that the origin of internal iliac artery was at the level of S1 vertebra in majority (58.3%) of the cases and the average length of internal iliac artery was 37 ± 4.62 mm (range, 13-54 mm). They further stated that the type I pattern of the internal iliac artery was most common (83.5%) followed by types III and II.

- **Ramakrishnan P K, Selvarasu C D, Elezy M A (2012)** conducted a descriptive anatomical study of the branching pattern of internal iliac artery in humans. In their study, they used 5 pelvic halves of embalmed cadavers and observed for variations in the origins of superior gluteal, inferior gluteal, internal pudendal and obturator arteries. They found among the 50 pelvic halves studied, the origins of superior gluteal, inferior gluteal and internal pudendal arteries confirmed to a Type I arrangement on the Adachi scale in 30 cases (60%), a Type in pattern being found in 15 cases (30%) and a Type II pattern was seen in 4 cases (8 %). Type IV was less frequent and was seen in only one case (2 %). The obturator artery arose directly from the anterior division of internal iliac artery in 40% of cases; in the rest of specimens, it arose as a branch from either the inferior gluteal-internal pudendal trunk or internal pudendal or superior gluteal or iliolumbar arteries. They concluded the branching pattern of internal iliac artery is subject to great variation, especially with regard to its four large parietal branches.

- **Vishnumukkala TR, Yalakurthy S, Bharath CH. Swayam JD, Puttagunta B and Kannan M (2013)** studied the parietal branching pattern of the internal iliac artery. They studied a total of 45 pelvic halves after a clear dissection and observed for the variations of major parietal branches of the internal iliac artery (The superior gluteal, inferior gluteal, and internal pudendal artery) based on adachi types. Of the pelvic halves, 5 were from female (adults), and 40 were from adult males, between the ages of forty and eighty-five. They observed that among the 45 pelvis halves, on the basis of adachis classification, was Type I: 66.68%, Type II: 2.22%, Type III: 24.4%, Type IV: 4.44%and Type V: 2.22%.

- **Havaldar PP, Taz S, Angadi AV and Saheb SH (2014)** conducted a morphological study of Internal iliac artery. 50 formalin fixed adult human pelvic halves were procured for this study. In this study, the most common site of origin of internal iliac artery was at the level of lumbo-sacral intervertebral disc found in 30 specimens (60%), opposite L5 vertebra in 10 specimens (20%), at the level of L4 and L5 disc in 8 specimens (16%) and opposite S1

vertebra in 2 specimens (4%). They found the length of internal iliac artery to be 3-5cm in 23 specimens (46%), 5-7 cm in 16 specimens (32%) and 1-3 cm in 11 specimens (22%), shortest being 1.5 cm and longest being 7 cm. The level of division of internal iliac artery took place above the greater sciatic foramen in 34 specimens (68%), at the upper border of greater sciatic foramen in 7 specimens (14%), and below the upper border of greater sciatic foramen in 9 specimens (18%). They further noted that the common trunk of internal iliac artery did not give any branch in 22 specimens (44%), gave origin to vertebral branches in 15 specimens (30%), to ilio-lumbar artery in 9 specimens (18%), superior gluteal artery in 1 specimen (2%), lateral sacral artery in 2 specimens (4%), both iliolumbar artery and lateral sacral artery in 1 specimen (2%).

- **Oana P, Bordei P, Iliescu D and Ionescu C (2014)** studied the morphological considerations on the origin and morphometry of the internal iliac arteries. In this study, the origin of the internal iliac artery, right and left, was studied in 76 cases, 58 cases of male (76.32% of all cases) and 18 female cases (23.68% of all cases). They considered the origin of the internal iliac arteries was considered in relation to the spine (lumbar-sacral). The right internal iliac artery males originate in a range from the upper edge of L4 vertebra - the lower part of fin sacral. It is found that in males, in most cases, 43 cases (74.14% of male cases), right internal iliac artery originates at different levels of sacral fin. We considered that the right iliac artery low origin only the cases in the lower part of the fin sacral, 10 cases (17.24% of male cases). Cases of high origin of the artery, above the fin sacral we found it in 15 cases (25.86% of male cases). From high origins, in the upper edge of the L4 vertebra and intervertebral disc at L4-L5, I met only one single case. Right internal iliac artery in females originated in a range between the upper edges of L5 - the lower part of sacral fin. In females, the right internal iliac artery origin, is located within narrower than in men, but in women, most frequently, 14 cases (77.78% of female the cases) was the origin of the internal iliac located at different levels of sacral fin. The females have not met internal iliac origin above the L5 vertebra or intervertebral disc level L4-L5. High origin was met it in 4 cases (22.22% of female the cases) and low origin

