

A COMPOSITE STUDY OF THE HYPOGASTRIC ARTERY AND ITS BRANCHES

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THE blood vascular tree has at all times been a particularly interesting phase of anatomical study. Its influence on the development of the individual, its practical importance in medicine, and the necessity for the surgeon to thoroughly orient himself with it give additional stimuli to further our knowledge concerning it.

Bader in 1866, Krause in 1868, and Ruge in 1883 commented upon the regularity and frequency of arterial variations and suggested grouping these variations into anatomic types. This phase of anatomical study, the establishment of anatomic types, aims to generalize the variations of the large arterial trunks of the body, to arrange them into a form more easily comprehended and retained and, if possible, to clear the unbelievable confusion and chaos that exist in the literature on arterial variations.

The observation and classification of the branches of any one of the large arterial trunks, in a sufficiently extensive series of cadavers, disclose the fact that variations of the blood-vascular tree fall naturally into distinct types. This conclusion is supported by the studies of Hitzrot on the axillary, Bean on the subclavian, and those of the writer on the femoral and coeliac axis arteries. Mention is made in the studies of the femoral and coeliac axis arteries of the occurrence of numerous minor arterial variations not entirely in accord with the described and classified types, yet the arteries observed allow of a distinct grouping into definite and well defined types. Analogous results are found in the present study of the hypogastric (internal iliac) artery.

This paper, the third of the blood-vascular tree studies, presents a composite study of the hypogastric (internal iliac) artery, and is based on records and observations made from student and personal dissections at the Daniel Baugh Institute of Anatomy of the Jefferson Medical College. Dissections of 93 cadavers were recorded: 72 male white, 11 female white, 7 male negro, and 3 female negro. There were 91 dissections of the hypogastric artery on the right side of the body and 90 dissections on the left side, making 181 dissections in all.

Section A of this paper presents observations on the point of bifurcation of the aorta, and the length and point of bifurcation of the common iliac and hypogastric (internal iliac) arteries. Section B contains a description of

STUDY OF THE HYPOGASTRIC ARTERY

the types of hypogastric artery. Section C embraces a description of the individual branches of the hypogastric artery. Section D summarizes and discusses the results of the present study.

SECTION A

In the course of the observations on the hypogastric artery, the point of division of the abdominal aorta was found as follows:

	Per cent.
Opposite the	
Third lumbar vertebra.....	4
Intervertebral disc between the third and fourth lumbar vertebræ..	9
Fourth lumbar vertebra.....	59
Intervertebral disc between the fourth and fifth lumbar vertebræ..	20
Fifth lumbar vertebra.....	8

Schwalbe and Pfitzner found the division of the aorta opposite the top of the fifth lumbar vertebra in 20 per cent. of their cases, and opposite some part of the fourth lumbar in 73.3 per cent.

Quain and Dwight report the following observations:

	Quain Per cent.	Dwight Per cent.
Opposite third lumbar	3	2.8
Between cartilage of the third and fourth lumbar vertebræ	6	3.5
Opposite fourth lumbar	62	76
Between cartilage of the fourth and fifth lumbar vertebræ	14	5
Opposite fifth lumbar vertebra.....	11	11.5

Arteria Iliac Communis.—The length of this artery presents considerable variation: Rauber gives its length as 4 to 6 cm.; Henle 2 to 8 cm. Sappey gives its normal length as 6 cm. Quain's observations vary from 2.5 to 10.1 cm.

The author's observations as to the point of division and length of the common iliac artery in 181 dissections are as follows:

	Number of arteries	Per cent.
Opposite fifth lumbar vertebra.....	24	14.5
Between fifth lumbar vertebra and superior margin of sacrum	120	85.5
Length of common iliac artery:		
2.5-4 cm.	29	15.2
4.0-5 cm.	59	36.0
5.0-6 cm.	52	27.2
6.0-7 cm.	11	5.8
7.0-8 cm.	19	10.0
8.0-9 cm.	10	5.2

There is a well marked tendency for the left common iliac artery to bifurcate at a lower level than the right. When the common iliac is more

than 6 cm. in length it is more or less tortuous in its course, and Thompson states that the length of the common iliac is somewhat greater in females and that the tendency in females is to bifurcate at a lower level. The number of females in this series is too small to make similar comparisons.

The length of the hypogastric artery varies considerably. Quain gives the average length of 2.5 to 4 cm.; Poirier, 2 to 4 cm. The observations in 181 dissections are as follows:

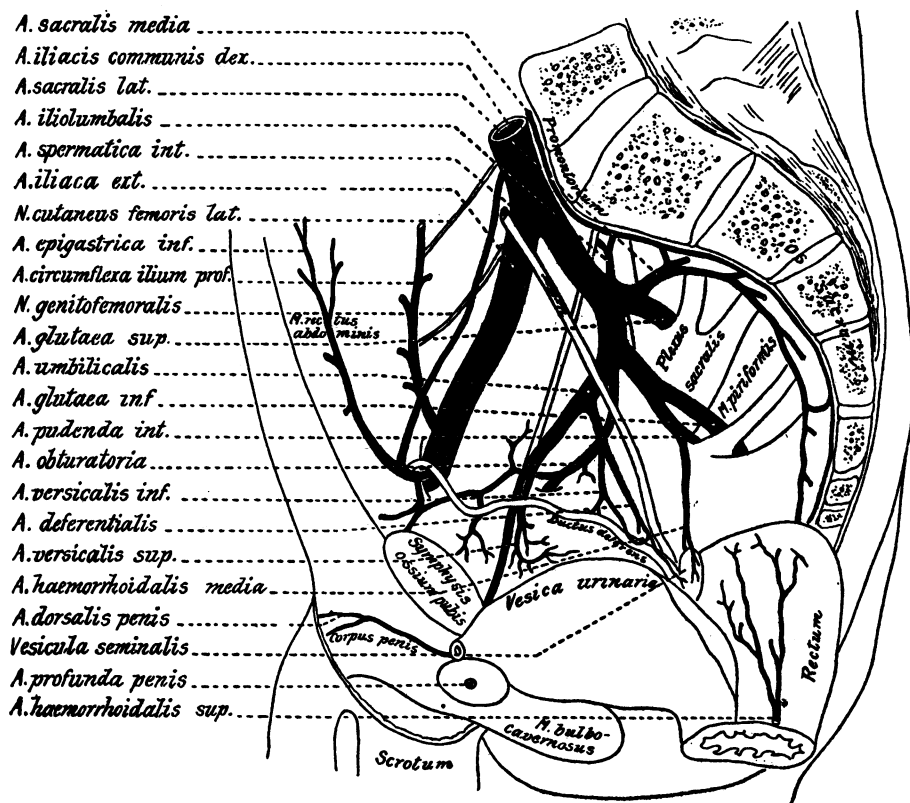


FIG. 1.—Type I occurs in 40 per cent. of the arteries studied.

	Number of arteries	Per cent.
1.5-2.5 cm.	24	13.5
2.5-3.5 cm.	50	28.0
3.5-4.5 cm.	67	37.6
4.5-5.5 cm.	20	11.2
5.5-6.7 cm.	17	9.5

It is worthy of note that if the aorta divides at a lower level, there is no shortening of the iliac or hypogastric arteries, the division of the latter vessels occurring at lower levels.

STUDY OF THE HYPOGASTRIC ARTERY

SECTION B—DESCRIPTION OF TYPES

TYPE I.—This type (Fig. 1) occurs in 40 per cent. of the cadavers studied, 24 per cent. on the right side of the body, and 16 per cent. on the left side. In this group the superior gluteal artery constitutes the largest branch and arises as the dorsal or posterior trunk of the hypogastric (internal iliac) artery; the internal pudendal (internal pudic) and the inferior gluteal arteries arise in a common trunk caudal to the superior gluteal.

