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ISSN: 0015-5659

e-ISSN: 1644-3284

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DOI: 10.5603/fm.101167

Article type: Review article

Submitted: 2024-06-14

Accepted: 2024-07-23

Published online: 2024-08-08

The arterial blood supply of the ovaries: a comprehensive review

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[Received: 14 June 2024; Accepted: 23 July 2024; Early publication date: xx August 2024]

ABSTRACT

The ovaries, resembling almonds in shape and size, are vital organs that serve as the female gonads where oocytes, or female gametes, undergo development and where various reproductive hormones are produced. The ovaries receive their arterial blood supply predominately from the ovarian artery but also from the ascending branches of the uterine artery. The arterial anatomy of the ovaries is highly significant in any gynecological surgical procedure, as hemorrhagic complications may be fatal. Therefore, the main objective of the present review is to comprehensively describe the complete anatomy of the arterial blood supply of the ovaries. The arterial blood supply to the ovaries is facilitated by a complex network of arteries, frequently characterized by diverse anastomoses. Notably, the ovarian artery and uterine artery exhibit significant variability, presenting challenges for physicians performing gynecological and endovascular procedures. This study showcased comprehensive and detailed insights into the arterial blood supply of the ovaries, serving as a valuable resource for practitioners navigating the complexities of these procedures. By offering clear and detailed information, the present study aimed to enhance the effectiveness and safety of medical interventions involving the ovaries.

Keywords: ovaries, gynecology, surgery, blood supply, anatomy

INTRODUCTION

The ovaries, resembling almonds in shape and size, are vital organs that serve as the female gonads where oocytes, or female gametes, undergo development and where various reproductive hormones are produced. They are suspended in the mesovarium, a short peritoneal fold or mesentery, which is also a subdivision of the broad ligament of the uterus.

The ovaries receive their arterial blood supply predominately from the ovarian artery (OA) but also from the ascending branches of the uterine artery (UA) (Fig. 1, 2). The arterial anatomy of the ovaries is highly significant in any gynecological surgical procedure, as hemorrhagic complications may be fatal. Therefore, the main objective of this review is to comprehensively describe the complete anatomy of the arterial blood supply of the ovaries.

The anatomy of the ovaries

The ovaries are the primary reproductive organs in females. They are located in the ovarian fossa, in the lateral wall of the pelvis. In the fossa, the mesovarium, a portion of the broad ligament of the uterus, suspends the ovaries. Via the mesovarium, neurovascular structures, such as the OA, ovarian vein, and nerves originating from the ovarian and uterine (pelvic) plexuses enter the ovary at the hilum. This neurovascular bundle, along with lymphatic vessels, infiltrates the ovary while being enclosed in the suspensory ligament, which extends from the ovary to the wall of the pelvis. The ovaries are also connected to the lateral surface of the uterus via another ligament, namely, the ovarian ligament.

Histologically, the ovary consists of three main segments: the surface (1) comprises simple cuboidal epithelium, commonly called germinal epithelium, and a dense connective tissue capsule beneath this layer. Meanwhile, the cortex (2) consists of a connective tissue stroma and numerous ovarian follicles. Each follicle houses an oocyte enveloped by a single layer of follicular cells. In contrast, the medulla (3) is constituted by loose connective tissue and a well-developed neurovascular network entering through the hilum of the ovary.

The ovary has two main functions, namely, to produce oocytes in preparation for fertilization and to produce sex steroid hormones (progesterone and estrogen) via the signaling hormones secreted by the pituitary gland (luteinizing hormone and follicle-stimulating hormone).

