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ORIGINAL ARTICLE

A reappraisal of the deep uterine vein: a multimodal exploration with implications for pelvic surgery

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Abstract

Purpose Pelvic gynecological surgeries, whether for malignant or benign conditions, frequently result in functional complications due to injuries to the autonomic nervous system. Recognizing the deep uterine vein (DUV) as an essential anatomical reference can aid in preserving these structures. Despite its significance, the DUV is infrequently studied and lacks comprehensive documentation in Terminologia Anatomica. This research endeavors to elucidate a detailed characterization of the DUV.

Methods We undertook a systematic literature review aligning with the "PRISMA" guidelines, sourcing from PUBMED and EMBASE. Our comprehensive anatomical examination encompassed cadaveric dissections and radio-anatomical evaluations utilizing the Anatomage® Table.

Results The literary exploration revealed a consensus on the DUV's description based on both anatomical and surgical observations. It arises from the merger of cervical, vesical, and vaginal veins, coursing through the paracervix in a descending and rearward direction before culminating in the internal iliac vein. The hands-on anatomical study further delineated the DUV's associations throughout its course, highlighting its role in bifurcating the uterus's lateral aspect into two distinct zones: a superior vascular zone housing the uterine artery and ureter and an inferior nervous segment below the DUV representing the autonomic nerve pathway.

Conclusion A profound understanding of the subperitoneal space anatomy is paramount for pelvic surgeons to mitigate postoperative complications. The DUV's intricate neurovascular interplays underscore its significance as an indispensable surgical guide for safeguarding nerves and the ureter.

Keywords Deep uterine vein · Nerve sparing · Pelvic surgery

Introduction

Pelvic surgeries, whether for benign or malignant conditions, necessitate precise visualization of anatomical landmarks. This precision is essential not only to mitigate postoperative complications but also to safeguard pelvic-perineal functions such as urinary, digestive, and sexual capacities [16, 24, 30]. Particularly in cases of cervical cancer—the second most prevalent cancer among women [29]—radical hysterectomy remains the benchmark treatment to eradicate stage IA2–IIA tumors effectively [17]. Similarly, deep pelvic endometriosis, afflicting over one in ten women [32], often demands intricate surgical interventions for thorough disease removal, especially when there is extraperitoneal disease progression [2]. Accessing such deep pelvic regions, especially the parametrium and paracervix, undeniably places pelvic nerves

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and the ureter in jeopardy [27]. This is evident from the wide-ranging 5% to 76% postoperative urinary dysfunction rates following radical hysterectomy or endometriosis surgeries, particularly for the more complex operations [3, 15, 33].

Emerging nerve-sparing techniques strive to curtail such postoperative ramifications. They prioritize the preservation of three primary nerves: (1) the hypogastric nerve, (2) the pelvic splanchnic nerves, and (3) the efferences of the inferior hypogastric plexus (IHP) [27]. Within this surgical context, the deep uterine vein (DUV) emerges as an invaluable anatomical touchstone. Its prominence in preventing pelvic nerve and ureter injury during deep pelvic access surgeries has been well-documented by experts such as Fujii and Yabuki [12, 31]. Consequently, pinpointing the DUV is paramount to conserving pelvic nerves, thereby maintaining postoperative pelvic floor functionality [13, 27]. In our preceding research, we underscored the DUV's functional significance, especially within uterine transplantation contexts [28].

Yet, a paradox exists. Despite the DUV's undeniable surgical significance and its recurring mention in scholarly articles, a detailed anatomical portrayal remains absent. Disturbingly, many classical texts neglect to feature it, and a lucid anatomical outline is missing even in the Terminologia Anatomica [11]. In light of this, our study aimed to furnish a meticulous anatomical delineation of the DUV, drawing from a systematic review, traditional dissection, and a 3D anatomical subject reconstruction.

Methods

Systematic review of the literature and meta-analysis

We conducted this systematic review in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-analysis guidelines (PRISMA) [21].

Two investigators (FR and MZ) performed a literature search on Medline (PubMed) and on Embase (Biomedical Database, Elsevier).

We selected articles in English and French published between January 2000 and March 2022.

The following keywords were used: "deep uterine vein" OR "nerve sparing" OR "anatomy" "endometriosis" OR "surgery."

We included all articles describing the DUV, the surgical anatomy of the pelvic nerves, or preservation of these nerves.

