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The complete anatomy of the prostatic artery: a meta-analysis based on 7421 arteries with implications for embolization and urological procedures

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Background: The goal of the present meta-analysis was to offer physicians the most evidence-based data concerning the anatomical characteristics of the prostatic artery (PA).

Materials and methods: Medical databases including PubMed, Scopus, Embase, Web of Science, Google Scholar and Cochrane Library were searched trough. The overall search process was performed in 3 stages.

Results: The results were established based on a total of 7421 arteries. PA was found to originate from an internal pudendal artery with a pooled prevalence of 28.81% (95% CI: 26.23–31.46%). Mean diameter of the PA was found to be 1.52 mm (SE = 0.07). Single PA was found to occur in 76.43% of the patients (95% CI: 60.96–89.12%).

Conclusions: In conclusion, the authors of the present study believe that this is the most accurate and up-to-date analysis regarding the highly variable anatomy of the PA. The PA originates most commonly from the internal pudendal artery (28.81%); however, it may also originate from other pelvic arteries, including the middle anorectal or the superior gluteal arteries. Moreover, accessory PAs may occur, yet, a single main PA supplying the prostate gland is most frequently observed (76.43%). The PA may also form anastomoses with the adjacent arteries (pooled prevalence of 45.20%), which may create a complex vascular network in the pelvis. It is hoped that the current meta-analysis may help to decrease the potential complications that may emerge from diverse endovascular and urological procedures. (Folia Morphol 2024; 83, 3: 630–638)

Keywords: prostatic artery, pelvis, prostate, surgery, embolization, anatomy

INTRODUCTION

The prostate gland is an important organ of the male reproductive system, located in the pelvis inferior to the bladder and anterior to the rectum. The gland is mainly supplied by the prostatic artery (PA), a branch of the internal iliac artery (Fig. 1, 2). The

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Figure 1. Prostatic artery (PA) and its close anatomical area. AT — anterior trunk; IIA — internal iliac artery; IPA — internal pudendal artery; PG — prostate gland; SV — seminal vesicle; UB — urine bladder; VD — vas deferens.

Figure 2. Prostatic artery (PA) and its close anatomical area. SV — seminal vesicle; UB — urine bladder. *the prostatic artery reaches to the superolateral side of the prostate gland.

PA is responsible for supplying blood to the prostate gland and the surrounding structures, including the urethra, bladder, seminal vesicles, and rectum. The anatomy of the PA has been the subject of extensive research due to its clinical significance and complex vascular anatomy.

Various studies have analysed the variable origin of the PA and other arteries of the pelvis [18, 23, 31–33, 39]. Moya et al. [29] presented the anterior division of the internal iliac artery, the gluteal-pudendal trunk, and the internal pudendal artery to be the main sources of PA. However, Boeken et al. [8] stated that the most frequent origin of PA was from a common trunk formed with the vesical artery from the anterior division of the internal iliac artery. The morphometric properties of the said vessel, such as the diameter, are especially important clinically, mainly when performing prostatic artery embolizations (PAE). Various diameters of the PA have been presented in the literature, ranging from 0.9 mm to 1.9 mm [37, 42]. Moreover, the PA forms complex anastomoses with surrounding arteries, supplying various organs in the pelvis. The overall prevalence of these anastomoses is quite controversial, with variable frequencies being presented in the past. Furthermore, the PA may form the said anastomoses with its contralateral vessel and with other arteries, such as the internal pudendal artery or the lateral sacral artery [7].

Understanding the anatomy of the prostatic artery is crucial for the successful management of prostate-related conditions, including prostate cancer, benign prostatic hyperplasia (BPH), and chronic prostatitis. BPH is among the top ten most prevalent and expensive diseases affecting men over 50 years of age in the United States [14]. While traditional treatment options for lower urinary tract symptoms caused by BPH exist, recent years have seen the emergence of PAE as a promising alternative therapy for certain patients [25, 29]. However, PAE can be challenging due to the anatomical variability of the PA, which can prolong the procedure time, with identification and catheterization of the PA often being the most difficult and time-consuming steps [3, 4]. Therefore, the goal of the present meta-analysis was to offer physicians the most evidence-based data concerning the anatomical characteristics of the PA. It is hoped that the results of the present study may aid in mitigating the potential risks associated with various urological and endovascular procedures.

