Arterial Blood Supply of the Mesosalpinx Appears Segmentally Organized in Absence of Uterine Tubes Arteries

Yana TAMASH[1], Niels HAMMER[2-4], Ivan VARGA[5], Alexey SUPILNIKOV[1], Sergei IUKHIMETC[1]

[1]Department of Morphology and Pathology, Medical University "Reaviz", Samara, Russia, [2]Division of Macroscopic and Clinical Anatomy, Gottfried Schatz Research Center, Medical University of Graz, Graz, Austria, [3]Department of Orthopedic and Trauma Surgery, University of Leipzig, Leipzig, Germany, [4]Fraunhofer Institute for Machine Tools and Forming Technology (IWU), Medical Branch, Chemnitz, Germany, [5]Institute of Histology and Embryology, Faculty of Medicine, Comenius University in Bratislava, Bratislava, Slovak Republic

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Summary

Arterial branches to the uterus and ovaries that pass through the mesosalpinx contribute significantly to the maintenance of the ovarian reserve. Especially arterial supply of the uterine tube is provided by a number of anastomoses between both the uterine and ovarian vessels. Knowledge on the morphologic peculiarities will allow to identify main contributors especially blood flow ultrasound examination for the purpose of ovary preserving surgery. This study aimed at identifying landmarks especially for so-called low-flow tubal vessels. Arteries of 17 female Thiel-embalmed bodies were studied along three preselected paramedian segments and measurements taken. A section was made through the center of the ovary perpendicular to uterine tube, then the mesosalpinx tissue distance was divided into 3 equivalent zones: upper, middle and lower thirds. The surface area of the mesosalpinx averaged 1088 ± 62 mm². 47.7 ± 7.1 % of the mesosalpinx zones included macroscopically visible vessels. The lower third segment of mesosalpinx was the thickest averaging 2.4 ± 1.5 mm. One to three tubal branches were identified in the middle third of the mesosalpinx. Arterial anastomoses were found in the upper segment of the mesosalpinx, but no presence of a marginal vessel supplying the fallopian tube could be found. Statistically significant moderate positive correlations were established between the diameters of the mesosalpingeal arteries between the three zones. The mesosalpinx, uterine tube and the ovary form areas of segmental blood supply. Variants of tubal vessels appear to be a sparse source of blood supply.

Keywords

Uterine tube • Mesosalpinx • Ovarian reserve • Salpingectomy • Salpinx • Vascularization

Corresponding author

Niels Hammer, Division of Macroscopic and Clinical Anatomy, Gottfried Schatz Research Center, Medical University of Graz, Auenbruggerplatz 25, 8036 Graz, Austria. Email: niels.hammer@medunigraz.at, nlshammer@googlemail.com

Introduction

The mesosalpinx forms an anatomical structure presenting a duplication of the peritoneum and contains numerous vessels and adipose tissue [1-2]. The surgical approach to the uterine tube for its dissection, both complete or for partial removal, can be performed through it. A number of practical recommendations are known for approaching and performing operations on the uterine appendages. While performing salpingectomy, some amount of tissue with vessels near the ovarian gates should be left so as not to cause its blood supply disturbance in the surgical follow up [3-4]. A decrease in blood flow in the ovarian tissues is associated with a diminished ovarian reserve.

Preservation of the uterine artery has been of particular importance for patients planning pregnancy using reproductive technologies. For this to happen, it is important to preserve the integrity of the ovarian ligament,

Fax +420 241 062 164, e-mail: physres@fgu.cas.cz, www.biomed.cas.cz/physiolres

in which medial branches of the uterine artery run at salpingotomy or partial salpingectomy [5].

In clinical practice, the opposite situations may occur when making attempt to preserve of the ovaries or uterine tubes, and the arteries remain invisible. The high risks associated with the occurrence of peritoneal carcinomatosis in tubal malignancy are believed to be the reason. Ovarian cancer has been described to primarily originates from the uterine tubes, then being spread via a hemato-lymphatic route to the ovary. In this case, bilateral salpingectomy is indicated as it helps reduce the risk of ovarian cancer by 65 % [6-7].

