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Cadaveric study on the incidence and morphological variations of the uterus: Embryological correlations and clinical implications

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Abstract:
Uterine (Müllerian duct) anomalies are clinically important congenital variations resulting from abnormal development of the paramesonephric ducts and may remain under recognised. This cross-sectional cadaveric study evaluated 15 adult female cadavers from a North Indian population over 18 months, with uterine morphology assessed during routine dissection and anomalies classified according to the ASRM Müllerian duct anomaly classification. Three specimens (20.0%) exhibited Müllerian duct anomalies, including two arcuate uteri (13.3%) and one complete bicornuate uterus (6.7%), while the remaining specimens showed normal uterine morphology. Recognition of such anatomical variations is important for accurate diagnosis and management of infertility, pregnancy related complications and other gynecological conditions. Thus, data shows the presence of clinically relevant Müllerian duct variations in the studied cadaveric population.

Keywords: Uterus, Müllerian duct anomalies, bicornuate uterus, arcuate uterus, cadaveric study, embryology, paramesonephric duct and clinical anatomy

Background:
The uterine tubes, also known as fallopian tubes or salpinges, are paired muscular structures measuring approximately 10 cm in length that extend from the uterine horns toward the ovaries and are situated within the superior margin of the broad ligament in a specialized fold called the mesosalpinx **[1]**. Each uterine tube is anatomically divided into four segments: the infundibulum, ampulla, isthmus and intramural part **[2]**. The infundibulum is the funnel-shaped lateral portion that opens into the peritoneal cavity and bears delicate finger-like fimbriae that facilitate capture of the ovum following ovulation **[3]**. Ciliary activity of the tubal epithelium, together with muscular contractions, contributes to the transport of the ovum and early embryo toward the uterine cavity **[4]**. The ampulla is the widest portion of the uterine tube and is the most common site of fertilization, while the narrower isthmus continues medially into the intramural segment that traverses the uterine wall and opens into the uterine cavity **[5].** The uterine tube provides an essential pathway for the transport of spermatozoa, oocytes and early embryos, while its epithelial secretions contribute to the nutritional and physiological environment required for gamete function and early embryonic development **[6]**. The tubal microenvironment may additionally influence early embryogenesis through molecular and epigenetic mechanisms **[7]**. Therefore, it is of interest to evaluate the anatomical variations and congenital anomalies associated with these vital, though often underappreciated, organs.

Materials and Methods:
The present cross-sectional study was undertaken on 15 adult female cadavers belonging to the North Indian population. All specimens were sourced from the Department of Anatomy, United institute of medical science, Prayagraj. The research spanned duration of one and a half years, commencing in January 2024 and concluding in August 2025.

Study procedure:
The cadaveric specimens underwent a process of anonymization, their identities obscured through random coding and detachment from any traceable sources (ICMR National Ethical Guidelines for Biomedical and Health Research Involving Human Participants, ICMR, 2017, Section 5, Box 5.2). During cadaveric dissections conducted for undergraduate anatomy teaching, careful observations were made on the position and peritoneal relations of the uterus. Special attention was given to its shape and to any anomalies. Anomalies were categorised using the American Society for Reproductive Medicine (ASRM) classification, which identifies seven categories of Müllerian duct anomalies (MDAs). Morphological variations were observed twice to minimize errors and the results were averaged. The acquired data were tabulated for analysis. Graphs and tables were prepared using Microsoft Excel and Microsoft Word 2013.

Results:
Of the 15 cadaveric specimens examined, 12 (80.0%) showed normal uterine morphology, while Müllerian duct anomalies were identified in 3 specimens (20.0%). The most frequent anomaly was the arcuate uterus, observed in 2 specimens (13.3%) and followed by a single complete bicornuate uterus (6.7%). No cases of hypoplasia/agenesis, unicornuate, didelphys, septate, or DES-related anomalies were encountered **(Table 1).**

Table 1: Distribution of Müllerian duct anomalies (MDAs) among the 15 cadaveric specimens examined

S.N.	Müllerian duct anomalies (MDAs)	Subtype	Number	Percentage
1	Hypoplasia / Agenesis		–	–
2	Unicornuate		–	–

3	Didelphys		–	–
4	Bicornuate	Complete	1	6.70%
		Partial	–	–
5	Septate		–	–
6	Arcuate		2	13.30%
7	DES drug related		–	–

Discussion:

Women having uterine anomalies have poorer reproductive outcomes and lower pregnancy rates as compared to those having a normal uterus. With advanced radiological tools like MRI and 2D ultrasonography, an increased rate of accurate diagnosis is possible **[8]**. Although more than 50% of women with a malformed uterus remain asymptomatic, they can present with obstetric complications such as infertility, early abortions, ectopic pregnancies, late abortions, premature birth and intrauterine growth restriction (IUGR) **[9].** Persistence of the uterine septum or obliteration of the lumen of the uterine canal constitutes the main abnormality of the uterus and vagina **[10]**. Müllerian duct disorders are of multifactorial inheritance. Developmental failure of the Müllerian duct is associated with a developmental defect of ureteric bud formation; thus, unilateral agenesis of the kidney is a common presentation on the ipsilateral side of non-development of the Müllerian duct **[11]**. Müllerian duct anomalies can be confused with fibroids or other masses and 3D ultrasonography can help in making the diagnosis. MRI is the most useful investigation to distinguish structural malformations **[12]**. Uterus bicornis is a developmental defect in which the uterus has two horns entering a common vagina. It is a relatively common anomaly among the uterine defects and is normally seen in many mammals below primates **[13]**.

Conclusion:

Müllerian duct anomalies were identified in 20% of the specimens examined, with the arcuate uterus being the most common variant and a single complete bicornuate uterus also observed. These findings reflect failure of normal fusion and canalization of the paramesonephric ducts during development. Awareness of such morphological variations and their embryological basis is important for accurate radiological interpretation and for the appropriate management of associated infertility and obstetric complications.

Limitations:

This study is based on a small cadaveric sample (n = 15) drawn from a single centre and a single regional (North Indian) population, which limits the precision of the estimated anomaly frequencies and their generalizability to other populations. As a cadaveric study, the findings could not be correlated with the reproductive, radiological or clinical history of the individuals. Anomalies were identified by gross morphological observation during routine dissection without confirmatory cross-sectional imaging (MRI or 3D ultrasonography) or histological examination. Larger, multi-centre cadaveric series with imaging and histological correlation would strengthen and refine these observations.

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