The obturator, vesical, middle hemorrhoidal, and uterine arteries arise as separate branches from the caudal continuation of the hypogastric artery. The obturator

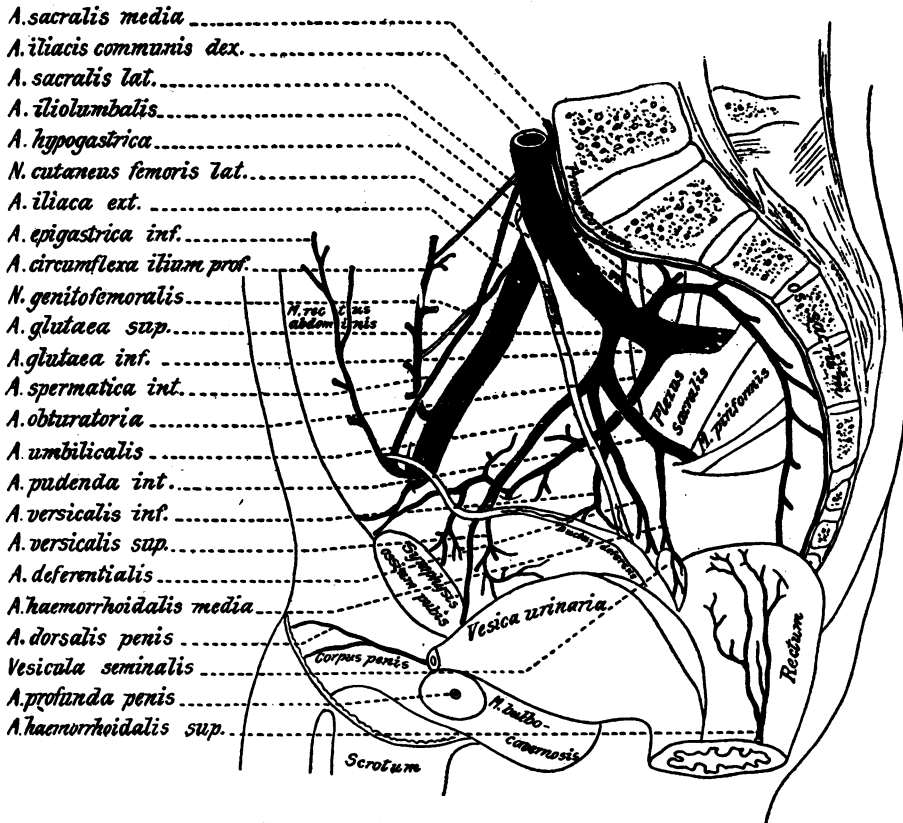


FIG. 2.—Type II is found in 24 per cent. of the arteries studied.

artery in 45 per cent. of the vessels of this group arises in a common trunk with the inferior (deep) epigastric artery from the external iliac.

The obturator artery arises 16 times as a separate branch from the superior gluteal artery. In one subject of this group the obturator is present as a branch of the femoral artery.

There are in this type 28 male white, 6 female white, 3 male negro, 1 female negro subjects. Jastschinski found this type present in 38 per cent. of the subjects classified, 20 per cent. on the right side of the body and 18 per cent. on the left side.

TYPE II.—This type (Fig. 2) occurs with slight variations in 24 per cent. of the vessels observed, 14 per cent. on the right side of the body, and 10 per cent. on the left side. The superior and inferior gluteal arteries arise from the hypogastric

BENJAMIN LIPSHUTZ

(internal iliac) artery in a common trunk. The internal pudendal, obturator, and uterine arteries arise as separate branches from the caudal continuation of the hypogastric artery.

In 40 per cent. of the arteries of this group, the obturator artery arises as a separate branch from the common trunk of the superior and inferior gluteal arteries. The obturator artery occurs three times in this group in a common trunk with the inferior (deep) epigastric, which common trunk arises from the external iliac artery. In every case observed the common trunk for the superior and inferior gluteal arteries makes its exit from the pelvis by passing through the great sacrosciatic foramen (foramen ischiadicum majus) cephalic to the pyriformis muscle (foramen suprapyriforme).

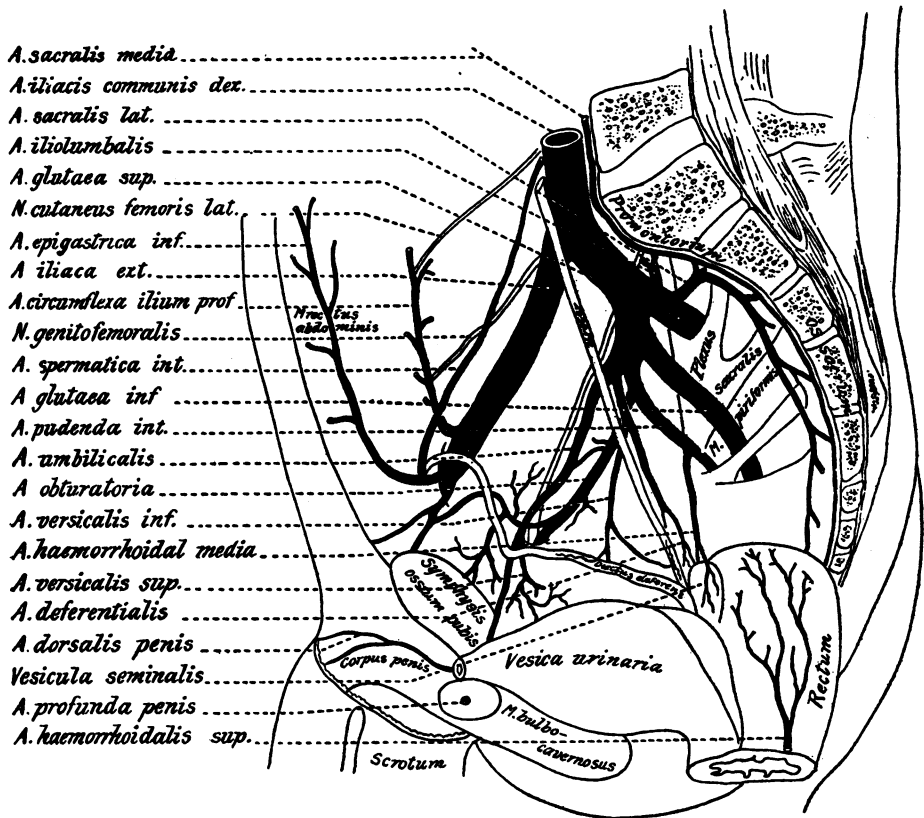


FIG. 3.—Type III occurs in 17 per cent. of the arteries studied.

The internal pudendal artery in two subjects of this group is present as a separate branch of the common trunk for the superior and inferior gluteal arteries after the trunk has made its exit from the pelvis.

There are in this type 22 subjects in all, 16 male white, 3 female white, 2 male negro, and 1 female negro.

TYPE III.—This type (Fig. 3) is found with slight variations in 17 per cent. of the arteries classified, 10 per cent. on the left side of the body and 7 per cent. on the right side. In this type the superior gluteal, inferior gluteal, and internal pudendal arteries occur as separate branches of the hypogastric artery. The obturator in this group is variable in its origin, occurring 17 times as a separate branch of the hypo-

STUDY OF THE HYPOGASTRIC ARTERY

gastric artery, 4 times as a branch of the inferior gluteal, 5 times as a branch of the internal pudendal, 4 times in a trunk common with the inferior (deep) epigastric, and in two cases it is present as a branch of a large middle hemorrhoidal artery.

There are in this type 16 subjects in all, 14 male white, 1 female white, and 1 male negro.

TYPE IV.—This type (Fig. 4) is found in 11 per cent. of the arteries observed, 3 per cent. on the right side of the body and 8 per cent. on the left side. In this group the obturator, the internal pudendal, and the inferior gluteal arteries arise from the hypogastric artery in a common trunk. The superior gluteal artery arises as a sepa-