Thus, a detailed description of mesosalpinx vascular anatomy is required to understand in detail a number of clinical questions related to uterine tube and ovarian surgery, especially advances in microsurgery and reproductive technologies. The data available in scientific literature is limited to the description of the main branches of the uterine and ovarian arteries located in the peritoneal duplication between these organs [8-11].

The aim of this given study was to investigate the anatomy of the mesosalpinx arteries involved in the blood supply of the uterine tubes and ovaries in human post mortem tissues. It was hypothesized that the arteries found in the mesosalpinx provide segmental blood supply to the uterine tubes and ovaries and potentially has side difference, our second hypothesis was the absence of tubal artery variation within the mesosalpinx.

Material and Methods

The study cohort comprised 38 female bodies aged 75 to 98 years, embalmed according to the Thiel protocol [12-14]. While alive, all donors had given their informed consent to the donation of their post-mortem tissues for teaching and research purposes. Ethical approval for the study was obtained the Ethics Committee at the Medical University of "Reaviz" (approval no. 24). The pelvic organs of all bodies were scanned for the presence of uteri using a Siemens Somatom Emotion 6 computed tomography (Siemens AG, Erlangen, Germany).

In total, 21 bodies were included. The excluded bodies failed presenting a uterus and/or uterine appendages or presented volumetrically solid and fluid masses with the size more than 20 mm surrounding the tissues. In case of hip prostheses or other metal implants, the tissues were also excluded as visibility was limited. Another four cases had to be excluded following dissection, as they presented pathological alterations with severely impact on the integrity of the internal genitals. Seventeen of the specimens matched the above-mentioned criteria data were further used for morphological study. The specimens presented uteri with bilateral appendages (n=14), or uteri with unilateral appendages (n=3).

All included specimens were primarily studied with the blunt eye. The uterine tubes were measured with a Vernier caliper (measuring range 150 mm, accuracy 0.02 mm). Uterine tube length and diameter were retrieved. The ovaries were measured similarly. Width, length and thickness were taken before the ovarian volume was calculated, applying a formula for a prolate ellipsoid using the longest longitudinal (d1), anteroposterior (d2), and transversal diameters (d3):

$$\text{volume} = d1 \times d2 \times d3 \times \pi/6 \text{ [15]}.$$

Transillumination was used with a light source placed anteriorly or posteriorly against the broad ligament to visualize the uterine and ovarian vessels and their branches, thus permitting to clearly visualize the vessels. The tissues were then photographed (ILCE-6500, objective E PZ 18-105mm f/4.0, both Sony Corp., Nihombashi, Tokyo, Japan) [16] for further study of the features of the vascular channel conditionally separated by horizontal planes in segments corresponding to upper, middle and lower thirds of mesosalpinx (Fig. 1).

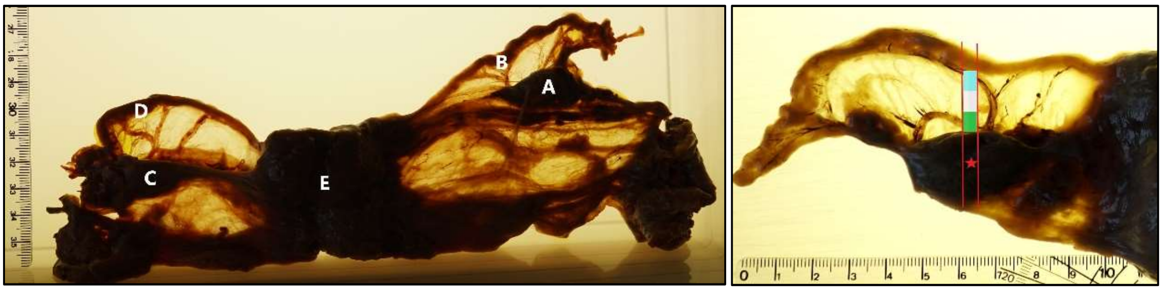

Fig. 1. Posterior view of a uterus with appendages in the coronary position. The left image shows: **A** - the right ovary, **B** - the right uterine tube and mesosalpinx, **C** - the left ovary, **D** - the left uterine tube and mesosalpinx, **E** - the uterus; the right image shows: the red asterix is the conditional midpoint of measuring the width of the ovary, as a guideline for the paramedial section (two red lines), with the division of the part of the mesosalpinx into 3 zones - the upper third is colored blue, the middle - white, the lower - green.