in 6 cases (33.33% of female the cases). Thelevel of the left internal iliac artery origin we studied 78 cases, finding it in the same range as in males, i.e., the upper edge of L4 vertebra - the front of the sacrum. In males, on a number of 57 cases (73.08% of all cases) the origin of the left internal iliac artery was made between the upper edge of the vertebra L4 - the front face of the sacrum, most commonly, in 44 cases (77 19% of male the cases) located in the sacral fin. The artery high origin I found it in 9 cases (15.79% of male the cases) and low origin in 18 cases (31.58% of male the cases). I have not met artery origin at L5-S1 intervertebral disc. In terms of low origin, only in males, the left internal iliac artery originated from the anterior to the sacrum, something not found the right internal iliac artery. In females, the 18 cases followed, had their origins in the range lower half of the L5 - middle sacral fin, 17 cases (94.44% of female the cases), terminating at the sacral fin. It is found that in women the origin of the left internal iliac artery is within narrower than the other cases described so far, showing the highest level of origin, this artery in females do not possess low origin. The high origin is present in a small percentage, only 5.56% of cases, encountering any case the origin of the left internal iliac artery is located at the L4 vertebra or the intervertebral discs at L4-L5 or L5-S1. Internal iliac artery diameter was followed on 90 cases, 44 cases for the right internal iliac artery and 46 cases for left internal iliac artery. In males, the right internal iliac artery I found a caliber between 3 to 9.8 mm. In women the right internal iliac artery caliber found between 3.9 to 6.9 mm.

- **Sakthivelavan S, Aristotle S, Sivanandan A, Sendiladibban S and Jebakani CF (2014)** conducted a study on variability in the branching pattern of the internal iliac artery in Indian population and its clinical importance. This study was performed on 116 pelvic halves from 58 embalmed cadavers in the age group of 30–80 years belonging to the Indian population and the specimens included sixty-eight male pelvic halves (34 right and 34 left sides) and forty eight female pelvic halves (24 right and 24 left sides). They noted that incidence of the patterns of branching was, type Ia in 60.6%, type Ib in 2.6%, type IIa in 15.8%, and type III in 21%. They observed the length of IIA ranging from the minimum measure of 2.3 cm to the maximum of 7.1 cm. However, in majority of specimens (67%), they found that the length of IIA

ranged from 2.5 to 4.2 cm and the mean length was found to be 3.7 cm. They further state that the IIA terminated by dividing into anterior and posterior trunks in 92 specimens (79.3%) and in the remaining (20.7%), it terminated by giving rise to its principal branches directly without dividing into two trunks. In this study, they observed that the highest proportion of cases displayed the branching patterns was type Ia of Adachi's classification and the order of frequency in Indian population was I > III > II as against most other studies.

- **Narayana AS and Padmini PM (2015)** studied the variations in the branching pattern of the internal iliac artery. They conducted the study by dissection of 50 adult pelvic halves. They observed that obturator artery was more variable and arose from the inferior epigastric artery in 26%, from the external iliac artery in 8%, from the common trunk of inferior gluteal-internal pudendal in 14%, from superior gluteal, inferior gluteal, and internal pudenda arteries in 4% of cases and from iliolumbar artery in 2%.