MATERIALS AND METHODS

Search strategy

In order to perform this meta-analysis, a systematic search was conducted in which all articles regarding the anatomy of the PA were searched for. Medical databases including PubMed, Scopus, Embase, Web of Science, Google Scholar and Cochrane Library were searched trough. The overall search process was performed in 3 stages. (1) In the first stage, all mentioned medical databases were searched using the following search term: prostatic AND artery. Neither date, language, article type, nor text availability conditions were applied. (2) Furthermore, the mentioned databases were searched through once again using another set of phrases: (a) [prostatic artery (title/abstract)] AND [anatomy (title/abstract)]; (b) [prostatic artery (title/abstract)] AND [variation (title/abstract)]; (c) [prostatic artery (title/abstract)] AND [morphology (title/abstract)]; (d) [prostatic artery (title/abstract)] AND [type (title/abstract)]; (e) [prostatic artery (title/abstract)] AND [topography (title/abstract)]; (f) [prostatic artery (title/abstract)] AND [course (title/abstract)]; (g) [prostatic artery (title/abstract)] AND [origin (title/abstract)]; (h) [prostatic artery (title/ /abstract)] AND [branch (title/abstract)]. Additionally, each phrase has been checked for dependence of results on grammatical variations of a given phrase and adjusted to the given database. (3) Furthermore, an additional, manual search was also conducted throughout all references from the initial submitted studies. The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines were followed. Additionally, The Critical Appraisal Tool for Anatomical Meta-analysis (CATAM) and Anatomical Quality assessment Tool (AQUA) were used to provide the highest quality findings [11].

Eligibility assessment and data extraction

The inclusion criteria were set as follows: original articles with extractable data on the anatomy, morphology, topography and/or variance of the PA. The exclusion criteria involved conference reports, case reports, case series, reviews, letters to the editor and studies with no relevant or incompatible data. The systematic search was performed by two independent researchers. A total of 6789 articles were initially evaluated. Finally, 26 articles matched the required criteria, and were included in this meta-analysis [1–10, 12, 13, 15–17, 26, 29, 34–39, 42, 43]. The overall process of data collection can be found in Figure 3. Characteristics of submitted studies can be found in Table 1.

Data from qualified studies were extracted by two independent researchers. Qualitative data were collected, such as year of publication, country, continent. Subsequently, quantitative data were gathered in several categories: (1) the origin of the PA; (2) the mean diameter of the PA; (3) a total number of multiplied Pas; (4) the origin of the accessory PA; (5) prevalence and characteristics of the PA anastomoses; (6) presence of the corkscrew pattern. Any discrepancies between the identified studies by researchers were resolved by contacting the authors of the original studies wherever possible or by consensus with a third person.

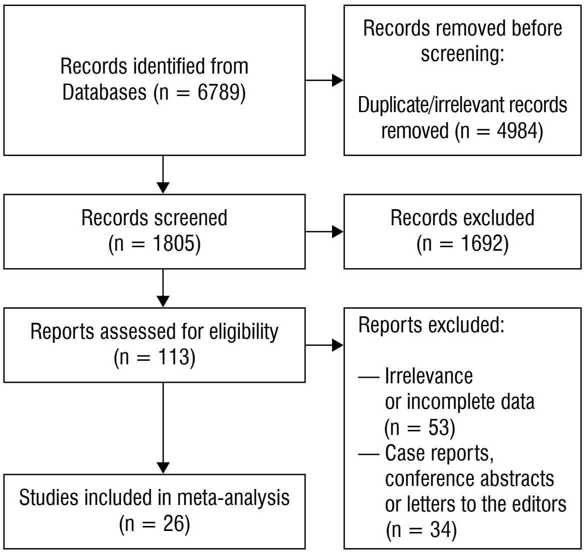

Figure 3. Flow diagram presenting process of collecting data included in this meta-analysis.

Statistical analysis

To perform this meta-analysis, STATISTICA version 13.1 software (StatSoft Inc., Tulsa, OK, USA), MetaXL version 5.3 software (EpiGear International Pty Ltd,Wilston, Queensland, Australia), and Comprehensive Meta-analysis version 4.0 software (Biostat Inc., Englewood, NJ, USA) were applied. A random effects model was used. The Chi-square test and the I-squared statistic were chosen to assess the heterogeneity among the studies [20, 21]. P-values and confidence intervals were used to determine the statistical significance between the studies. A p-value lower than 0.05 was considered statistically significant. In the event of overlapping confidence intervals, the differences were considered statistically insignificant. I-squared statistics were interpreted as follows: values of 0–40% were considered as "might not be important", values of 30–60% were considered as "might

Table 1. Characteristics of the studies submitted to this meta-analysis.