We excluded articles relating only to the male sex, clinical studies of nonfunctional complications such as adjacent organ damage, and conference-related papers. Articles were selected by title and abstract.

Anatomical study

Study design

The anatomical data were obtained from two types of sources: i. 18 hemi-pelvis from nine female anatomical subjects dissected at the Rennes School of Surgery (Anatomy Laboratory of Rennes University) and ii. digital reconstruction with the Anatomage® Table of four hemi-pelvis from two additional female subjects.

The Scientific Committee of Rennes University ensured that written consent for body donation had been obtained and filed prior to death for all the anatomical subjects.

Our work complied with French regulations, which waver Ethics Committee approval for epidemiological surveys. The study was also exempt from French law pertaining to biomedical research (the Huriet–Serusclat law, December 20, 1998) as no additional interventions were required.

Terminology

The revised *Terminologia Anatomica* was used to avoid confusion in describing the anatomical terms of the pelvic connective tissues [7]. When a term was missing in the *Terminologia Anatomica*, we used unofficial, but frequently cited, terms [8].

Dissection of fresh female anatomical subjects

Procedure None of the subjects had a history of abdominopelvic surgery. A cruciate abdominal incision was performed with the subject in a supine position on the autopsy table. The sigmoid colon and the upper rectum were sectioned, and the entire digestive tract was reclined upward for better exposure of the pelvis. Dissection was performed following the first steps of radical hysterectomy with nerve sparing. The paravesical and pararectal spaces were developed. The medial pararectal space, also called the Okabayashi space, was opened backward and laterally to the uterosacral ligament [25]. The hypogastric nerve (HN) was identified within this space. The ureter was isolated to expose the beginning of the ureteral tunnel and followed until its path crossed the uterine artery. The crossing of the uterine artery and ureter marks the parametrium. We then identified the uterine vein below the uterine artery [28] within the paracervix. The dissection was resumed from the hypogastric nerve to gradually reach the IHP. The pelvic splanchnic nerve originating from sacral roots was also isolated.

Digital reconstruction with the Anatomage Table

The Anatomage Table (Anatomage, Inc., San Jose, CA) is a virtual dissection table created through the imaging of real human anatomical subjects. Reconstructions combine data from the Visible Korean Project and the Visible Human Project. In both projects, cadavers underwent MRI and CT scanning. The cadavers were then cut into sections ranging from 0.2 to 1 mm using a cryomicrotome, and the slices were photographed with a digital camera. By combining computerized data, the table produces a real cadaver bed and demonstrates real patient data on a real-size scale [1, 18, 22]. These data are used for research with the agreement of the company Anatomage Inc. We provide a digital reconstruction of the pelvic area from a deceased subject to illustrate our data highlighting the uterine veins and artery, the ureter, and the IHP.

Results

Systematic review of the literature and meta-analysis

In our extensive database search adhering to PRISMA criteria, 838 studies were initially earmarked. Subsequently, a refined selection narrowed down 18 of these for inclusion, as depicted in Fig. 1. Nine of these studies utilized anatomical subjects, while two adopted a histological approach toward microanatomy. The remaining seven studies drew upon data harvested during surgical procedures.

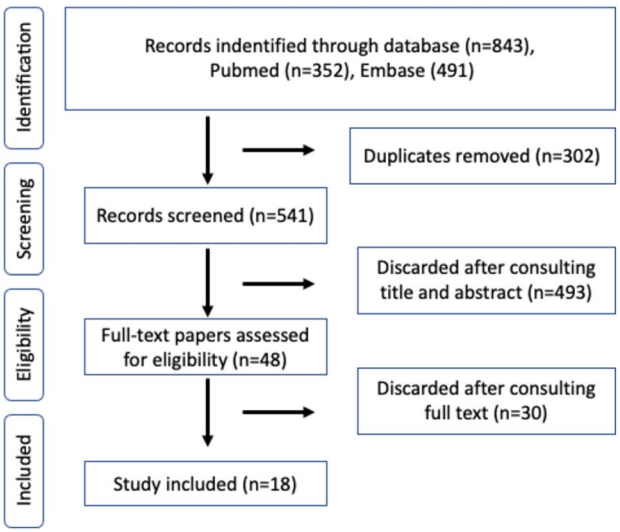

Fig. 1 PRISMA flowchart

An amalgamation of all pertinent data on the anatomy of the DUV, extracted after a meticulous review of the primary articles, is encapsulated in Table 1.