The arterial blood supply of the ovaries

The ovaries receive their arterial blood supply mainly from the OA and the ascending branch of the uterine artery. The OAs originate from the abdominal aorta, descending along the posterior abdominal wall. As they reach the pelvic brim, they traverse over the external iliac vessels and enter the suspensory ligaments, approaching the lateral regions of the ovaries and uterine tubes. Simultaneously, the ascending branches of the uterine arteries, deriving from the internal iliac arteries, course along the lateral aspects of the uterus and proceed toward the medial aspects of the ovaries and tubes. The termination of both the ovarian and ascending uterine arteries involves bifurcation into ovarian and tubal branches. This intricate vascular network supplies the ovaries and fallopian tubes from the opposite ends, forming an anastomosis, the utero-ovarian anastomosis, that establishes collateral circulation. However, the general anatomy of the OAs may exhibit considerable variability in its origin, course, and more. Moreover, the overall prevalence and anatomical features of the utero-ovarian anastomosis can also be highly variable [31].

The distribution of the blood supply to the ovaries

The dominant source of arterial blood to the ovaries has been discussed in the past. Lippert and Pabst [24] stated that the ovaries are supplied predominantly by the OAs in 40% of the population, by the uterine artery in 4%, and by both vessels in 56%. The general pattern of the blood supply to the ovaries was also demonstrated by Mocquot and Rouvillois [29], with a classification system consisting of four subtypes. In Type I, there is an equal supply to the ovary as the ovarian and uterine arteries anastomose, distributing their branches evenly. Type II involves both arteries supplying the ovarian gland and establishing an anastomosis with each other. In Type III, the primary arterial supply comes from the UA, with a minor anastomosis with the OA. Type IV is characterized by the OA being the primary supplier to the ovarian gland, with a small anastomosis occurring either with the UA or its tubal branch. Types I and II were described as the most frequent types [3].

The anatomy of the ovarian artery

As mentioned earlier, the OAs arise from the aorta, inferior to the renal arteries, and descend laterally to the pelvis. At the pelvic brim, they cross the external iliac artery and veins and reach the ovaries through the ovarian suspensory ligament [47]. However, numerous other origins have been demonstrated in the literature. The OA may also originate from the renal, accessory renal, segmental renal, middle suprarenal, lumbar, iliolumbar, internal iliac, common iliac, and external iliac arteries [2, 19, 22, 23, 26, 28, 43, 44, 47]. The prevalence of variations of the origin is quite variable, ranging from 0% to even 22.6% of the cases [7, 11, 27, 32]. However, the most common variation is the OA originating from the renal artery, one of its branches, or the accessory renal artery [38]. This variability in the origin of the OA has been said to stem from the persistence of the lateral mesonephric arteries during embryological development [10].

As stated earlier, the aberrant origins of the OAs have been presented in the literature. An abnormally superior origin of the vessel was described by Rahmad et al. [39], where the left OA originated from the abdominal aorta superior to the level of the renal vessels. In the case report, the left OA gave rise to two branches, the suprarenal and inferior phrenic arteries. Therefore, the OA may not only exhibit variations in its origin, but also in its branching pattern.

Studies have also demonstrated the presence of double gonadal arteries, but unfortunately, without specifying if it was the testicular or OA [38]. On the other hand, a bilateral absence of the OAs was demonstrated in a female Tanzanian cadaver [17]. In that case, the ascending branches of the uterine artery were the main providers of blood to the ovaries.

The course of the OAs has been described extensively in the past. The high degree of tortuosity of the OAs has been hypothesized to stem from the compression and fixation of the OA by the angle formed by the renal vein and adrenal vein along with the angle formed by the renal artery and the aorta, and the caudal end of the OA being fixed by the ovary [8, 15]. The elongation of the vessel between the two fixation points may induce tortuosity, with the slender diameter observed at the outset of the OA supporting this hypothesis. Its relationship to the abdominal venous vessels has been classified into three types in the literature. In Type 1, the left and right OAs arise from the anterolateral aspect of the abdominal aorta, situated inferior to the renal veins, and descend inferiorly - the right OA courses from the anterior side of the inferior vena cava. In Type 2, the right OA originates superiorly to the renal vein on the anterolateral aspect of the abdominal aorta, moving downward behind the inferior vena cava and in front of the right renal vein. Simultaneously, the left OA arises above the left renal vein, descending inferiorly and anteriorly to the left renal vein. In Type 3, the right OA emerges from the anterolateral aspect of the abdominal aorta, below the left renal vein, arching over the right renal vein. The left OA, originating below the left renal vein, descends inferiorly, arching over the left renal vein [32, 47]. It has been indicated that Type 1 is the most common variant, and Type 3 is the least common [32, 45]. Another reported variant describes ovarian arteries emerging below the renal veins, coursing posteriorly to the inferior vena cava, with the left OA originating above the renal vein and following a course along the posterolateral aspect of the left kidney [39, 45]. Nevertheless, the anatomy of the OA is variable across the whole spectrum of its characteristics, namely its origin, branching pattern, and course.