- **Mamatha H, Hemalatha B, Vinodini P, Souza AS and Suhani S (2015)** performed an anatomical study on the variations in the branching pattern of Internal Iliac Artery. The study included 50 human cadaveric bisected pelvises. They observed the vertebral level of origin of the IIA and to determine the level of the division and the branching patterns of the IIA. They observed that the origin of the IIA at the level of S1 vertebra was seen in 36 cases (72 %), at the level of L5-S1 in 12 cases (24 %), and in two cases (4 %). They further noted that the distance from the greater sciatic notch is 3 cm above in nine cases (18 %), 2 cm above in 14 (28 %) cases, 2.5 cm above in 18 specimens (36 %), 3.5 cm above in eight cases (16 %), and 1 cm below the greater sciatic notch in one case (2 %).

- **Francis YM, Balaji T, Rajendran HS, Gnanasundaram V, Subramanian A and Kaunakaran B (2018)** studied the variations in the origin and branching pattern of internal iliac artery in Cadavers. A Total of 80 formalin fixed specimen, inclusive of both male and female were utilized for the present study. In all 80 specimens, the length of internal iliac artery was

measured by them. They observed the length of right internal iliac artery ranged from 2.4 cm to 5.4 cm with average length of 3.943cm ± 0.859cm, whereas the length of left internal iliac artery ranged from 2.7cm to 4.7cm with average length of 3.610cm ± 0.626cm. They observed that the calculated P valve (0.0914) shows that the differences between the lengths of internal iliac artery of both sides were statistically not significant. They noted that the calibre thickness of main trunk of internal iliac artery was 4.85 ± 0.60cm, obturator artery was 3.27 ± 0.52cm, ilio-lumbar artery was 3.25 ± 0.49cm. They found that obturator artery took origin from several sources; it originated from anterior division of internal iliac artery (45%), posterior division of internal iliac artery (20%), with ilio-lumbar artery (3%) or superior gluteal artery (5%), directly from external iliac artery (5%) or from inferior epigastric artery (22%). They concluded that the origin of iliolumbar artery from main trunk of internal iliac artery was observed in 75%.

- **Mohammadbaigi H, Darvishi M and Moayeri A (2019)** conducted a systematic review of the variations of anterior and posterior division of internal iliac artery and its clinical implications. They stated that identifying and reviewing the locations, orientations, and anatomical details of the IIA is essential for successful performance of endoscopic extraperitoneal inguinal hernioplasty (TEP), ligation of IIA during acute hemorrhage, ureteral injury and vein laceration. They further stated that pelvic surgeries may lead to hemorrhage if branching patterns of the IIA are incorrectly interpreted and in particular in women, acquiring information on the pelvic vascularization and anatomic variations is necessary for protecting perineal functionality in the case of blood vessels injury. They noted that it is important for surgeons and radiologists to have anatomical information about common variations of the uterine artery because these variations may depend on the procedures used to improve hemostasis and failure to understand the IIA variations can lead to bleeding and thus endanger the patient's life, exclusively in the severe complications such as ligation of the external iliac artery, removing the prostate, hernia repair or uterine fibroid.

- **In 2021, Ongidi et al**. conducted a study on variability in morphology and branching of the internal iliac artery and its implications for pelvic surgery. They used fifty-seven pairs of right and left-sided hemi-pelvises, 48 from males and 9 from females, for this study. They collected data on the internal iliac artery origin, relations, termination, branching, length and course of parietal branches. From their study they found that, in all cases, the internal iliac artery originated singly from the common iliac artery above the vertebral level of the L5/S1 disk (pelvic brim) in 52.6% cases, with the highest observed at L4 while in most cases (56.8%), the IIA terminated at S1 vertebral level. They also found that the internal iliac artery laid medial, anterior and lateral to the sacroiliac joint in 64.9%, 30.6% and 5% cases respectively. Regarding parietal branching, in their study 64.8% cases had a type 1 pattern as per the Adachi classification. They further stated that the mean diameter and length of the internal iliac artery were 7.32 ± 1.69 mm and 36.97 ± 14.12 mm, respectively in their study and the differences in dimensions of the IIA between the left and the right sides were not significant.

3.6 ANATOMICAL VARIATIONS IN PELVIC VASCULATURE

Multiple variations of pelvic vasculature were reported by various researchers as a Case Report. Few of them were mentioned below.