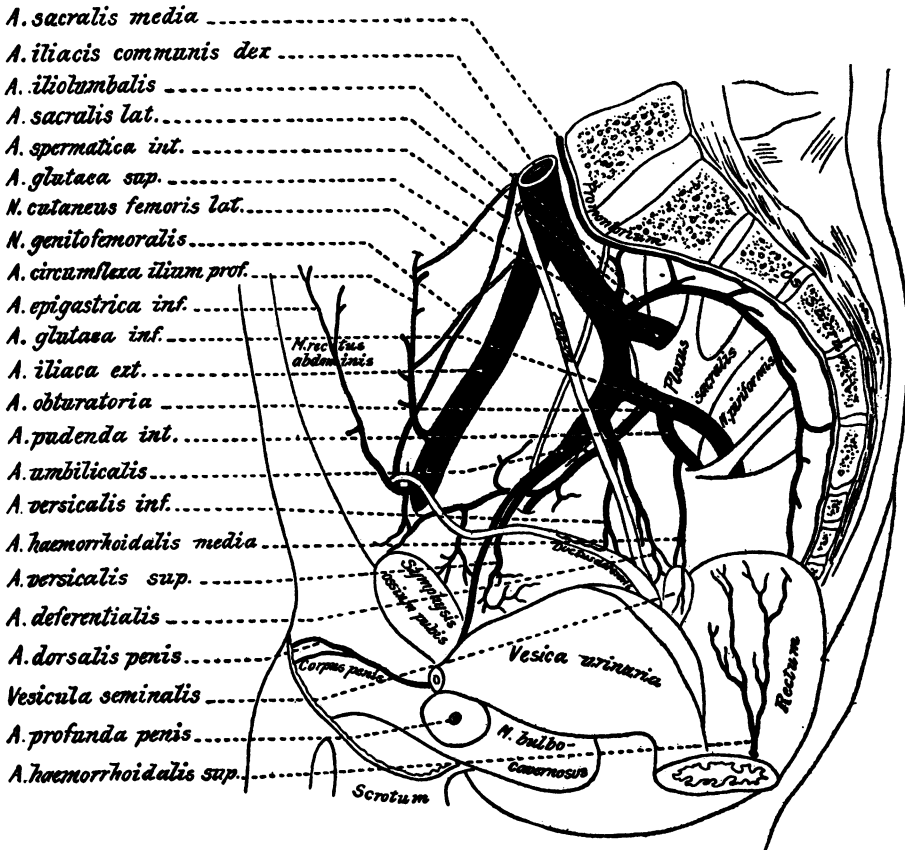


FIG. 4.—Type IV occurs in 11 per cent. of the arteries studied.

rate branch dorsal to the trunk for the inferior gluteal, obturator, and internal pudendal arteries.

The superior gluteal artery is usually larger than the trunk for the inferior gluteal, obturator and internal pudendal arteries. There are in this type 11 subjects in all, 8 male white, 1 female white, 1 male negro, and 1 female negro.

TYPE V.—This type (Fig. 5) occurs in 7 per cent. of the arteries observed, 2 per cent. on the right side of the body and 5 per cent. on the left side. In this group the superior gluteal, inferior gluteal, obturator and internal pudendal arteries arise from the hypogastric artery in a common trunk. It is interesting to note in this connection that this group is represented wholly by male whites, 6 in all.

SECTION C—DESCRIPTION OF BRANCHES

A. obturatoria: Probably no artery in the human body of proportionate size has so voluminous a literature as the obturator artery. It has been the subject of repeated anatomical research. Haller, in 1745, first observed and noted the origin of the obturator artery as a branch of the inferior epigastric. Murray and Portal recorded instances in which this vessel arises variously as a branch of the external iliac, femoral and inferior epigastric arteries. Monroe in 1805, Cooper in 1807, and Barclay in 1806 noted

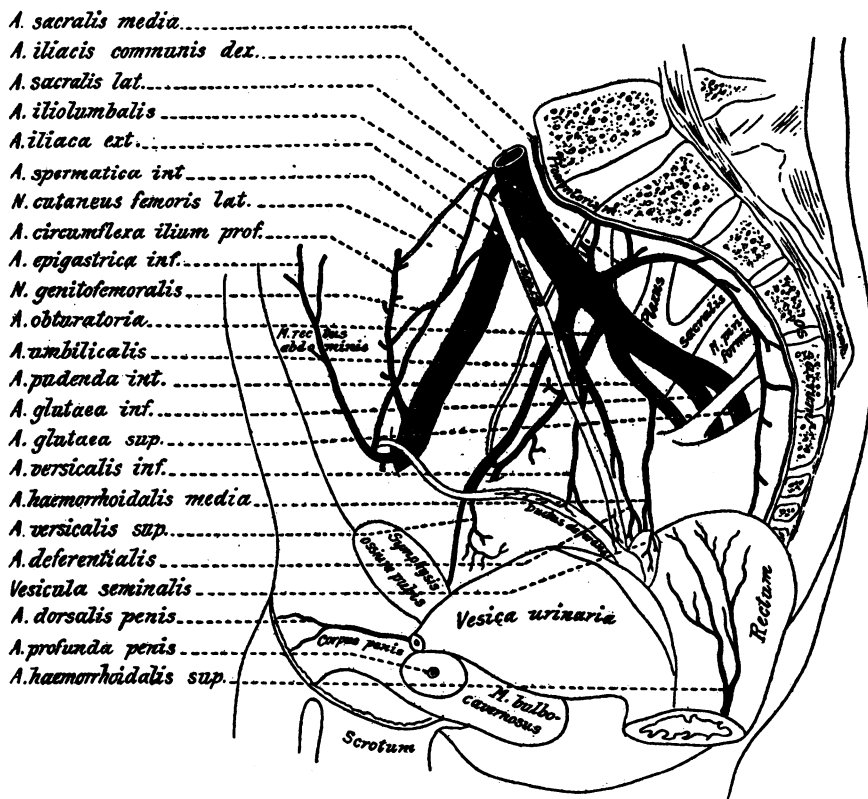


FIG. 5.—Type V occurs in 7 per cent. of the arteries studied.

anomalous obturator vessels coursing in relation to the free edge of the lacunar (Gimbernat's) ligament and their importance to femoral hernia.

The obturator artery presents considerable variation in its origin, size and distribution. It arises in a trunk common with the inferior epigastric in 19.3 per cent. of the cadavers studied. This variation occurs in 12 per cent. of the cadavers on the right side of the body, and in approximately 7 per cent. on the left side, and in 30 per cent. on both sides of the same body. The important statistics in literature as to the frequency of this variation are stated in the following table:

STUDY OF THE HYPOGASTRIC ARTERY

	Number of bodies examined	Per cent.
Quain	400	31.9
Brochet	63	..
Cloquet	500	31.4
Hoffman	63	32.5
Pfitzner	307	37.6
Hesselbach	64	42.2
Krusche	63	21.2
Dwight	500	25.8
Jastschinski	404	24
Levi	100	25.2

The obturator artery arises 16 times (9 per cent.) as a separate branch of the superior gluteal artery; 5 times (3.5 per cent.) as a branch of the inferior gluteal; 7 times (4 per cent.) as a branch of the pudendal artery. The obturator artery arises 17 times (9.4 per cent.) as a separate branch from the common trunk for the superior and inferior gluteal arteries. In 10 per cent. of the subjects observed, this vessel is found in a common trunk with the superior and inferior gluteal arteries and in 7 per cent. in a common trunk with the superior gluteal, inferior gluteal, and internal pudendal arteries. It arises three times as a branch of the external iliac artery caudal to the origin of the inferior epigastric.

In two cases observed, it occurs as a branch of the femoral artery. Mention is made by the writer in the study of the femoral artery of the occurrence in two subjects of the obturator artery arising in a common trunk with the medial circumflex and inferior epigastric arteries, which trunk takes origin from the external iliac. This unusual variation was not observed in this series.

The obturator arises in two stems which unite to form a single obturator artery in 11 of the cases observed. In six of the subjects of the latter group, one stem takes origin from the inferior epigastric artery and the other from the hypogastric artery. The obturator occurs three times as a twin vessel, both rami remaining independent. Jastschinski in study of 88 fetuses states that the inferior epigastric artery rarely arises in two stems, and that the additional vessel is in reality another obturator artery.

The common trunk for the obturator and inferior epigastric arteries varies in length from 1 to 3 cm. The common origin of the obturator and the inferior epigastric is of importance since, in its course through the pelvis to the obturator canal, it is in close relation with the femoral (crural) ring (annulus femoralis). The femoral ring is above the inner opening of the obturator canal.

The relation of the obturator artery to the femoral ring varies as follows:

1. If it arises from the external iliac artery it bears little or no relation to the femoral region.
2. If it arises from the femoral artery it usually courses between the femoral vein and the lacunar (Gimbernats) ligament, usually dorsal and caudal to the femoral ring. In about one-half of the recorded cases in

literature the obturator artery courses along the outer half or two-thirds of the femoral ring, in the latter position it is most likely to be injured and result in dangerous hemorrhage. To avoid this injury the iliopubic ligament should be incised as near as possible to the lacunar ligament.

3. If it arises as a common trunk with the inferior epigastric, the relation of the obturator to the femoral ring varies—(a) if from the central portion of the artery between the external iliac artery and the inguinal ligament, or from the summit of the common trunk of the inferior epigastric and obturator arteries, it pursues an arched course and is usually related to the lateral border of the femoral ring; (b) if it arises at or above the inguinal ligament, it lies at the medial border or middle of the femoral ring. It is usually related to the lateral side of a femoral hernia. The obturator artery courses transversely across the hernia according to Jastschinski in 22 per cent. of the cases. The writer observed two cases in which the obturator artery courses transversely across the annulus femoralis. In female subjects the obturator artery courses more frequently along the lateral border of the femoral ring than the medial.