Interestingly, many studies bore overlapping outcomes. They primarily described the DUV as stemming from the convergence of the inferior vesical veins, vaginal veins, and the cervix–uterine venous plexus. The predominant view placed the DUV in the paracervix, traversing beneath the ureter in a slant, inferiorly positioned relative to the uterine artery. Its culmination into the primary trunk of the iliac vein was frequently noted. The consistent observation was its placement—posterior and below the pelvic ureter. Yet, while the nerve structures' relative position—posterior and inferior to the DUV—was consistent, the specific nervous structures varied across studies, being identified as either the IHP, hypogastric nerve, or the splanchnic nerves.

Anatomical exposition of the deep uterine vein

Our anatomical investigation drew insights from nine freshly dissected anatomical subjects and two anatomical subject digital reconstructions courtesy of the Anatomage Table.

The DUV emerges from the confluence of the para-uterine venous plexuses and the cervicovaginal veins, as visualized in Fig. 2. Adopting a posterior, lateral, and caudal trajectory, it courses through the paracervix, situated superiorly to the vaginal artery and inferiorly to the uterine artery, as depicted in Fig. 3. In around one-third of our sampled subjects, it is accompanied by a slender superficial uterine vein that meanders above the ureter, later merging with it laterally. In all subjects, it converges with the internal iliac vein along the pelvis's lateral wall.

Based on our observations, we discerned two distinct sections around the paracervix. The first, termed the "pars vasculosa," comprises the DUV, along with vaginal and uterine arteries, beneath which the ureter threads. The subsequent section, the "pars nervosa," situated beneath the DUV, initiates with the splanchnic nerves, as showcased in Fig. 4, and is succeeded posteriorly by the IHP and its corresponding efferences, detailed in Fig. 5.

Discussion

The current study delves into the nuanced and clinically significant anatomy of the dorsal uterine vein (DUV) employing a comprehensive multimodal approach. The DUV is formed by the convergence of the inferior vesical veins, vaginal veins, and the intricate cervix–uterine venous plexus. Breaking it down further, the lateral facet of the uterus demarcated by the DUV showcases two integrated segments. The uppermost segment, termed the pars vasculosa, is dominated by vascular structures housing the uterine artery and

Table 1 Results of the systematic review and meta-analysis of articles that met the PRISMA criteria

Author	Date	Type of study	N	Research context	Origin	Path	Ending	Relationship	Clinical implication
Yabuki et al. [34]	1991	Surgical	51	Cancer	NA	Parametrial connective tissue (cardinal ligament at the level of ischial spine)	Internal iliac vein	1. Uterine artery above. 2. Pelvic splanchnic nerves below 3. Middle rectal artery below	Lymphadenectomy
Yabuki et al. [35]	1996	Surgical	15	Cancer	Uterine, vaginal, and vesical venous plexus and anastomoses with the middle rectal vein	Rectovaginal ligament	Internal iliac vein	1. Uterine artery above. 2. Middle rectal pedicle below 3. Inferior hypogastric nerve plexus	Radical hysterectomy
Yabuki et al. [36]	2000	Surgical		Cancer	Superior vesical veins, uterine, vaginal, and venous plexus	Deep layer of the vesicouterine ligament	Internal iliac vein	1. Uterine artery above 2. Ureter forward 3. Pelvic plexus nerves below	Radical hysterectomy
Ercoli et al. [37]	2003	Cadaveric	11	Cancer	Upper third of the vagina	Paracervix	Internal iliac vein	Pelvis plexus below	Nerve sparing
Sakuragi et al. [38]	2005	Surgical	27	Cancer	Vesicovaginal veins	Paracervix	Internal iliac vein	Pelvis plexus below	Nerve sparing
Fuji et al. [27]	2007	Surgical	24	Cancer	Vesicouterine ligament: *Posterior leaf*: middle vesical vein, inferior vesical vein. *Anterior leaf*: cervicovesical veins (plexus)	Parametrial connective tissue, below uterine artery, adipose tissues, and lymph nodes	Internal iliac vein	Ureter forward	Radical hysterectomy
Katahira et al. [39]	2008	Histological	6	Cancer	Vesical veins, cervical veins	Posterior leaf of the vesicouterine ligament	Internal iliac vein: The terminal portion of the deep uterine vein was clearly covered by the parietal fascia	Pelvic splanchnic nerves below, ureter forward	Nerve sparing