The utero-ovarian anastomosis

A dense collateral network provides the arterial blood supply of the female reproductive system, consisting of various arterial anastomoses. These anastomoses are divided into two main types, mainly ipsilateral and contralateral. One of the most clinically significant arterial anastomoses of the female reproductive system is the ipsilateral anastomoses between the ascending branch of the uterine artery and the OA [21]. The general characteristics of the utero-ovarian anastomosis have been discussed extensively throughout the last century [47]. In 1925, Dubreuil-Chambardel [9] documented five types of the utero-ovarian anastomosis: Type I consisted of a dominant OA supplying the uterine tube and extending to the body of the uterus, forming an anastomosis with the ipsilateral UA. Type II features anastomoses located between the ovary and uterus, unrelated to either organ. Type III involves anastomoses at the distal pole of the ovary, while Type IV has anastomoses at the midpoint of the ovary. In Type V, anastomoses occur at the tubular pole of the ovary, with a dominant OA supplying both the uterine tube and the ovary.

Later, Mocquot and Rouvillois [29] presented the classification system of the blood supply of the ovary mentioned earlier. This demonstrates that the anatomy of this arterial anastomosis has been a topic of interest for decades.

The prevalence of the utero-ovarian anastomosis varies considerably across the literature, ranging from 30.0% to even 58.0% [1, 13, 41]. A recent meta-analysis resolved the discrepancies regarding this matter [33], demonstrating a pooled prevalence of 48.57%. This data demonstrates that this arterial anastomosis may be found in half of the general population, making it incredibly relevant in surgical and endovascular procedures of the female reproductive system.

Clinical significance

Uterine artery embolization (UAE) is a minimally invasive procedure that gained recognition progressively following a 1995 study by Ravina et al. and subsequent studies spanning multiple centers and investigators [18]. The main indication for the procedure is uterine fibroids, which is the most common benign gynecological neoplasm in women of childbearing age [42]. When symptomatic, patients may present with menorrhagia that may result in anemia, bulk symptoms with bladder and bowel dysfunction and abdominal protrusion, dysmenorrhea, and infertility [20]. Since its introduction, UAE has been proven to reduce the size of fibroids and relieve symptoms. These days, approximately 25,000 UAE procedures are now carried out annually, allowing patients to avoid invasive procedures and retain a high degree of safety and efficacy [34]. However, the arterial anatomy of the uterus and ovaries should be considered since the size of the OA and the type of anastomosis existing between the OA and UA may lead to failure in treatment. Previously, it has been widely accepted that uterine fibroids mainly receive their blood from the UA [37]. Now, it is known that the utero-ovarian anastomosis, especially depending on the type of anastomosis, may continue to supply fibroids following UAE, potentially resulting in treatment failure [37]. Nonetheless, hysterectomy has been and is the most common treatment of uterine fibroids [18]. However, a systemic review comparing UAE to hysterectomy concluded that UAE offers less blood loss, beneficial effects of refractory postpartum hemorrhage, shortened operating time and length of stay [25].