The ramus pubicus superior usually occurs as a branch of the inferior (deep) epigastric artery. Not infrequently this vessel arises from the inferior epigastric at the medial border of the femoral ring and frequently is of large calibre and easily injured in operative procedures, becoming a source of troublesome and dangerous hemorrhage. The obturator artery leaves the obturator canal and usually divides into two diverging branches, both of which course on the pelvic (ental) side of the obturator membrane between the latter and the obturator externus muscle. The ventral branch lies on the bone, the dorsal branch lies on the ectal surface of the obturator membrane. The ventral branch gives off a large number of small rami, some of which supply the obturator internus muscle. The obturator artery usually pierces the obturator canal and divides into two terminal branches, ramus anterior and posterior. The ramus anterior sends a branch to the symphysis pubis and then courses along the inferior ramus of the pubis. The ramus posterior usually gives off three branches; the ramus acetabular, the ramus internus to the medial surface of the obturator membrane, and the ramus externus which supplies the ischial nutrient arteries.

Arteria prostatica: This vessel varies in its course, origin and distribution. It arises in 10 per cent. of the cadavers observed as a branch of the middle hemorrhoidal, 5 times as a branch of the inferior gluteal, 15 times as a branch of the obturator, 10 times as a branch of the ischiopudendal trunk, and 30 times as a branch of the anterior trunk of the hypogastric artery after its division. It is also not infrequently present as a branch of the umbilical artery. Occasionally it arises in a common trunk with the inferior vesicle artery. The direction of the prostatic artery varies in accordance with its origin. The usual course is caudal, medial and ventral. The consideration of the prostatic artery as the trunk of origin for the profunda and dorsalis penis arteries will be described subsequently.

STUDY OF THE HYPOGASTRIC ARTERY

Arteria vaginalis: This vessel is the homologue of the prostatic artery in the male. It is frequently confused with the inferior vesicle artery. The vaginal artery is represented as a twin vessel in 40 per cent. of the female subjects of this series. This vessel may occur as a branch of (a) the inferior gluteal, (b) the ischiopudendal trunk, (c) the obturator, (d) the anterior trunk of the hypogastric and uterine arteries. The vaginal artery arises in two subjects in a common trunk with the middle hemorrhoidal.

In those subjects in which the vaginal is represented as a double vessel, the proximal artery is found either as a branch of the anterior trunk of the hypogastric, uterine or internal pudendal, the distal artery either from the internal pudendal, ischiopudendal trunk, obturator, inferior gluteal or in a common trunk with the middle hemorrhoidal.

The vaginal artery is distributed to the lateral surface of the vagina, the posterior surface being vascularized by the middle hemorrhoidal artery.

A. glutea inferior (A. ischiadica): This vessel presents considerable variation in its course, origin and distribution.

The committee on collected statistics and investigations, in an observation of 50 cases, state that this vessel arises in 75 per cent. of the arteries recorded from the anterior trunk of the hypogastric artery, in 21.4 per cent. as a branch of the superior gluteal artery.

Cruveilhier and Sappey describe the inferior gluteal as arising either in a common trunk with the superior gluteal or internal pudendal arteries.

The inferior gluteal artery arises in a common trunk with the internal pudendal artery in 40 per cent. of the cases classified. The length of the ischiopudendal trunk varies from 2 to 8 cm. In 25 per cent. of the subjects in which this arterial trunk is present, it is from 6–8 cm. and divides into the internal pudendal and inferior gluteal arteries after its exit from the pelvis. This division occurs at or close to the sacrotuberous ligament under cover of, or at the lower margin of, the pyriformis muscle, and at times 2–4 cm. caudal to the pyriformis muscle. In approximately 30 per cent. of the subjects, the ischiopudendal trunk is from 0.02–2.5 cm. in length. The ischiopudendal trunk usually divides into the internal pudendal and inferior gluteal arteries in the pelvis; the internal pudendal artery occasionally arising from the ischiopudendal trunk within 1 cm. of the lateral margin of the sacrotuberous ligament. The inferior gluteal frequently takes a circuitous course at first medial to the internal pudendal artery, then crosses the latter vessel and has a position lateral to the (Fig. 6) internal pudendal artery and medial to the sciatic nerve.

The inferior gluteal artery arises, in 24 per cent. of the cadavers studied, in a common trunk with the superior gluteal artery. The inferior gluteal artery in these cases usually leaves the pelvis through the suprapyriforme, and is given off by the common trunk for the superior and inferior gluteal arteries at or just below the cephalic border of the pyriformis muscle. Less frequently the inferior gluteal artery takes origin from the common trunk of the superior and inferior gluteal arteries, either in the pelvis or under cover

of the upper fibres of the pyriformis muscle, leaving the pelvis through the foramen infrapyriforme. The inferior gluteal artery in 17 per cent. of the subjects studied is present as a separate branch of the anterior trunk of the hypogastric artery. In 10 per cent. of the subjects studied, it occurs in a common trunk with the internal pudendal and obturator arteries. In 7 per cent. of the subjects studied the inferior gluteal artery is found in a common trunk with the superior gluteal, obturator and internal pudendal arteries.

The inferior gluteal artery is represented by two vessels, each having a separate origin in 16 per cent. of the arteries observed; both inferior gluteal arteries arise from the ischiopudendal trunk ten times. One inferior gluteal

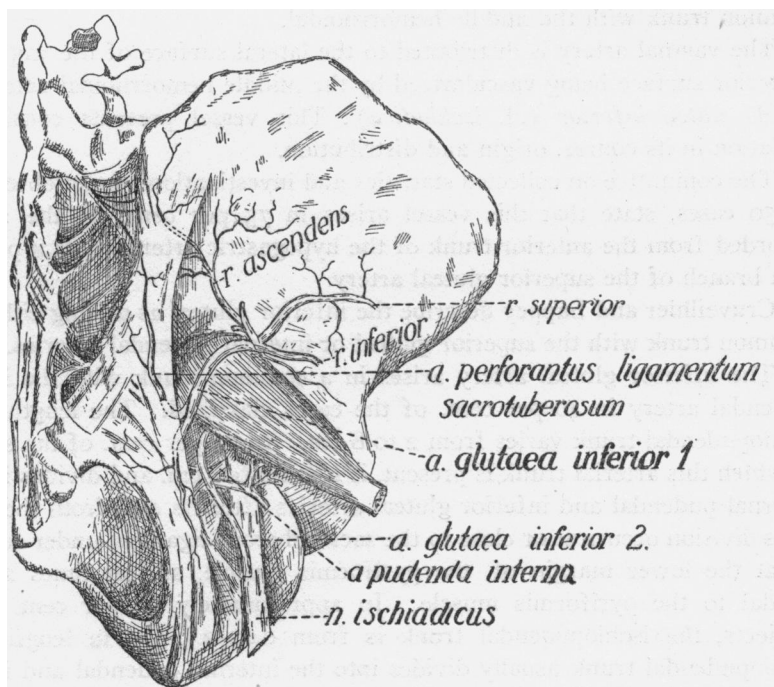


FIG. 6.—Type VI illustrates the occurrence of the inferior gluteal artery as a twin vessel. It also illustrates the usual relations of the sciatic nerve, inferior gluteal artery and internal pudendal artery.

artery arises as a branch of the anterior trunk of the hypogastric artery or in a common trunk with the internal pudendal, the other as a branch of the superior gluteal twelve times (Fig. 6). Both inferior gluteal arteries arise from the superior gluteal in nine of the cases. In three of the subjects studied, one inferior gluteal artery is present as a branch of the ischiopudendal trunk, the other as a branch of the obturator artery.

The inferior gluteal is usually dorsal, cephalic and medial to the internal pudendal artery in the pelvis.

Poirier describes four terminal branches: (a) R. posterior internus, (b) R. posterior externus, (c) R. inferior externus, (d) R. inferior internus,

STUDY OF THE HYPOGASTRIC ARTERY

which is the dorsal and caudal continuation of the main stem of the artery. I have used the nomenclature of Poirier in the description of the terminal branches of the inferior gluteal artery.