Table 1 (continued)

Author	Date	Type of study	N	Research context	Origin	Path	Ending	Relationship	Clinical implication
Ercoli et al. [40]	2010	Cadaveric	18	Cancer	Vesicovaginal veins	Paracervix	Internal iliac vein	1. Uterine artery above, 2. Inferior hypogastric plexus and their efferent branches. 3. Infraureteral paracervical lymphatic pathway, above the DUV and below the ureter 4. Neural pathway comprised between the DUV and the pelvic floor	Lymphadenectomy
Li et al.[41]	2014	Cadaveric and histological	15	Cancer	Vesical veins (middle, and inferior vesical vein), and cervical branche rossing below the ureter and finally joining the DUV	Vesicocervical ligament	Internal iliac vein, 70% des cas main stem; 23% anterior stem, 6.4 posterior	HN anteroinferiorly to below the DUV and PSN, ureter forward and the uterine artery in forward of the ureter	Nerve sparing
Fermaut et al. [42]	2016	Cadaveric	5	Endometriosis	Uterine fundus, below the plane of the uterine artery and above the NH	Mediolateral, and anteroposterior, to the internal iliac vein	Internal iliac vein	IHP efferences, laterally	Nerve sparing
Zhang et al. [43]	2017	Surgical	49	Cancer	NA	NA	NA	Inferior hypogastric plexus inferiorly, ureter forward	Nerve sparing
Jiang et al. [44]	2019	Surgical	93	Cancer	Vesicovaginal veins	Posterior leaf of the vesicocervical ligament	Internal iliac vein	Inferior hypogastric plexus inferiorly	Nerve sparing
Scattarelli et al. [45]	2020	Cadaveric	1	Endometriosis	NA	Paracervix	NA	Pelvic splanchnic nerves below	Nerve sparing
Ray et al. [26]	2020	Surgical	105	Cancer	Cervix–uterine venous plexus	Runs below the ureter obliquely inferior to the uterine artery	Internal iliac vein	Hypogastric and pelvic splanchnic nerve below	Nerve sparing
Horie et al. [46]	2021	Surgical	1	Cancer	Vesical veins, cervical veins			Ureter and HN below	Nerve sparing
Robin et al. [15]	2022	Cadaveric	8	Transplant	Uterine plexus	Paracervix	Internal iliac vein	Inferior hypogastric plexus inferiorly, ureter forward	Transplantation

Table 1 (continued)

Author	Date	Type of study	N	Research context	Origin	Path	Ending	Relationship	Clinical implication
Shu et al. [47]	2022	Cadaveric and histological	14	Cancer	Vesical plexus, uterine plexus	NA	NA	Cross relationship of HN, PSN, and their confluence of IHP with deep uterine vein and its branches	Nerve sparing
Yabuki Y. [13]	2023	Cadaveric	26	Cancer	Superior vesical veins, uterine, vaginal, and venous plexus	Transverse cardinal ligament	Internal iliac vein	1. Forward ureter 2. Inferior vesical vessels posteriorly	Radical hysterectomy

NA: not available, *DUV*: deep uterine vein, *HN*: hypogastric nerve, *PSN*: pelvic splanchnic nerve, *IHP*: inferior hypogastric plexus

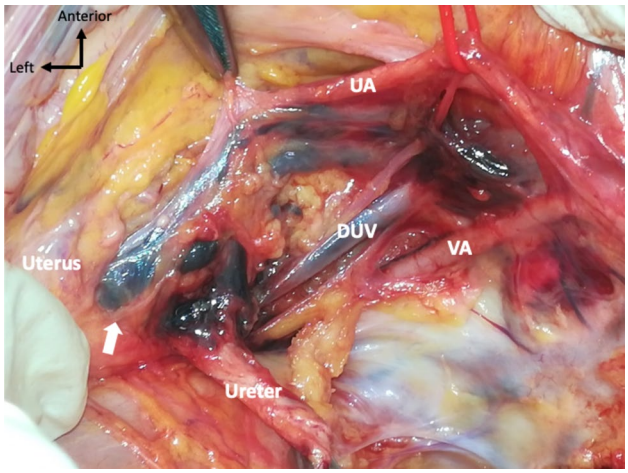

Fig. 2 Origin of the deep uterine vein. View of a dissection of the right hemi-pelvis of a fresh female cadaver. *UA*: uterine artery, *DUV*: deep uterine vein, *VA*: vaginal artery, white arrow: uterine plexus