Ovarian artery embolization (OAE) is another procedure used to treat uterine fibroids, although it is not yet a formally accepted treatment option [4]. As mentioned before, UAE has an increased risk of surgical failure compared to traditional methods due to a portion of cases of uterine fibroids being supplied by the anastomosing OA. OAE allows patients to continue treatment without invasive surgery. OAE has been employed in cases where the fibroids appeared to receive most of their supply from the OAs, visible on imaging or during the procedure [35]. Although research regarding OAE has shown safe and effective results, there are still possible negative side effects. Amenorrhea and ovarian dysfunction may occur, and long-term effects on ovarian function remain unknown [4]. OAE has also been utilized in ovarian-remnant syndrome, which refers to persistent pelvic pain caused by the post-oophorectomy remains of ovarian tissue [15]. Studies have shown a 44.0% reduction in the incidence of ovarian-remnant syndrome among patients who underwent OAE, showcasing a considerable reduction in pain [5]. While spontaneous rupture of an OA aneurysm is rare, it can result in life-threatening retroperitoneal hemorrhage [6, 36, 40, 46, 48]. The majority of instances of spontaneous rupture of an OA aneurysm are associated with pregnancy and typically occur during the peripartum or postpartum periods [12, 14, 16, 30]. Historically, the ruptured aneurysms were diagnosed and treated laparoscopically. However, due to the advances in imaging modalities and interventional radiology, ruptured OAs are often treated endovascularly with OAE [46].

CONCLUSIONS

In conclusion, the arterial blood supply to the ovaries is facilitated by a complex network of arteries, frequently characterized by diverse anastomoses. Notably, the OA and UA exhibit significant variability, presenting challenges for physicians performing gynecological and endovascular procedures. This study showcased comprehensive and detailed insights into the arterial blood supply of the ovaries, serving as a valuable resource for practitioners navigating the complexities of these procedures. By offering clear and detailed information, the present study aimed to enhance the effectiveness and safety of medical interventions involving the ovaries.

ARTICLE INFORMATION AND DECLARATIONS

Data availability statement

The data that support the findings of this study are available from the corresponding author, upon reasonable request.

Author contributions

Monika Konarska-Włosińska — literature, writing, figure. Ameen Nasser — literature, writing. Patryk Ostrowski — literature, writing, figure. Michał Bonczar — writing, figure. Kajetan Ochwat — literature, writing. Jerzy Walocha — writing. Mateusz Koziej — writing.

Funding

The authors received no financial support for the research, authorship, and/or publication of this article.

Conflict of interest

The authors declare that they have no conflict of interest.

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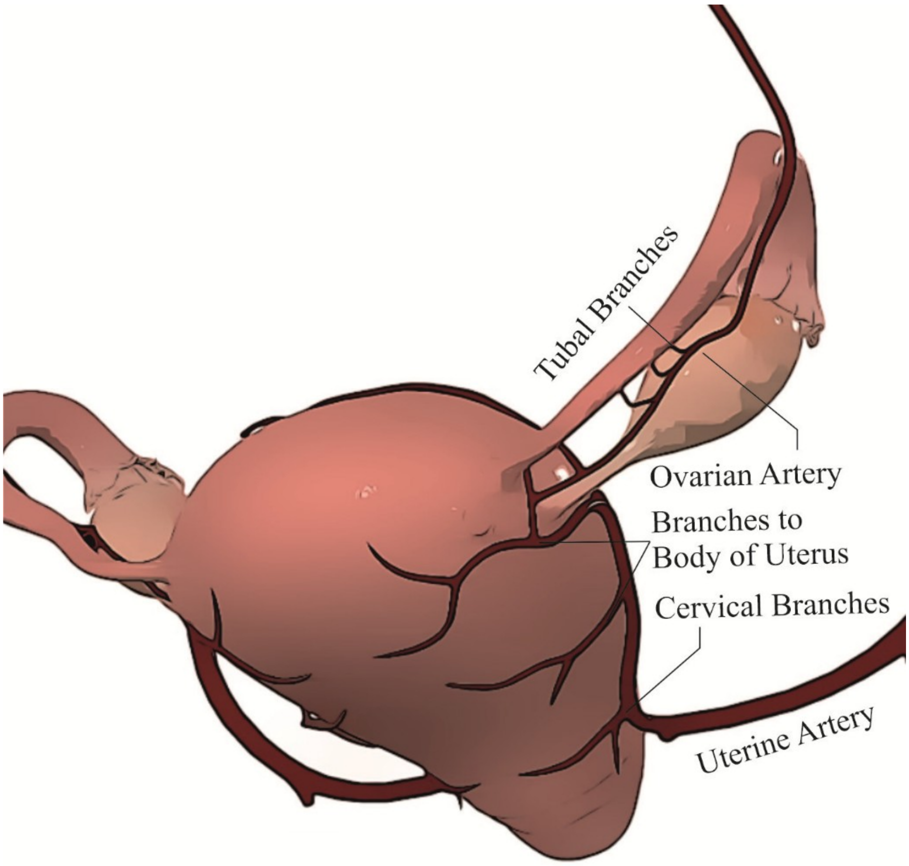