The inferior gluteal artery is at times the trunk of origin of the obturator, middle hemorrhoidal, prostatic and vaginal arteries. The extrapelvic are, however, the more conspicuous branches of this vessel.

Ramus posterior internus (Arteria perforans ligamentum sacrotuberosum): This vessel is usually well marked and of large calibre. It arises under cover of the pyriformis muscle, courses medially and cephalically between the fibrous planes of the sacrotuberous ligament and here redivides and arborizes and occasionally reaches the sacrum. The branches perforate the sacrotuberous ligament and terminate either in the ligament or in the gluteus maximus muscle.

The number of arteries to the sacrotuberous ligament varies from 1 to 4 and the point of origin is variable. In 19 per cent. of the cases it arises at the caudal margin of the pyriformis, close to the lateral margin of the sacrotuberous ligament. It frequently divides before it enters the fibrous planes of the ligament. When the perforating arteries are 3 to 4 in number they enter the ligament immediately cephalic to the spine of the ischium.

In those subjects in which the inferior gluteal is represented as a double vessel, one of the latter usually becomes the A. perforans ligamentum sacrotuberosum. The perforating artery also occurs as a separate branch of the hypogastric artery or in a common trunk with the internal pudendal artery. It is also found as a branch of the obturator or superior gluteal arteries.

Ramus posterior externus: This vessel is not constant and presents considerable variation in its point of origin and number. It arises frequently from 2 to 4 cm. from the caudal margin of the pyriformis muscle. The vessel gives branches to the gluteus maximus, pyriformis, gemelli, and quadratus femoris muscles.

Ramus inferior internus: This is not infrequently a well marked vessel. As it descends between the gluteus maximus and tuberosity of the ischium it divides into 2 to 4 branches, terminating close to the caudal margin of the gluteus maximus muscle.

Ramus inferior externus: This vessel is of larger calibre than the R. inferior internus and is the caudal continuation of the inferior gluteal artery. It is usually medial to the posterior femoral cutaneous (lesser sciatic) nerve or between the posterior femoral cutaneous and the ischiadic (great sciatic) nerves. This vessel not infrequently pierces the sciatic nerve, separates its fibres and becomes ensheathed by the fascia covering the nerve. In its course it gives rami to the quadratus femoris, gemelli, and adductor magnus muscles. The A. comitans nervi ischiadici is essentially this vessel, or the latter occurs as a descending branch. In very rare instances the A. comitans nervi ischiadici is an artery of large calibre and is the principal vessel of the thigh, retaining its connection with the popliteal

artery. This anomaly is described by the writer in the study of the femoral artery.

Arteria iliolumbalis: Cruveilhier considers this vessel as a branch of the hypogastric artery, although frequently arising from the superior gluteal, as stated by Theile and Henle. This vessel is found in 38 per cent. of the cases studied as a branch of the superior gluteal and in 52 per cent. as a separate branch from the hypogastric artery. The distance between the origin of the iliolumbar artery and the origin of the superior gluteal is variable, in 60 per cent. of the subjects it is 1 to 1.5 cm., in the remaining subjects it varies from 1.5 to 3 cm., the latter distance is found only 6 times.

The iliolumbar artery occurs 3 times as a separate branch of the anterior trunk of the hypogastric artery; 4 times as a branch of the common iliac artery, and in 2 cases as a branch of the external iliac artery. It also arises 6 times from the hypogastric artery in a common trunk with the lateral sacral. It is found absent in 5 subjects, and in these cases it is replaced by the fourth lumbar. An additional small lumbar artery is found 18 times.

The iliolumbar artery usually divides into its terminal branches from 1 to 2.5 cm. from its origin. It usually divides into two terminal branches, less frequently into three—the ramus lumbalis or ascending branch and the ramus iliacus or transverse branch. The ramus lumbalis and ramus iliacus arise as separate branches in 18 per cent. of the cases observed.

Arteria sacralis lateralis: These vessels vary in calibre, number and distribution. There are usually two lateral sacral arteries on each side of the body. In 51 per cent. of the cases classified, the sacral arteries arise in a common trunk. In 10 per cent. of the arteries studied three sacral arteries are observed; the additional vessel usually enters the second sacral foramen as a separate branch. The superior lateral sacral artery gives origin to the spinal branch, which enters the first sacral foramen; the inferior lateral sacral artery gives origin to the spinal branches which enter the second, third and fourth sacral foramina.

In those subjects in which the lateral sacral arteries are found to arise in a common trunk, the latter single trunk arises in 88 per cent. of the subjects from the superior gluteal artery and in 12 per cent. from the hypogastric artery. Its origin is always caudal to the origin of the iliolumbar artery. The lateral sacral arteries arise six times in a trunk common with the iliolumbar.

Arteria glutea superior: Cruveilhier and Theile describe this vessel as representing the direct continuation of the hypogastric artery. This vessel is the largest branch of the hypogastric artery. Its calibre is usually larger than the combined calibre of all the other branches of the hypogastric artery. The superior gluteal artery arises in 24 per cent. of the subjects studied in a common trunk with the inferior gluteal artery. The obturator artery arises sixteen times as a branch of the superior gluteal. In 7 per cent. of the cadavers studied, the superior gluteal artery arises in a common stem with the obturator, internal pudendal and inferior gluteal (sciatic) arteries. The

STUDY OF THE HYPOGASTRIC ARTERY

iliolumbar artery in 31 per cent. of the vessels observed occurs as a separate branch arising from the superior gluteal. The stem of the superior gluteal gives origin to lateral sacral arteries in 88 per cent. of the cases classified.

The superior gluteal artery in 80 per cent. of the subjects observed passes outward between the lumbosacral trunk and the first sacral nerve. In the remaining subjects it courses lateralward and somewhat caudalward to the lumbosacral trunk. This vessel makes its exit from the pelvis through the great sacrosciatic foramen (foramen ischiadicum majus) cephalic to the pyriformis muscle (foramen suprapyriforme).

As it passes above the pyriformis muscle it is rarely of any length, never more than 1 cm., and divides immediately at its emergence into 2 to 4 large arborescent branches. In 10 per cent. of the subjects observed, it divides into 5 or 6 terminal rami.

The ramus superior of the superior gluteal artery usually ascends and divides into numerous smaller rami between the gluteus medius and the maximus, and the ramus inferior, the descending or deep branch, is constant and lies between the gluteus minimus and medius muscles. This branch divides again into transverse, lateral, and descending branches. The inferior ramus arises as a separate branch from the ramus superior in 16 per cent. of the cases classified.

Arteria pudenda interna: This vessel presents considerable variation in its origin, distribution and branches. It arises in 40 per cent. of the subjects observed in a common stem with the inferior gluteal artery; in 24 per cent. as a separate branch of anterior trunk of the hypogastric artery; in 17 per cent. in a common trunk with the obturator and inferior gluteal arteries, and in 7 per cent. in a common trunk with the superior gluteal, inferior gluteal, and obturator arteries. The internal pudendal artery is found in two subjects as a separate branch of the common trunk for the superior and inferior gluteal arteries after the common trunk has made its exit from the pelvis through the foramen suprapyriforme. The internal pudendal artery occurs four times as a branch of the middle hemorrhoidal and in two cases as a branch of the uterine artery. The internal pudendal artery usually has an intrapelvic course of 4 cm. The consideration of the branches of the internal pudendal arteries and their variations follows:

(a) *The arteria hemorrhoidalis inferior* (1 to 3 in number) pierces the obturator fascia and courses medially into the fat of the ischioanal fossa. Cerf states that the terminal branches of the inferior hemorrhoidal arteries go to the cutis ani and to the portion of the rectum caudal to the levator and sphincter ani muscles. It vascularizes the external sphincter ani and the skin only.

The levator ani muscle is vascularized by separate branches which arise from either the inferior hemorrhoidal or from the internal pudendal under cover of the levator ani muscle. They are smaller than the hemorrhoidal vessels, meet the parietal wall of the rectum, enter the submucosa, ascend,

and at times anastomose with the superior hemorrhoidal arteries. This affirms the work of Waldeyer.

The inferior hemorrhoidal arteries occasionally take origin as branches from the inferior gluteal. When only one inferior hemorrhoidal artery is present it arises under the spine of the ischium. The second hemorrhoidal arises in 22 per cent. of the subjects from the perineal branch of the internal pudendal; arising from the latter vessel near its origin or in the perineum.