The total area of mesosalpinx and proportion (%) of the area occupied by arteries were calculated using ImageJ (National Institutes of Health, Bethesda, Massachusetts, USA) using the 'contour' feature. Zones of area were calculated manually from images in a horizontal arrangement and subsequently confirmed using a semi-automatic mode. Next, surgical dissection of the vessels of mesosalpinx was performed. For this purpose, a paramedian incision through the center of the ovary was made (slice thickness 5 mm), before stepwise microdissection of all its arteries between the anterior and posterior leaves of the mesosalpinx was performed under a binocular stereomicroscope (Eschenbach Lupe 2.5, Nürnberg, Germany).

After dissection had been completed, the external diameter of the arteries was measured in three given segments using the caliper. The segments were defined by drawing two parallel, perpendicular lines through a paramedian section. A 5-mm paramedian slice of the tissue was positioned close to the ruler so that a section of the medial surface was visible, then the mesosalpinx distance from the lower edge of the fallopian tube to the beginning of the mesovarium was measured. The resulting parameter was divided into 3 equivalent distances: upper, middle and lower thirds, within which the remaining parameters were studied. The external diameter of the arteries was measured if it could be identified being 0.1 mm or more. In ImageJ, distances were measured in pixels using the quantitative segmented line feature and the scale setting in millimeters [17].

The data was processed and statistically analyzed using Microsoft Excel (version 16.16.25, Redmont, Washington, USA), GraphPad Prism (version 7.0a, La Jolla, California, USA). Normality distribution was tested using the Kolmogorov-Smirnov test. The groups were then compared using One-Way ANOVA with post-hoc correction, assuming non-normally distributed data. A significance level of 95 % ($p \leq 0.05$) was chosen to decide on the presence of differences. The Spearman's rank correlation coefficient was calculated for the diameters of the mesosalpinx arteries depending on the segment.

Results

Uterine tube and ovary morphometry appears not to be side dependent

Comparison of the values obtained revealed no statistically significant differences between the right and left sides. The resulting measurements obtained from the uterine tubes, ovaries and surrounding tissues are shown in Table 1.

Table 1. Uterine tube and ovary morphometries

Indicator	Mean value ± standard deviation
Uterine tube	
Length [mm]	100.7 ± 21.7
External diameter [mm]	3.2 ± 1.3
Ovary	
Length [mm]	22.5 ± 6.9
Width [mm]	10.2 ± 2.5
Thickness [mm]	7.2 ± 2.9
Volume [mm^3]	820 ± 61

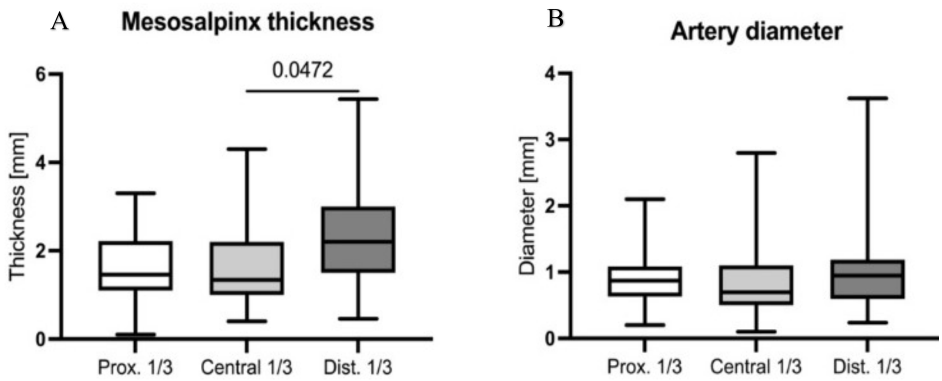

Fig. 2. Box representing mesovarium thickness (**A**) and arterial diameter (**B**) at three predefined segments of the mesosalpinx. The boxes indicate the 25th, 50th and 75th percentile; whiskers the minima and maxima. Significant difference was observed when comparing the central to the distal third thickness of the mesovarium. Dist. = distal, Prox. = proximal