Figure 1. An illustration of simplified arterial anatomy of the uterus and ovaries. The figure is based on the figures provided by the Complete Anatomy program (3D4 Medical, 2021. Complete Anatomy. Retrieved from https:// 3d4me dical. com/).

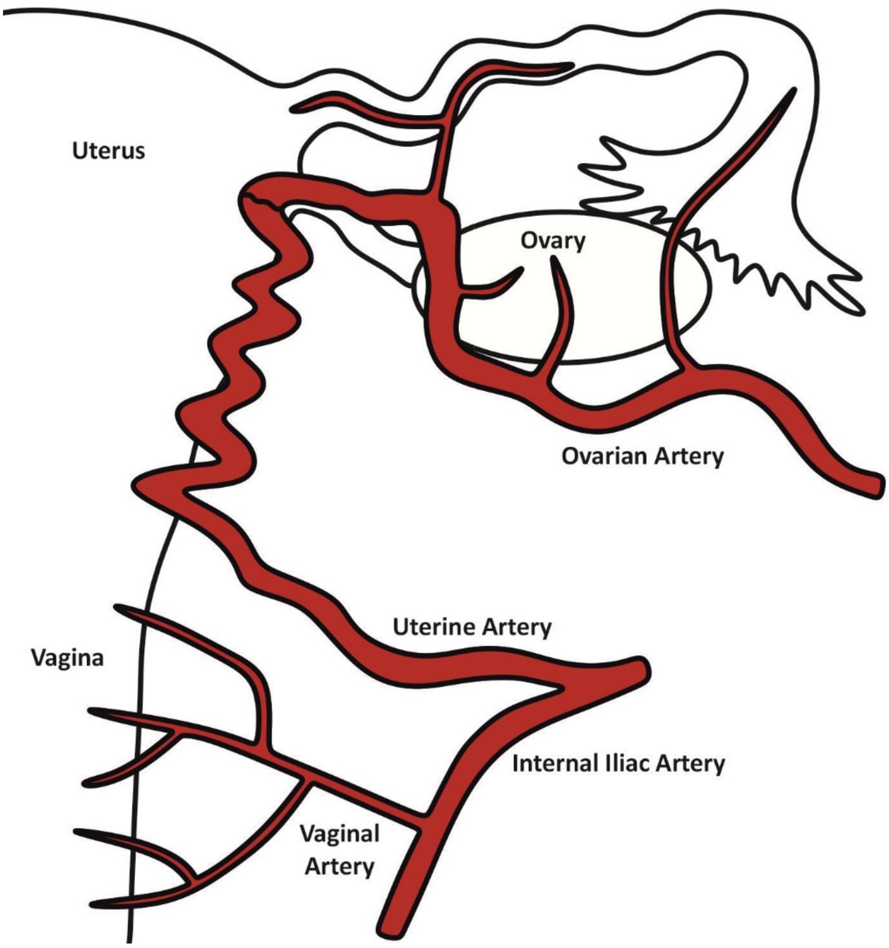

Figure 2. A scheme presenting the arterial blood supply of the uterus and ovaries.