The artery to the obturator internus muscle arises as a separate branch from the internal pudendal or in a common trunk with the inferior hemorrhoidal. It anastomoses with the obturator or with the intrapelvic branches of the internal pudendal.

In the further description of the branches of the internal pudendal artery, the writer presents the latter vessel as dividing in the perineum into two terminal branches: (a) perineal artery (superficial perineal), so called because it courses through the superficial perineal interspace; (b) the deep perineal, which vessel courses through the deep perineal interspace between the layers of the triangular ligament, and in this part of its course gives origin to the urethral and bulbar arteries. The deep perineal artery continues forward and divides into two terminal branches: (a) A. profunda penis (artery to the corpus cavernosum) and (b) the A. dorsalis penis which reaches the dorsum of the penis by piercing the superficial layers of the triangular ligament.

(b) *Arteria perinei* (superficial perineal): This vessel usually arises caudal to the inferior hemorrhoidal. In 28 of the cases observed it is the terminal branch of the internal pudendal, the artery to the bulb and the penile artery then arising as branches of the prostatic artery. I have not been able to confirm the statement of Poirier who states that the perineal artery is larger in the female. The perineal artery courses over or under the superficial transversus perinei muscle in the superficial perineal interspace, becomes superficial, terminating on the posterior surface of the scrotum in the male and on the labia majora in the female. In three subjects the posterior scrotal artery is replaced by a branch of the external spermatic artery. The deep branch (A. transversus perinei) of this vessel courses transversely toward the median line, vascularizes the bulbocavernosus, ischio-cavernosus, the sphincter ani muscles and superficial muscles of the perineum, the vessel anastomosing with its fellow of the opposite side.

Waldeyer describes the perineal artery as giving the following branches: (a) Branch to ischiocavernosus; (b) skin of the perineum and inner side of the thigh (the latter may arise as a separate branch of the internal pudendal); (c) a vaginal branch to the vestibule (in 50 per cent. of the subjects); (d) a branch to the bulbus urethrae or bulbi vestibuli vaginæ (A. bulbi urethrae; bulbi vestibuli vaginæ). This vessel usually arises from the deep perineal artery between the layers of the triangular ligament and about $\frac{1}{2}$ cm. above the level of the base of the trigonum urogenitale (triangular ligament). It is a large vessel in the male and courses transversely toward

STUDY OF THE HYPOGASTRIC ARTERY

the median line and pierces the superficial layer of the triangular ligament. The branch to the bulb divides into a number of rami and gives off a ventral branch to the corpus cavernosum and a branch to the glandula bulbo-urethralia (Cowper's gland) and anastomoses with the bulbar artery of the opposite side.

This vessel arises 14 times as a branch of the prostatic artery. It occasionally occurs as a branch of the inferior hemorrhoidal artery. It arises as a separate branch from the perineal artery in 11 per cent. of the subjects. The bulbo-urethral artery is represented as a twin vessel twelve times.

Arteria urethralis (bulbourethralis of Kobalt) usually arises in the deep perineal interspace from the deep perineal artery ventral to the origin of the bulbar artery, pierces the superficial layer of the ligament and enters into the sulcus between the corpus cavernosa and corpus spongiosum. This vessel gives origin to one or two branches to the root of the corpus cavernosa, enters the corpora of the same side and courses to the glans penis and anastomoses with the dorsalis and profunda penis arteries.

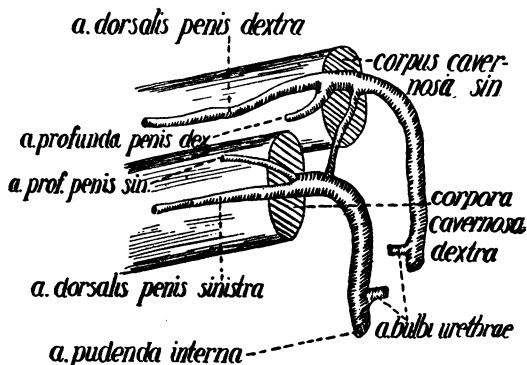


FIG. 7.—Illustrates the presence of an anastomotic branch between the dorsalis penis arteries dorsal to the origin of the profunda penis and occurs in 15 of the arteries studied. Figs. 7 to 11 illustrate unusual variations in the profunda and dorsalis penis arteries.

Arteria dorsalis penis (or *clitoris*): Cruveilhier and Poirier consider this vessel as the terminal artery of the internal pudendal. Henle and Sappey consider both the profunda penis and the dorsal artery of the penis as terminal arteries of the internal pudendal. The dorsalis penis artery is the continuation of the internal pudendal beyond the origin of the profunda penis. This vessel follows its usual course and distribution in only less than one-half of the cases observed. In the remaining subjects, it presents variation in its point of origin, in its branches and in the presence of anastomotic rami. Every artery observed in the latter group presents some variation; the latter are so numerous that I will only note the more important and conspicuous variations.

The arteriæ profunda penis and dorsalis penis are considered under a single heading because of their close relation.

An anastomotic branch is found between the dorsalis penis arteries dorsal (or proximal) (Fig. 7) to the origin of the profunda penis artery in

15 of the cases observed. This transverse anastomotic branch occurs three times ventral (or distal) (Fig. 8) to the origin of the profunda penis artery, and gives origin to a double left profunda penis; the right profunda penis arising as a branch from the right penile artery dorsal to the anastomotic branch. In one subject both profunda penis arteries unite and after a course of 1 cm. redivide again into the right and left profunda penis arteries.

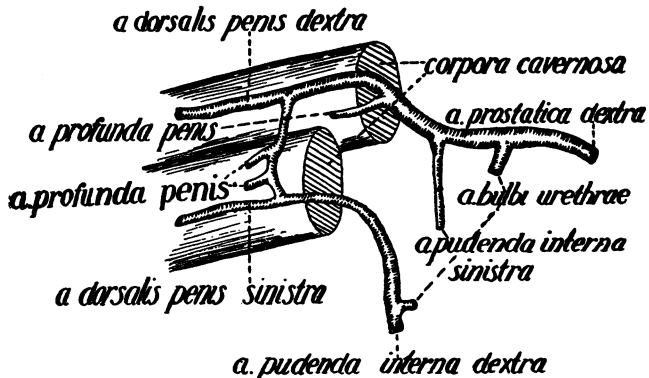


FIG. 8.—Represents the transverse anastomotic branch ventral to the profunda penis artery. This occurs in three subjects.

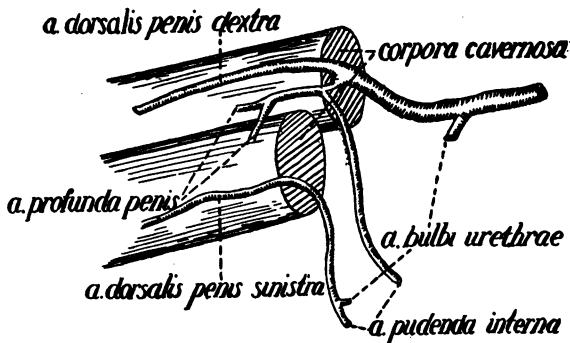


FIG. 9.—Represents the origin of the right dorsalis penis artery from the prostatic; and the former artery gives origin to a branch which is a common trunk for the right and left profunda penis arteries. This occurs in six of the subjects studied.

The right dorsalis penis artery arises from the right prostatic artery and gives origin to a branch which is a common trunk for the right and left profunda penis arteries (Fig. 9); the profunda of the left side is absent. This arrangement is found six times. An accessory profunda penis which arises from the inferior vesical occurs four times.

In two cases the left dorsalis penis artery arises from the inferior vesical artery (Fig. 10); in these subjects both profunda penis arteries arise in a common trunk from the internal pudental artery. This common trunk presents an anastomotic branch with left penile artery which arises from the inferior vesical.

STUDY OF THE HYPOGASTRIC ARTERY

In 5 subjects the right internal pudendal terminates as the profunda penis artery, in these subjects the left prostatic continues forward and gives origin to the right dorsalis penis artery, the trunk then divides into the left profunda and left dorsal penis arteries.

In 7 of the cases observed both profunda penis arteries redivide and have a bilateral distribution (Fig. 11).

The dorsalis penis arises in two of the cases observed as a branch of the obturator.