Mesosalpinx artery thickness and diameter appear to be interconnected between the different segments

The area of the mesosalpinx averaged 108.8 ± 6.2 mm^2. 47.7±7.1 % of the area were occupied by vessels. The area of highest vascularity was localized inthe lower third of the mesosalpinx. The average thickness of the mesosalpinx in the upper third averaged 1.7 ± 0.8 mm [95 % CI 1.3 - 2.1] and 1.7 ± 1.0 mm [95 % CI 1.2 - 2.2] in the middle third, respectively (Fig. 2A). The greatest thickness of the mesosalpinx was found in its lower segment, averaging 2.4 ± 1.5 mm [95 % CI 1.7 - 3.1], therefore being significantly higher than in the upper and middle third ($p=0.02$; Fig. 2).

Moderate positive correlations were found for the arterial diameters of the mesosalpinx in the upper and middle third ($r=0.398$, $p=0.029$), the upper and lower third ($r=0.423$, $p=0.022$), and the middle and lower third ($r=0.655$, $p<0.001$), respectively.

Blood supply to the ampullary part and fimbriae is mainly provided by the ovarian artery

Detailed study on the arterial variation inside the mesosalpinx revealed the absence of an axial blood supply vessel of the uterine tube. The intermediate segment of the mesosalpinx comprised medial, middle and lateral tubal branches. The lower segment of the mesosalpinx contained the ovarian artery, from which the tubal branches originated, supplying blood mainly to the ampullary and the fimbrial parts of the uterine tube.

Twelve of the here investigated cases showed the medial tubal branches with single rami facing towards the uterine tube at an obtuse angle facing lateral. These branches originated from the medial or median part of the ovarian portal. Three specimens showed two branches of medial tubal branches; two specimens showed medial tubal branches with three rami. The middle tubal branches originated from the central part of the ovarian collar, branching off perpendicularly from the arterial trunk. In the majority of cases (n=11), the middle tubal branches formed two further branches. Five cases had one branch; one case had three branches (with the medial branch forming an anastomosis with the "medial tubal branches").

The ‘lateral tubal branches’ of eleven dissections were represented by one branch originating from the lateral part of the ovarian portal. This branch formed plentiful small anastomosing vessels involved in the blood supply to the fimbriae of the uterine tube through numerous anastomoses. In most of the cases, one branch from the ovarian artery passed along the lower free mesosalpingeal margin to the fimbrial section. Five further preparations showed that the lateral tubal branches consisted of two branches, with the second branch located medially, forming an anastomosis with the middle tubal branches at an acute angle. In one case, three branches of the lateral tubal branches were revealed.

The upper segment of the mesosalpinx consisted of anastomoses formed by the arch of the terminal branch of the uterine artery on one side and the terminal branch of the ovarian artery on the other side. In the area of the mesenteric attachment of the uterine tube, the course of the anastomoses was parallel to the uterine tube, which upon visual inspection created a false impression of a single artery, a ‘marginal vessel’, from which the uterine tube was supplied with blood almost throughout its entire length. Blood supply of the uterine tube walls in all sections was carried out by perforating arteries originating from the ‘marginal vessel’ and located perpendicularly to it. The diameter of the arteries of the mesosalpinx averaged 0.9 ± 0.4 mm in the upper, 1.0 ± 0.6 mm in the middle and 1.0 ± 0.3 mm in the lower part, respectively. Pairwise comparison of the obtained values of arterial diameter in different segments did not reveal any significant difference (Fig. 2B).

Discussion

The value in understanding the blood supply of the uterine tubes has risen and is associated with the recent developments of angiography, reproductive technology, and transplantation. The blood supply to the uterine tubes is known to be provided by the branches of the uterine and ovarian arteries. The venous drainage follows a similar pattern as the arteries with related capillary networks under the serous membrane, in the muscular layer and in the mucosa [18]. These anatomical data form a basis for the known technologies of surgical intervention to the uterine appendages. Mesosalpinx and mesovarium arteries, veins, capillaries, as well as lymphatic vessels form a so-called perivascular complex. Its components not only interact morphologically, but also functionally, creating an environment for physiological processes, in particular during retrograde transmission of ovarian hormones [19]. These morphologic and functional findings underline the necessity for the detailed study of the vascular anatomy of this anatomical region.