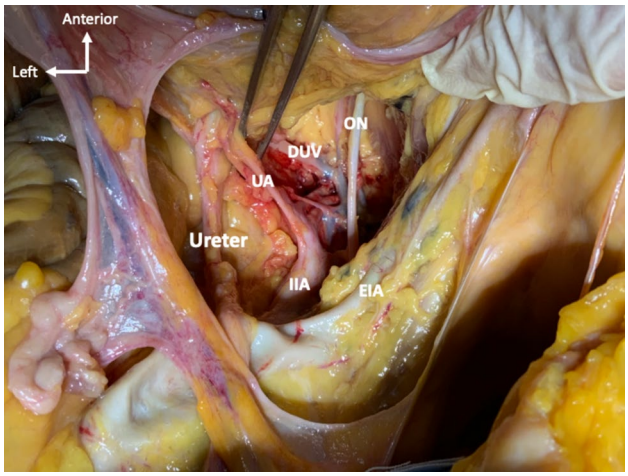

Fig. 3 DUV route and relationships. View of a dissection of the right hemi-pelvis of a fresh female cadaver. *UA*: uterine artery, *IIA*: internal iliac artery, *EIA*: external iliac artery

the ureter. In contrast, the segment beneath the DUV, named the pars nervosa, is replete with neural components.

Historically, the DUV holds significance as an essential reference for pelvic surgeries. Yet, its anatomy, often alluded to in surgical texts, remains bereft of standardization. Yabuki's seminal research on the history of anatomical understanding in this domain suggests that the prevalent misconceptions might owe their roots to the 15th edition of Gray's Anatomy (1901) [31]. This specific edition portrayed the uterine and vaginal vessels branching from the internal iliac vessels, distributing independently to the uterus and vagina. This portrayal, still echoing in today's medical world, underscores the imperative to reevaluate and

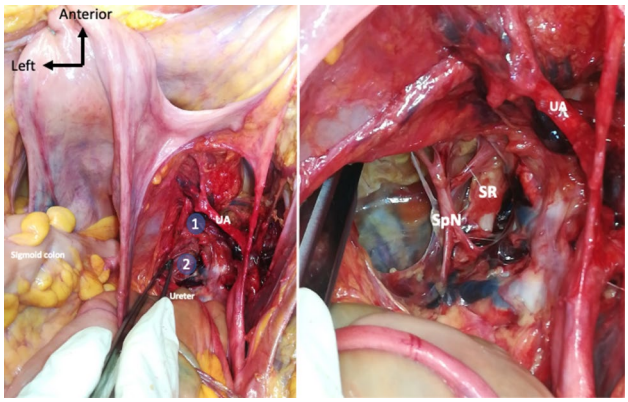

Fig. 4 Inferior relationships of the DUV. Views of a dissection of the right hemi-pelvis of a fresh female cadaver where the DUV has been resected. *UA:* uterine artery, *SpN*: splanchnic nerves, *SR*: sacral roots, 1: pars vasculosa, 2: pars nervosa

challenge long-standing anatomical notions through contemporary research tools and techniques. Significantly, in the uterine transplantation, the DUV has been underscored as pivotal for the ureter's identification [28]. Our current endeavor's uniqueness stems from its varied investigative sources, including literature reviews, meticulous anatomical dissections, and innovative 3D reconstructions. This confluence of methodologies offers a robust consensus view, amalgamating both surgical insights and anatomical perspectives, aiming to enhance the Terminologia Anatomica.