- **Shetty et al. (2011)** reported the case of a 60year old male Indian cadaver in which the posterior division of the internal iliac artery terminated as the superior and inferior gluteal arteries with the ventral ramus of first sacral nerve descending between them. In addition, the obturator artery arose close to the bifurcation of the posterior division and subsequently passed deep to the internal iliac vein along the lateral pelvic wall, was crossed by the ureter and ductus deferens on its medial side, and then coursed downward and forward, deep to the internal pudendal artery.
- **Badagabettu et al. (2013)** reported the case of a 65 year old male Indian cadaver in which the right internal iliac artery divided into three main trunks that gave origin to the iliolumbar and lateral sacral arteries (trunk 1), the inferior gluteal and internal pudendal arteries (trunk 2), and the superior

vesical and obturator arteries (trunk 3). In the same specimen the superior gluteal and middle rectal arteries arose directly from the main part of the internal iliac artery. The superior gluteal artery entered the gluteal region through the greater sciatic foramen by passing above the lumbosacral trunk, instead of passing between the lumbosacral trunk and the S1 ventral ramus. The superior vesical artery supplied the territory of the inferior vesical artery, since the inferior vesical artery was absent.

- **Sunita V (2014)** presented a case report on the combined contribution of both anterior and posterior divisions of internal iliac artery. They found unilateral variant formation of the inferior gluteal and the internal pudendal arteries by the contribution of both the anterior and posterior divisions of the Internal iliac artery. They observed this during the routine dissection class of pelvic region for the first-year medical undergraduates in a 55-year-old male cadaver. They noted that the iliolumbar artery arose from the main trunk of left Internal iliac artery, which was 2.5 cm below the bifurcation of common iliac artery. They stated that the lateral sacral artery, superior gluteal artery and the posterior root of the common trunk of the inferior gluteal and the internal pudendal artery originated from the posterior division of the internal iliac artery. They found that the anterior root of the common trunk of inferior gluteal and internal pudendal artery originated from the anterior division and no variation found in the branches and their course. They also observed no variation in the branches & their course of right internal iliac artery. They noted that by the both the roots the common trunk was formed, which ran downwards for 2.2cm over the piriformis muscle and then bifurcated into the Inferior gluteal artery and the Internal pudendal artery and the course of inferior gluteal and internal pudendal arteries was normal.

- **Fander J, Buttner M, Kielstein H and Jasinski-Bergner S (2018)** reported a missing posterior division of the internal iliac artery. During the dissection of a 73-year-old white male with influenza A infection, pneumonia, and hypovolaemia, the missing posterior division of the internal iliac artery on the left side, but not on the right side, was observed. The appropriate vessels were

further prepared by the authors. They found that on the left side, because of the missing posterior division of the IIA, the ILA, LSA, and SGL originated from the CIA (Fig. 1A and B). Interestingly, they noted that on the right side the respective posterior division of the IIA was normal. They observed remarkable differences in the circumferences of the common iliac and internal iliac arteries of the right and the left side. On the left side the CIA was measured only 5.4 cm, whereas the right CIA was larger at 6.2 cm. Furthermore, they found that the left internal iliac artery with the missing posterior division was smaller (2.8 cm), compared with the normally formed right side with a circumference of 4.0 cm.

3.7 STUDIES ON ORIGIN OF OBTURATOR ARTERY

- **Pai MM, Krishnamurthy A, Prabhu LV, Pai MV, Kumar SA and Hadimani GA (2009)** studied the variability in the origin of the obturator artery. They conducted the study on 98 pelvic halves of embalmed cadavers, and the origin and course of the obturator artery were traced and noted. In 79% of the specimens, they observed that the obturator artery was a branch of the internal iliac artery and it branched off at different levels either from the anterior division or posterior division, individually or with other named branches. In 19% of the cases, the obturator artery was observed branching off from the external iliac artery as a separate branch or with the inferior epigastric artery. However, in the remaining 2% of the specimens, they found that both the internal and the external iliac arteries branched to form an anastomotic structure within the pelvic cavity.