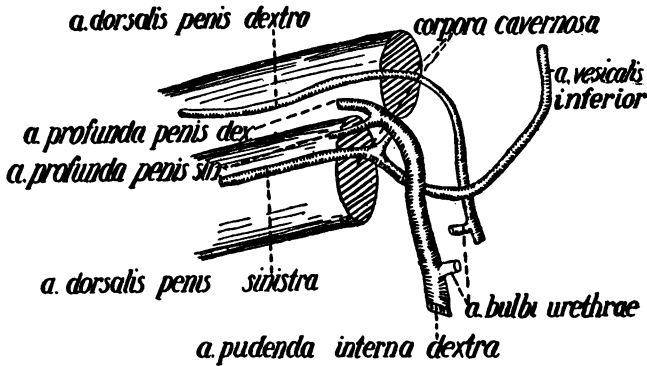


FIG. 10.—Represents the origin of the left dorsalis penis artery from the inferior vesicle. This occurs in two of the arteries studied.

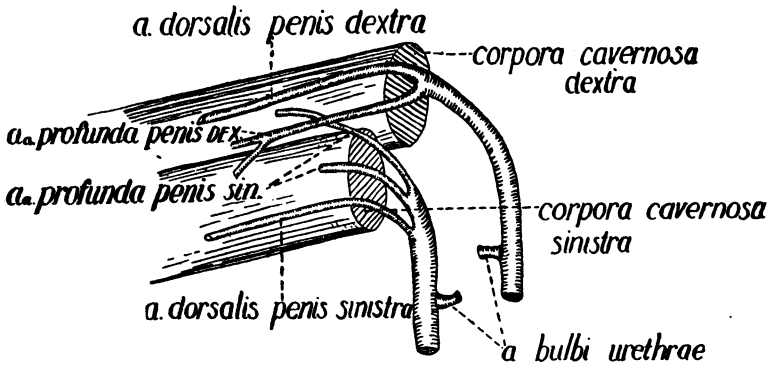


FIG. 11.—Represents both profunda penis arteries as having a bilateral distribution. This arrangement occurs seven times.

The middle hemorrhoidal and prostatic arteries are found frequently as branches of the internal pudendal.

Ischaussow has described several anomalies of the pudendal artery, 2 cases in which the penile artery arises from the obturator; 1 case in which the penile and bulbar arteries arise from the prostatic, the prostatic artery coursing lateral to the pelvic-prostatic capsule of Retzii. Wassiliew in 100 cases demonstrated in 19 anomalies of the penile artery; the latter vessel arises in two subjects from the obturator, 3 times as a branch of the vesiculo-

prostatic and in one subject from a proximal point in the normal pudendal artery. The course of the anomalous branch is always the same along the base of the bladder and prostate.

Arteria hemorrhoidalis media: This vessel is not constant. It is present in only 72 per cent. of the subjects observed. It varies in its calibre and origin. The middle hemorrhoidal artery arises most frequently as a branch of the internal pudendal. This origin occurs in 54 per cent. of the cases observed.

The *middle hemorrhoidal artery* arises 41 times as a branch of the inferior gluteal, 5 times as a branch of the obturator, 3 times as a branch of the vesiculodeferential artery and 3 times as a branch of the anterior trunk of the hypogastric artery.

In 15 per cent. of the subjects studied, this vessel is found double, the branches arising either from the internal pudendal or the anterior trunk of the hypogastric artery.

The middle hemorrhoidal not infrequently arises in a common stem with the vesiculodeferential artery, 10 times from the internal pudendal, 4 times from the inferior gluteal and 3 times from the anterior trunk of the hypogastric artery.

The blood supply of the middle hemorrhoidal to the rectum is not important. The principal blood supply of the rectum is the superior hemorrhoidal artery. Waldeyer affirms this anatomic fact. The anastomosis between the superior and inferior hemorrhoidal is submucous, that of the superior and middle hemorrhoidal subperitoneal.

The middle hemorrhoidal divides into 2 to 4 rami to the lateral parietes of the pelvis and gives small rami to the obturator internus, gemelli and pyriformis muscles, and in the female partly vascularizes the lateral and dorsal surfaces of the vagina.

Arteria vesicalis inferior: This vessel is not constant. It is found in only 70 per cent. of the subjects studied. Poirier describes this vessel as rising in a common trunk with prostatic, vesicodeferential or middle hemorrhoidal arteries.

The inferior vesical artery arises as a separate branch from the prostatic artery in 34 subjects studied. It occurs 3 times as a branch of the vaginal, 8 times as a branch of the umbilical distal to the uterine artery, 9 times as a branch of the vesiculodeferential artery, and 5 times as a branch of the internal pudendal artery.

This vessel occasionally replaces one or more of the branches of a defective internal pudendal artery; cases of this type are noted in a description of the latter vessel.

Arteria deferentialis: This vessel is homologous to the uterine in the female. It is constantly observed. It occurs most frequently as a branch of the anterior trunk of the hypogastric artery. This vessel is found 4 times as a branch of the middle hemorrhoidal, 3 times as a branch of the interior

STUDY OF THE HYPOGASTRIC ARTERY

pubdental and in 2 subjects as a branch of the prostatic artery. The deferential artery occasionally replaces the internal spermatic artery.

Arteria uterina: The uterine artery is the homologue of the deferential artery in the male and arises more commonly second in order as a well-marked vessel from the ventral or anterior trunk of the hypogastric artery. This vessel occurs four times in a common trunk with the superior vesical artery; in two cases in a common trunk with the internal pudental and in one subject in a common trunk with the obturator. The uterine artery pursues a tortuous, medially directed course, insinuates itself between the layers of the broad ligament, and courses along its base. On approaching the neck of the uterus it usually divides into ascending branch running along the side of the uterus and a descending branch to the cervix. The ascending branch supplies the body of the uterus, and in this part of the course it gives off branches to the ventral and dorsal surfaces of the uterus which anastomose with the corresponding branches of the opposite uterine. The latter vessels diminish greatly in calibre as they pass forward to the medial line. The uterine artery usually gives origin to a branch to the fundus uteri; and two lateral branches: (a) Ramus tubarius, which anastomoses with the tubal branch of the ovarian artery; (b) a branch to the ovary (R. ovarii), which anastomoses with the ovarian. The latter branch gives a number of small branches to the broad ligament, which anastomose with the inferior epigastric. The uterine artery also gives off a number of small rami to ureter and bladder.

The uterine artery at its origin lies at a deeper level and lateral to the ureter. At the level of the spine of the ischium, the uterine artery enters the broad ligament to reach the uterus and in its course along the base of the broad ligament passes ventrad to the ureter.

The distance between the right and left ureters at the point of crossing between the ureter and uterine artery is from 6.5 to 7.5 cm., and 4 cm. at the level of the ostium externum uteri.

In one subject the uterine artery arises bilaterally in a common trunk with the internal pudental and at a more caudal level than the normal uterine; the uterine artery courses slightly lateral and dorsal to the ureter, and at the point of crossing, the uterine artery passes dorsal to the ureter.

This unusual relation of the ureter ventral to the uterine artery is evidently of the rarest occurrence. The writer could not find a single instance in the literature in which this anomalous relation was reported.

This unusual relation should be borne in mind by the surgeon in ligation of the uterine artery, in order that he may avoid injury to the ureter.

Arteria vesicalis superior: This vessel represents the persistence of the proximal end of the umbilical artery in the foetus. It arises four times in a common trunk with the uterine artery and also occurs in a common trunk with the vaginal and obturator arteries. The superior vesical artery divides into numerous branches (Rami vesicales) which supply the apex and body of the bladder and anastomose with the corresponding vessels of the opposite side.

BENJAMIN LIPSHUTZ

SECTION D—SUMMARY AND DISCUSSION

1. A comparison of the types of the arteria hypogastrica demonstrates the predominance of Type I on both sides of the body. This arrangement of the branches of the hypogastric artery occurs in 40 per cent. of the arteries studied, 24 per cent. on the right side of the body and 16 per cent. on the left side.

Type II occurs in 24 per cent. of the arteries observed, 14 per cent. on the right side and 10 per cent. on the left side; Type III in 17 per cent.; Type IV in 11 per cent. of the subjects, and Type V in 7 per cent.

A similar arrangement of the branches on each side of the body is present in 35 per cent. of the cadavers observed.

2. This study embraces the dissection of 93 cadavers: 72 male white, 11 female white, 7 male negro and 3 female negro. There are 91 dissections from the right side of the body and 90 dissections from the left side.