While anatomically deciphering uterine arteries is streamlined via sectional imaging techniques such as MRI and CT, the venous structures pose a more intricate challenge. Their diminutive size, coupled with their inherent variability, places them within a complex anastomotic matrix in the subperitoneal domain. Unraveling their precise course and interrelations within a meshwork of arterial, neural, adipose,

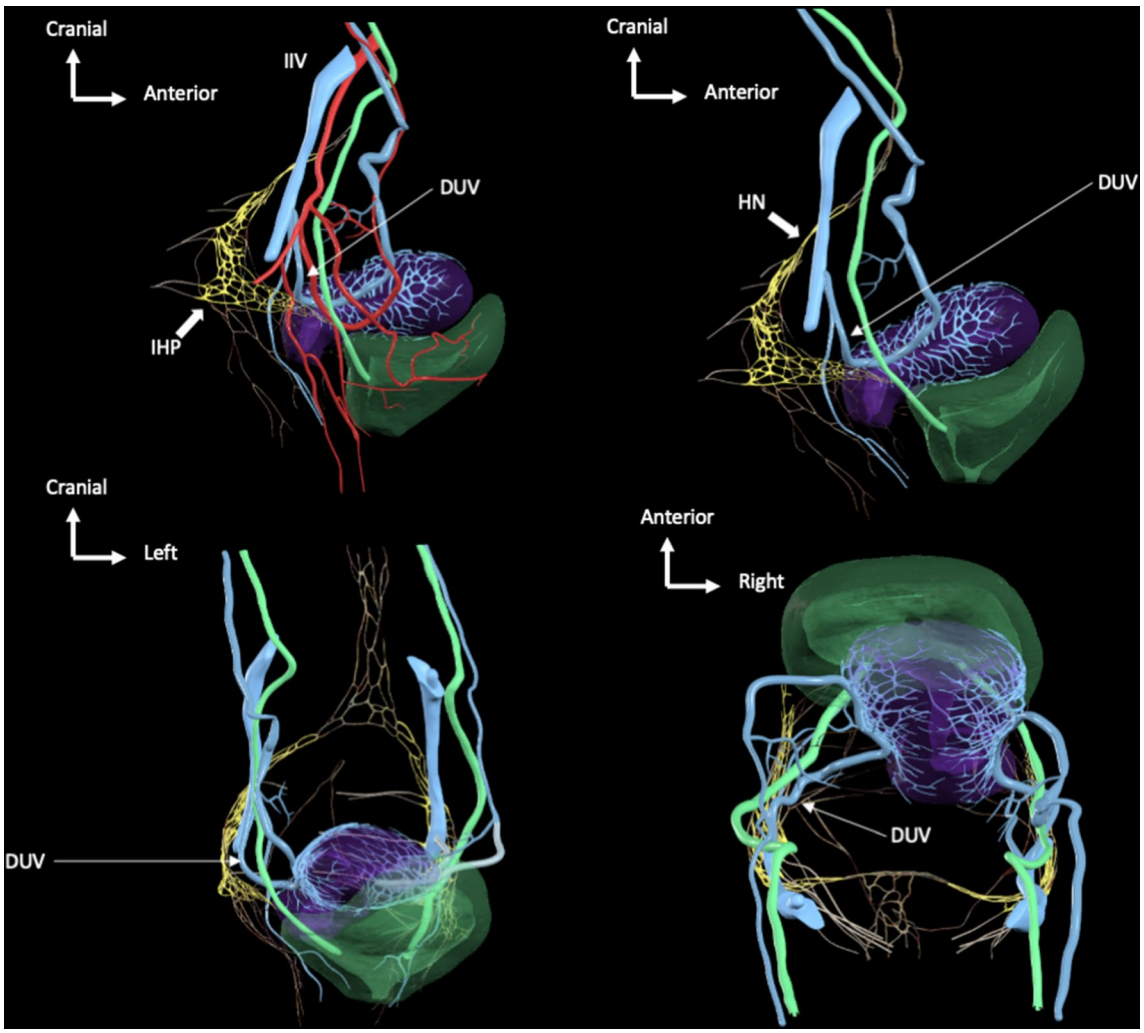

Fig. 5 Relationship of the DUV with the inferior hypogastric plexus. Digital reconstruction with the Anatomage Table of a female right hemi-pelvis. White arrow: DUV

and lymphatic components demands rigorous pelvic surgical or anatomical observations.

Among the various studies, the point of contention invariably remains the DUV's origin. Authors have variably attributed its genesis to vaginal, vesical, or cervical veins [9, 10, 26]. These inconsistencies might stem from the innate variability of the pelvic venous system or the challenges associated with the comprehensive depiction of the venous framework. However, a common thread across all research is the consensus that the DUV invariably culminates in the internal iliac vein. Its trajectory is well-defined, navigating beneath the broad ligament's lower segment and traversing the vesicocervical ligament's posterior leaf. Within the vascular segment, the DUV forms an intimate association with the uterine and vaginal arteries situated above it, while the ureter weaves its way between these arterial and venous structures. This vascular territory resonates with the "Red Alert Zone" as delineated by Ray and colleagues in their surgical annotations, highlighting its importance in averting hemorrhagic complications [26].