- **Nayak SB and Soumya KV in 2009** presented a case report on variation of obturator vessels. They observed that the obturator artery took its origin from the external iliac artery and passed medially superficial to the external iliac vein. Then it crossed the pelvic brim and descended anteriorly into the obturator canal. The obturator vein and the nerve entered the canal below the artery.

- **Jusoh AR, Rahman NA, Latiff AA, Othman F, Das S, Ghafar NA et al. in 2010** conducted a study on the anomalous origin and branches of the obturator artery with its clinical implications. In this study, they observed the origin and the branching pattern of the OA on 34 lower limbs (17 right sides and 17 left sides) irrespective of sex. They found the bifurcation of the common iliac artery into internal and external iliac from the sacral ala varied between 4.3–5.3 cm and the distance of the origin of the anterior division of internal iliac artery from the bifurcation of common iliac artery varied between 1–6 cm. Moreover, the distance of the origin of the posterior division of the internal iliac artery from the point of bifurcation of the common iliac artery varied between 0–6 cm. Out of 34 lower limbs studied, they noted two specimens (5.8%) showed anomalous origin of the OA originating from the posterior division of the internal iliac artery and of these two, one limb belonged to the right side while the other was from the left side. They stated that the anomalous OA gave off an inferior vesical branch to the prostate in both the specimens. They concluded that no other associated anomalies regarding the origin or branching pattern of the OA were observed.

- **Biswas S, Bandopadhyay M, Adhikari A, Kundu P and Roy R (2010)** studied the variation of origin of obturator artery in Eastern Indian population. A total of 56 pelvic halves were studied, all of which were examined completely, i.e., both halves of the same pelvis. Of these, 18 pelvises were of adult female cadavers and 38 were of adult males. They observed that in 25 out of 56 pelvic halves examined, obturator artery was a direct branch of the anterior division of the internal iliac artery. It arose from the superior gluteal artery in 9 pelvic halves. Obturator artery was seen to arise from the inferior epigastric artery in 13 cases and directly from the external iliac artery in 2 cases. Posterior division of the internal iliac artery gave origin to the obturator artery (Figure 3) in 7 cases. They also noted that obturator artery originating from the inferior gluteal or internal pudendal artery or by dual root from both internal and external iliac sources was not encountered in their study. In 8 cadavers or 16 pelvic halves, obturator arteries of both the sides had similar origins.

- **Naveen NS, Murlimanju BV, Kumar V, Jayanthi KS, Rao K and Pulakunta T (2011)** conducted the morphological analysis of the human internal iliac artery in South Indian population. Their study included 60 human bisected pelvises irrespective of their side and sex. They collected the specimens from the anatomy laboratory and fixed with the formalin. The branching patterns were studied and demonstrated as per the guidelines of Adachi. In their study they found that the origin of internal iliac artery was at the level of S1 vertebra in majority (58.3%) of the cases and the average length of internal iliac artery was 37 ± 4.62 mm (range, 13-54 mm). They further noted that the type I pattern of the internal iliac artery was most common (83.5%) followed by types III and II. Moreover, the type IV and V pattern of adachi were not observed.

- **Vishnumukkala TR, Yalakurthy S and Raj SJ (2013)** studied the anomalous origin of obturator artery and its clinical importance in humans. They conducted on a total of 45 pelvic halves had been studied and the material consisted of adult subjects between the ages of forty and eighty-five. They noted that the origin of obturator artery was most frequently a direct branch of the anterior division of the internal iliac artery, in 16 specimens (35.55%). They observed that the obturator artery was arising from the inferior epigastric artery in 12 specimens (26.66%) while from the common trunk of inferior gluteal and internal pudendal artery in 6 specimens (13.33%) etc.