For this given study, anatomical specimens of the reproductive system of geriatric females were included as the study cohort. This choice was determined by previously obtained research data, which demonstrated that the anatomy of arteries and arterioles did not undergo significant changes during puberty, menstrual cycle or in menopause [20]. Primarily, general morphometric data was obtained, characterizing the uterine tubes and ovaries. During the measurements of the organs, we did not get data beyond the reference values [22]. The comparative analyses of measurement results did not allow us to establish significant differences between the right and left appendages.

The data obtained on the area of the mesosalpinx and the proportion occupied by the arteries showed that it forms a critical zone, where the arteries supplying the uterine tube and ovary of the corresponding side were located. Thus, areas with significant existence of arteries account for less than half of the total area of the mesosalpinx. On one hand, this fact may play a positive role while performing surgical interventions to reduce the risks of blood loss. On the other hand, it should be considered as a risk factor of unsatisfactory results and decreased ovarian reserve in organ-preserving surgeries. The functional link between blood supply and ovarian reserve seems to be new in light of contemporary research [23].

Measurements on mesosalpinx thickness in the selected segments showed that it reaches its greatest thickness in the lower third. It can therefore be hypothesized that due to the presence of the ovarian artery, this region seems best supplied. However, further comparative analyses on the diameter of the lower segment arteries of to the other segments yielded no significant difference. The greatest thickness of the lower third of the mesosalpinx was due to the greater density of arterial vessels in this zone.

This given study revealed some peculiarities of the vascular morphology of the arteries in the central part of the mesosalpinx. At the same time, some terminological difficulties in their designation should be noted. As such, the concept of middle, medius and lateral tubal branches has been mentioned only in one study devoted to the anatomy of the reproductive system [24]. A variability in the number of each tubal branch from one to three was noted. Although the average diameter of all tubal branches was greater than the average diameters of the arteries in the lower and upper segments, the thickness of the mesosalpinx in this segment remained the smallest.

The upper segment of the mesosalpinx was supplied by anastomoses exclusively. This finding may add to the intriguing impression of a single artery presence the ‘marginal vessel’, from which the uterine tube is supplied with blood almost throughout its entire length. This contradicts previous data on the presence of tubal rami of the uterine artery, which courses parallel in the mesentery of the uterine tube [24, 25]. Thus, the mesosalpinx, the uterine tube and the ovary form a zone with the segmental type of blood supply and variants of tubal rami of the uterine artery is a sparsely source of its vasculature.

Theses given results are coherent with the data of previous studies devoted to the peculiarities of blood supply to the mesosalpinx and uterine tubes and confirm that the latter are not characterized by an ‘axial type’ of blood supply. This supply is carried out by small arterial branches, forming a utero-ovarian arterial circle. Due to this, the walls of uterine tubes are known to be the areas with ‘deteriorated conditions’ of blood supply [26], which should be taken into account when evaluating the long-term results of organ-preserving operations on the fallopian tubes and ovary, as well as to improve surgical techniques.

In a clinical setting, the study of ovarian, uterine tube and uterine blood flow is performed using color Doppler mapping ultrasound. Despite the high diagnostic value that comes with this method, it only allows to evaluate the functional parameters of blood flow, namely its direction, velocity and type. Detailed knowledge on mesosalpinx morphology and its associated blood supply may bring the potential to optimize deep learning training algorithms for the detection ‘healthy’ pelvic organs [27,28] regarding its blood supply.

Limitations

A number of limitations need to be addressed. Thiel-embalmed specimens were used, which are known to be unsuitable for histological study [14]. Further to this, the relatively small study cohort comprised geriatric cadavers with an unknown medical history only. Due to the reflections on the photo of paramedian sections, preference was given manual measurements which was accurate but time-consuming.

Conflict of Interest

There is no conflict of interest.

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