Our delineation lays special emphasis on the neural domain beneath the DUV, housing the autonomic nerve pathways, specifically the splanchnic nerves and the IHP. This section is vital for nerve-preserving strategies in pelvic surgeries. These nerves have a characteristic medial-to-lateral growth below the DUV. Fuji and team have meticulously mapped the DUV, marking it as a boundary beyond which nerves critical for preserving urinary, digestive, and genital functions reside [12, 14].

The implications of our findings are profound. They offer insights for pelvic surgeries, particularly for the escalating surgical interventions in endometriosis. Here, the precision excision of deep endometriotic nodules, akin to oncological surgeries, necessitates intricate dissections within the subperitoneal deep recesses, where vasculature and neural pathways intertwine. Nerve-preserving strategies are paramount in this context, ensuring pelvic pain is not supplanted by newfound ailments linked to sexual, urinary, or digestive dysfunctions [6], culminating in deteriorating life quality. On the oncological front, advancements in both medical and surgical spheres have bolstered patient outcomes, with an increased focus on survivors' quality of life [27]. Mastery over the DUV's anatomy will enable refined surgical interventions, optimizing tumor resection while safeguarding the neighboring nerve networks.

Zooming out to the broader perspective of transplantation, our prior research earmarked this vessel as the uterus's primary drainage conduit [28]. Its preservation during organ extraction is a linchpin for the success of uterine transplantation [5]. A holistic grasp of its anatomy is paramount to safeguard the graft's viability and maintain the integrity of nearby neural structures during the procurement phase, especially in live donors.

For radical pelvic surgeries, a profound understanding of the deep pelvic structures and recognizing vulnerable anatomical zones is nonnegotiable [10]. Deep space studies have perennially posed challenges, primarily because the subperitoneal space is restricted. Traditional cadaveric dissections can inadvertently create artificial spaces, leading to varying interpretations across researchers. The quest for a standardized approach is palpable [20]. The advent of pioneering digital educational innovations, epitomized by the Anatomage Table, offers a solution. This digital dissection platform facilitates the exploration of genuine human anatomy, devoid of any distortions often encountered with cadaveric specimens. Anatomage emerges as a dual boon—an avant-garde educational medium and a credible data reservoir for morphological research [19]. The amalgamation of histological sections with digital reconstructions [23] also presents an opportune method to probe the neural and vascular architectures, which form the crux of our study. Additionally, the ascendancy of surgical robots equipped with magnified 3D visuals now capacitates the precise identification and dissection of the DUV and the autonomic nervous pathway as delineated [4]. This study on the deep uterine vein encounters limitations due to the absence of specific terms in the current Terminologia Anatomica, leading to challenges in describing certain anatomical aspects. To address this, we propose submitting our identified terms, e.g., "deep uterine vein" and "superficial uterine vein," for inclusion in the next revision of the Terminologia Anatomica, expected at the 2024 IFAA congress. This step is essential for improving the precision and uniformity of anatomical nomenclature in future research.

In summation, our study, driven by a diverse methodological arsenal, furnishes the maiden detailed and standardized portrayal of the DUV. This knowledge is indispensable for pelvic surgeons across the board and is poised to significantly elevate the outcomes in surgeries related to endometriosis, oncology, and uterine transplantation.

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Author contributions FR and KNT involved in protocol/project development. FR, LD, MZA, LR, and JL involved in data collection or management. FR, KNT, and VL analyzed the data. FR, KNT, VL, XM, and LS wrote and edited the manuscript.

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

Declarations

Conflict of interest Authors are required to disclose financial or non-financial interests that are directly or indirectly related to the work submitted for publication.

Ethical approval The study complied with all French regulations on cadaver studies that authorize epidemiological surveys. Furthermore, it was exempt from the French law pertaining to biomedical research (Huriet-Serusclat law, December 20, 1998, Jardé law, November 16, 2016) as no additional interventions were required. The local scientific committee of surgery ensured that written consent for body donation had been obtained and filed prior to death for each of the anatomic subjects.

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