- **Rajive AV and Pillay M (2015)** studied the variations in the origin of Obturator artery and its clinical significance. Here, they carried out the study on fifty hemi pelvises of embalmed cadavers and the origin and course of the arteries were traced and noted. Of the 50 pelvic halves, they stated that in 27 specimens, the obturator took origin from the anterior division of internal iliac artery and in the remaining 23 specimen variations was observed. They further stated that the origin of the obturator artery was from the inferior epigastric artery in 11 cases, from the common stem of the internal iliac artery and the external iliac artery in 2 cases each, from the posterior trunk of the internal iliac artery in 5 and one each from superior gluteal, inferior gluteal, and

internal pudendal artery. They noted that the origin of the obturator artery is highly variable and it can take origin from the stem of the internal iliac artery or from its anterior or posterior division, or from one of the branches of the divisions and also from external iliac artery or its inferior epigastric branch.

- **Sakthivel and Priyadarshini S (2015)** analysed the variability of origin of obturator artery and its clinical significance. They used 60 formalin fixed pelvic halves and out of all the specimens, they observed that in 36.6%, (26.67% in males and 10% in females), the origin of obturator artery was from anterior division of internal iliac artery and about 63.63% from various other sources i.e., posterior division of internal iliac artery, superior gluteal artery, combined with iliolumbar artery and direct branch from external iliac or inferior epigastric artery. In variation 1, they observed that the origin of obturator artery from the trunk of external iliac artery was found in a total of 5 specimens (male 4 and female 1). The obturator artery passed anteriorly over the superior ramus of pubis and turned inwards to enter into the obturator canal. In their study, the incidence of obturator artery from direct branch of external iliac artery was found to be 8.33%. In variation 2, They observed that the obturator artery emerged from posterior division of internal iliac artery instead of the usual anterior division of internal iliac artery and the incidence percentage of this particular type of variation in the present study was found to be 11.67%. In variation 3, they noted a rather uncommon type of variation where the obturator artery along with Ilio-lumbar artery was found to arise as a common trunk from posterior division of internal iliac artery. This type of variation was observed in 2 specimens. In variation 4, they observed the origin of obturator artery from the superior gluteal artery in a total of 9 specimens (male 7 and female 2). The artery from its origin was found to pass beneath the branches of anterior division to enter the obturator foramen and the artery was related to obturator nerve above.

- **Rekhalatha and Arunachalam K (2015)** studied the classification of the main branches of the internal iliac artery. They dissected forty (thirty-eight male and two females) cadavers and observed the arterial vascular trees and

distribution. They observed the obturator artery and found them classifiable into nine types; Type I: One Subtype: The obturator arose from a common stem giving off the pudendal and gluteals; Type II: Four subtypes: The obturator arose from a common stem or from the inferior gluteal or internal iliac or from the inferior epigastric, but proximal to the other branches; Type III: 5 subtypes: Obturator from inferior gluteal or from a common stem or from the superior vesical or internal pudendal or inferior epigastric; Type IV: Nine subtypes: Obturator from inferior gluteal, or superior vesical, or from the bifurcation of the common stem from superior vesical and internal pudendal or from inferior epigastric or superior gluteal or from bifurcation of superior vesical and internal pudendal or common stem of the gluteals or from the internal pudendal itself. Type V: sixteen subtypes: Obturator from superior vesical, or internal iliac or from inferior epigastric or as a complement of superior gluteal and superior vesical but arising from the opposite direction from the internal iliac or from the inferior gluteal or from the interior gluteal or from the internal iliac as its most proximal branch or from superior gluteal or from a common stem giving off internal pudendal and inferior gluteal or as additional branches or from superior gluteal or inferior epigastric differing from another cited subtype in that here the proxima; artery is the superior vesical or from the inferior epigastric differing in that it is proximal to the origin of superior gluteal and obturator from a common stem giving off internal pudendal and inferior gluteal) or as before, but with the superior vesical arising as the most proximal branch or as the most proximal branch of the internal iliac with a minor variation from another subtype or from the bifurcation of internal pudendal and inferior gluteal or arising from internal iliac proximal to the superior vesical; Type VI: six subtypes: Obturator arising from a common stem with gluteals or from superior vesical or from a common stem for internal pudendal and gluteals or from inferior epigastric or from a common stem for gluteals as a variant from the first subtype but with a common stem for superior vesical and pudendal or from inferior epigastric; Type VII: five subtypes: obturator artery arising from internal pudendal or superior vesical or inferior epigastric or superior gluteal or inferior gluteal; Type VIII: one subtype: The obturator is given off by superior vesical; Type IX: one subtype: The internal iliac dividing into a trifid stem with the gluteals

as two divisions, the superior vesical, obturator and pudendal arising from a common origin from the third division.