No relation of the branches to age could be drawn as there were only adults in this series. In the study of the femoral artery, the negro subjects presented a greater proportionate number of variations and anomalies than the white. Twelve per cent. of the dissections of this study were made on negro subjects. The latter subjects did not present proportionately a greater number of variations and anomalies. Unusual variations occur with greater frequency on the left side of the body.

3. Many of the variations which are found in studying the arterial tree in man, occur as normal types of vessels in lower forms. There is a normal type for each order. The careful comparative anatomy studies of Zuckerkandl and Popyski fail to disclose any well defined gradation of changes or laws upon which to base explanations of the genesis of variations. Tandler in his careful research and studies on the arteries of the head in animals affirms this anatomic fact, yet comparative anatomy appears to indicate that there has been a progressive change toward well defined types. It is reasonable to assume that in the higher mammals the arterial system is as complex as it is in man and that arterial variations occur with the same degree of frequency. This phase of the study of arterial variations—the explanation of their genesis on a comparative anatomy and embryologic basis, will be presented in detail in a later study.

4. The middle hemorrhoidal artery is found in 72 per cent. of the subjects observed. This vessel occurs most frequently as a branch of the internal pudendal (internal pudic) artery. The middle hemorrhoidal is frequently present as a separate branch arising from the inferior gluteal artery. In 15 per cent. of the subjects the middle hemorrhoidal is represented as a double vessel. The blood supply of the middle hemorrhoidal to the rectum is not important. The principal blood supply of the rectum is the superior hemorrhoidal artery. The anastomosis between superior and inferior hemorrhoidal is submucous, the anastomosis between the superior and middle hemorrhoidal arteries is subperitoneal. The middle hemorrhoidal also partly vascularizes the lateral and dorsal surfaces of the vagina. The vaginal

STUDY OF THE HYPOGASTRIC ARTERY

artery usually vascularizes the lateral surface of the vagina. The vaginal artery is represented as a twin vessel in 40 per cent. of the subjects of this series.

The inferior gluteal artery arises in a common trunk with the superior gluteal artery in 24 per cent. of the arteries classified, the inferior gluteal artery in 40 per cent. of the arteries studied arises in a common trunk with the internal pudendal artery. This ischiopudendal trunk in 25 per cent. of the subjects divides into the inferior gluteal and internal pudendal arteries after it has made its exit from the pelvis.

The inferior gluteal artery in 16 per cent. of the cases observed is represented as a twin vessel, each of which has a separate origin.

The *arteria perforans ligamentum sacrotuberosum* is one of the terminal branches of the inferior gluteal and is usually a vessel of large size, coursing between the fibrous layers of the sacrotuberous ligament. The R. inferior internus represents the caudal continuation of the inferior gluteal artery. This vessel not infrequently pierces the sciatic nerve, separating its nerve fibres and becomes ensheathed by the fascia covering the sciatic nerve.

The iliolumbar artery is found absent 5 times, in which subjects it is replaced by the fourth lumbar artery.

The superior gluteal is the largest branch of the hypogastric artery and in the adult is the direct continuation of the hypogastric artery. The superior gluteal artery courses between the lumbosacral trunk and first sacral nerve. This vessel makes its exit from the pelvis through the great sacrosacral foramen (*foramen ischiadicum majus*) cephalic to the pyriformis muscle, as it passes above the pyriformis muscle, it is rarely of any length, never more than 1 cm., and divides into a variable number of large arborescent branches.

The internal pudendal arises in 40 per cent. of the cases classified in a common trunk with the inferior gluteal artery; in 24 per cent. it arises as a separate branch from the anterior trunk of the hypogastric artery.

The internal pudendal terminates 28 times as the perineal artery, the prostatic replacing the vessels of the defective internal pudendal artery. Anastomosis between the penile arteries on both sides of the body is frequent in the male. The penile artery at times has a bilateral distribution. The *dorsalis penis* and *profunda penis* may arise from the prostatic artery, less frequently from the inferior vesical and obturator arteries. Approximately one-half of the *dorsalis penis* and *profunda penis* arteries present variations.

The obturator artery arises in a common trunk with the inferior epigastric artery in 19.3 per cent. of the subjects studied. The obturator arises not infrequently as a separate branch from the superior gluteal artery. The obturator artery occurs three times as a branch of the external iliac, and in two cases as a branch of the femoral artery. The obturator artery also occurs as a branch of the inferior gluteal artery, internal pudendal artery, the ischiopudendal trunk and the common trunk for the superior and in-

ferior gluteal arteries. The obturator artery is represented as a twin vessel in 11 of the cases observed.

The obturator artery varies in its relation to the femoral ring in accordance to its origin. 1. If it arises from the external iliac artery, it bears little or no relation to the femoral ring. 2. If it arises from the femoral artery and there is a hernia present, the obturator artery is usually caudal and dorsal to the femoral ring. In about one-half of the cases in which the obturator artery arises from the femoral artery, it is related to the outer half of the femoral ring and in this position it is likely to be injured and result in dangerous hemorrhage. To avoid this injury incise the iliopubic ligament as near as possible to the lacunar (Gimbernat's) ligament. 3. If it arises with deep epigastric artery, the relation of obturator artery to femoral ring varies in proportion to the height of its origin—(a) if it arises below (Poupart's) inguinal ligament, its course is lateral to the hernia; (b) if it arises above inguinal ligament, it pursues an arched course and is medial to the femoral ring. In a number of latter subjects, the obturator artery is lateral to the femoral ring.

The ramus pubicus superior arises occasionally at the inner edge of the femoral ring. This vessel is at times of large calibre and is easily injured in operative procedures in this anatomical region.

The aorta bifurcates most frequently at the level of the fourth lumbar vertebra.

The common iliac artery is usually from 4 to 6 cm. in length and divides most commonly between the fifth lumbar vertebra and the superior margin of the sacrum. The hypogastric artery varies in length from 2 to 5 cm. and its point of division varies from the superior margin of the sacrum to the upper border of the sacrosciatic foramen (foramen ischiadici majus).

The uterine artery usually arises from the anterior trunk of the hypogastric artery as its second branch. It enters the base of the broad ligament opposite the spine of the ischium, and in its course to the uterus passes ventrad to the ureter. This point of crossing occurs at the level of the ostium uteri interni. The right and left ureters are from 6 to 7.5 cm. distant from one another at the point of crossing and 4 cm. at the level of the ostium uteri externi.

In one subject the uterine artery arises on both sides of the body in a common trunk with the internal pudendal arteries. In the latter subject the uterine artery courses slightly lateral and dorsal to the ureter and at the point of crossing the uterine artery passes dorsal to the ureter. This unusual relation of the ureter being ventral to the uterine artery at the point of crossing is of the rarest occurrence, and should be borne in mind by the surgeon in ligation of the uterine artery, in order that he may avoid injury to the ureter.

Ellis, Eckhard and Ledwich have recorded cases in which the hypogastric (internal iliac) artery is absent on the left side of the body and its

STUDY OF THE HYPOGASTRIC ARTERY

branches derived from a root of the external iliac artery dipping into the pelvis. This unusual variation is not observed in this study.

This study again illustrates the fact that the observation and classification of any one of the large arterial trunks of the body in a sufficiently extensive series of cadavers allow of a natural grouping into distinct types. The descriptions of the arterial trunks as contained in standard anatomical textbooks conform usually to but one type. The usual and accepted conventional opinion that whenever a vessel occurs which is at variance with a classic textbook description it is an anomaly, needs to be revised. In studying a large number of arteries of any one of the large arterial trunks, certain variations are found to occur with sufficient frequency to justify the establishment of distinct groups. At times variations occur which differ so widely from the normal types of the vessel that they cannot be classified, these alone should be termed anomalous. In the present study, every vessel observed conformed to one of the types. In the previous studies of the femoral and cœliac axis arteries only less than two per cent. of the arteries observed were at variance to the described types.

This interesting phase of anatomical study—the establishment of anatomic types—brings together in a concrete and definite form all the possible variations of the particular artery. A knowledge of the types of the larger arterial trunks will aid the surgeon in avoiding troublesome and dangerous hemorrhage that otherwise could not be averted, and it is incumbent that he move slowly in operative procedures until he has determined the exact anatomy of the part. A constant variation in size, calibre and number of branches (defective arteriogenesis) is undoubtedly an etiological factor in the production of certain pathologic conditions.

My best thanks are due to Professor J. Parsons Schaeffer, Head of the Department of Anatomy, for his permission to make liberal use of all the material in his department and for his constant attention, interest and criticism in this study.

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BENJAMIN LIPSHUTZ

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