- **Nayak SB, Deepthinath R, Prasad AM, Shetty SD and Aithal AP (2016)** conducted a South Indian cadaveric study on obturator neurovascular bundle with a special emphasis on high prevalence of 'venous corona mortis'. We conducted this study on 73 cadaveric pelvic halves. Out of the 73 hemi pelvises, 36 were normal without any variations of the obturator vessels while 37 hemi pelvises (51%) showed the presence of abnormal obturator vessels which proves to be a very high incidence in terms of variations. Out of the 37 hemi pelvises, 25 (68%) showed the presence of 2 obturator veins, out of which 1 was normal and the other was an abnormal obturator vein. 8 hemi pelvises (22%) had only abnormal obturator vein. Most of the abnormal obturator veins drained into the external iliac vein, while two veins drained into inferior epigastric veins. Venous corona mortis is said to be frequently encountered during surgery and is considered to be as important as arterial corona mortis in its clinical implications. Individual evaluation of this risky anatomical structure should be done prior to any surgical interventions.

- **Sonje PD and Vatsalaswamy, in 2017**, conducted a study on the variations in the origin of obturator artery. Their study comprised of thirty five pelvises from thirty five cadavers. They observed that the obturator artery was arising from the posterior division of internal iliac artery in eight cases and of these, six were male cadavers and two were female cadavers. In three cases, they found that it was bilateral while in five cases it was unilateral. In three cases, they found that obturator artery was seen arising from an external iliac artery and this variation was bilaterally seen in two cases, while it was unilateral in one case. Of three, two were male cadavers and one was female cadaver. In one case they found that obturator artery was arising from a common stem for obturator and inferior epigastric artery. In three cases, it was found to be arising from internal pudendal artery and all three were male cadavers. It was unilateral in two cases and bilateral in one case. In two cases, they noted that

the obturator artery was arising from inferior gluteal artery and both were unilateral and male cadavers.

- **In 2018, Nayak SB** reported a case report on the surgically important giant obturator artery, its variant distribution and other associated vascular variations in a male pelvis. During routine dissection classes for undergraduate medical student, they noted the following vascular variations in the right pelvic half of an adult male cadaver, aged approximately 60 years. They observed that the internal iliac artery divided into anterior and posterior divisions. The posterior division gave iliolumbar, lateral sacral and superior gluteal arteries and the anterior division gave superior vesical, inferior vesical, middle rectal, obturator and a common trunk which divided into internal pudendal and inferior gluteal arteries. The obturator artery was huge and it divided into two divisions. They further observed that the lateral division accompanied the obturator nerve and vein and entered the medial compartment of the thigh by passing through the obturator foramen while the medial division gave two vesical branches, which divided and formed a tuft of arteries near the lateral side of the neck of the bladder. It also gave a slender branch, which entered the obturator foramen along with the main obturator neurovascular bundle. They noted that the medial division passed through the puboprostatic ligaments and divided into a prostatic and a penile branch. The penile branch entered the crus of the penis as the deep artery of the penis. They observed that the dorsal artery of the penis was a direct continuation of the artery of penis, which was derived from the pudendal artery. Further another unique feature of the case report was that the common trunk of inferior gluteal and internal pudendal arteries divided into terminal branches in the gluteal region, below the piriformis muscle.

3.8 STUDIES ON ORIGIN OF ILIOLUMBAR ARTERY

- **Kiray A, Akcali O, Tayefi H, Kosay C and Ergur I (2010)** conducted study on the anatomical variations of iliolumbar artery and its relation with surgical landmarks. They observed the origin, diameter, and tract of iliolumbar artery bilaterally in 21 formalin-fixed adult male cadavers (21 right and 21 left

arteries). They noted that the Iliolumbar artery was originating from common iliac artery in 4.8% (2 arteries), internal iliac artery in 71.4% (30 arteries), posterior trunk of internal iliac artery in 19% (8 arteries), and as two different arteries from internal iliac artery in 4.8% (2 arteries) of the cases. The stated that the mean diameter of the iliolumbar artery was 3.7 mm. From their study, they concluded that the anatomical properties of iliolumbar artery and its relation with anatomical landmarks, which were presented, would be helpful in decreasing iatrogenic trauma to iliolumbar artery during surgery.

- **Teli CG, Kate NN and Kothandaraman U (2013)** conducted a study on morphometry of the Iliolumbar artery and the Iliolumbar veins and their correlations with the Lumbosacral trunk and the Obturator nerve. They dissected the iliolumbar region bilaterally in 20 formalin-fixed adult cadavers. They measured the diameter of the iliolumbar artery at its origin, its length up to the branching point, the distance between the iliolumbar artery and the inferior margin of the fifth lumbar vertebra and the distance between the iliolumbar artery and the bifurcation point of the common iliac artery. The pattern of drainage, the dimensions, the points of confluence with the common iliac vein and the obliquity of the iliolumbar vein were also noted. They recorded the correlation between the iliolumbar artery and the veins to the obturator nerve and the lumbosacral trunk. They observed if the iliolumbar artery originated from the posterior trunk of the internal iliac artery or from the internal iliac artery. They found that the mean diameter of the iliolumbar artery, at its origin, was 3.5±0.5 mm and the mean distance between the origin of the iliolumbar artery and the bifurcation point to the iliac and the lumbar branches was 12.2±5.5 mm. The distance between the origin of the iliolumbar artery and the lower edge of the fifth lumbar vertebra was 43.2±11.6 mm while the distance between the origin of the iliolumbar artery and the bifurcation point of the common iliac artery was 38.7±10.6 mm. The mean distance of the iliolumbar veins from the inferior vena cava, overall, was 35± 9.9 mm and that of the mouth of the iliolumbar vein was10.7 ± 5.1 mm and the mean angle of obliquity of the vein with respect to the long axis of the common iliac vein was 75.50. They observed variation in tributaries which drained into the main iliolumbar vein. The iliolumbar artery passed anterior in

70% and it passed posterior to the obturator nerve in 30%. The veins were lying anterior to the obturator nerve in 45% and they were lying posterior in 55%. They stated that the multiple tributaries which drained into the iliolumbar vein relation of the tributaries were variable, few passed anterior and few passed posterior. They saw iliolumbar artery was anterior to the lumbosacral trunk in 30%, it was posterior in 54%, it was cleaved in 8% and the branches of the artery were passing on either side of the lumbosacral trunk to enclose it like a clasp in 8% and the veins were anterior to the lumbosacral trunk in 40% and they were posterior in 60%.

- **Koç T, Gilan IY, Aktekin M, Kurtoglu Z, Dağtekin A, Aytaç G and Coşgun E (2016)** evaluated the origin and branching patterns of the iliolumbar artery and its implications on pelvic and vertebral surgery. For this study, pelvises of 11 male formalin-fixed human cadavers were dissected by anterior and posterior approaches under surgical microscop and then origins, distribution patterns, calibers, and distances to certain structures were measured. They found that the ILA was a single trunk on 17 sides arising either from the IIA (12 sides, 70.6%) or the PT (5 sides, 29.4%) and the average caliber of those originated from the posterior trunk was significantly larger (p=0.010). The ILA started as a single trunk in 17 sides, while its lumbar and iliac branches separately originating from different arteries in 4 sides. They also observed a close relation of the posterior rami of both the lumbar and iliac branches with transverse process and spinal nerve were noted.

- **Gadagi RS and Mulage SK in 2018** conducted cadaveric study on the origin variability of the iliolumbar artery and its clinical significance. 30 bisected pelvises specimens were used for this study. They observed that the ILA was most commonly originated from the trunk of IIA in 36.67%, from posterior division of IIA in 23.33%, and from the common iliac artery in 13.33%. Moreover, the incidence of absence of ILA was recorded in 26.67% specimen.