First author	Year of publication	Continent	Country	Method
Fu J. X. [15]	2023	Asia	China	DSA
Barral M. [5]	2021	Europe	France	CB-CT
Boeken T. [8]	2020	Europe	France	MRI
Xu Z-W. [38]	2020	Asia	China	CT + MRI + Angiogram
Eldem F. G. [12]	2020	Asia	Turkey	PAE
Enderlein G. F. [13]	2019	Europe	Germany	CB-CT
Schnapauff D. [34]	2019	Europe	Germany	DSA + CB-CT
Anract J. [2]	2019	Europe	France	Arteriographies
Garcia-Monaco [17]	2019	South America	Argentina	Cadavers
Zhang J. L. [43]	2019	Asia	China	DSA + MRA
Xuan H. N. [39]	2019	Asia	Vietnam	DSA
Amouyal G. [1]	2018	Europe	France	Angiogram
Çelebioğlu E. C. [9]	2018	Asia	Turkey	CTA
Maclean D. [26]	2017	Europe	UK	CT Angiogram
Moya C. [29]	2016	Europe	Spain	Cadavers + DSA
Wang M. Q. [37]	2016	Asia	China	DSA + CB-CT
Zhang G. [42]	2015	Asia	China	CB-CT
De Assis A. M. [3]	2015	South America	Brazil	Angiogram + PAE
Garcia-Monaco [16]	2014	South America	Argentina	Cadavers
Bagla S. [4]	2013	North America	USA	CB-CT
Bilhim T. [7]	2012	Europe	Portugal	CTA + DSA
Bilhim T. [6]	2011	Europe	Portugal	Angio-CT
Nehra A. [30]	2008	North America	USA	Pharmacoangiograms
Secin F. [36]	2007	North America	USA	Laparoscopic prostectomy
Secin F. [35]	2005	North America	USA	Laparoscopic prostectomy
Clegg E. J. [10]	1955	Europe	UK	Cadavers

CB-CT — cone beam computed tomography; CT — computed tomography; DSA — digital subtraction angiography; MRA — magnetic resonance angiography; MRI — magnetic resonance imaging; PAE — prostatic artery embolization.

Table 2. Statistical results of this meta-analysis regarding the origin of the PA.

Origin of the PA	N	Pooled prevalence	LCI	HCI	Q	I^2
Internal pudendal artery	4115	28.81%	26.23%	31.46%	73.42	64.59
Obturator artery	4115	14.35%	11.37%	17.61%	184.97	85.94
Inferior vesical artery	4115	12.28%	5.73%	20.72%	1301.91	98.00
Anterior Division of Internal Iliac Artery	4115	10.76%	6.24%	16.29%	650.76	96.00
Gluteal-pudendal trunk	4115	5.01%	1.54%	10.09%	918.40	97.17
Other	4115	3.34%	1.67%	5.54%	269.48	90.35
Superior vesical artery	4115	2.04%	0.35%	4.83%	564.00	95.39
Middle anorectal artery	4115	0.99%	0.35%	1.92%	135.35	80.79
Inferior gluteal artery	4115	0.75%	0.31%	1.37%	77.60	66.50
Superior gluteal artery	4115	0.20%	0.09%	0.37%	18.58	0.00

HCI – higher confidence interval; LCI — lower confidence interval; Q — Cochran's Q; PA — prostatic artery.

Table 3. Statistical results of this meta-analysis regarding mean maximal diameter of the prostatic artery (PA).

Category	Mean [mm]	Standard error	Variance	Lower limit	Upper limit	Z-value	P-value
Mean diameter of the PA	1.52	0.07	0.01	1.38	1.66	21.52	0.00

Table 4. Statistical results of this meta-analysis regarding the number of PA on patients' one side.

Number of PAs	N	Pooled prevalence	LCI	HCI	Q	I^2
Single PA	3145	76.43%	60.96%	89.12%	1380.45	98.77
Double PA	3145	23.18%	10.60%	38.59%	1378.42	98.77
Triple PA	3145	0.13%	0.03%	0.29%	13.44	0.00

HCI – higher confidence interval; LCI — lower confidence interval; Q — Cochran's Q; PA — prostatic artery.

indicate moderate heterogeneity", values of 50–90% were considered as "may indicate substantial heterogeneity", and values of 75–100% were considered as "may indicate substantial heterogeneity".

RESULTS

A total of 26 studies were qualified for the statistical analysis in the present study. The results were established based on a total of 7421 arteries. PA was found to originate from an internal pudendal artery with a pooled prevalence of 28.81% [95% confidence intervals (CI): 26.23–31.46%]. The aforementioned artery was found to be the most common origin artery of the PA. Obturator artery was found to be an origin of the PA in 14.35% of the cases (95% CI: 11.37–17.61%). PA was found to originate from an inferior vesical artery in 12.25% of the studied cases (95% CI: 5.73–20.72%). All the results mentioned before and more detailed ones can be found in Table 2.

Mean diameter of the PA was found to be 1.52 mm (SE = 0.07). More detailed statistics regarding the PA diameter can be found in Table 3. Single PA was found to occur in 76.43% of the patients (95% CI: 60.96–89.12%), whereas the double and triple PA were found to occur in 23.18% (95% CI: 10.60–38.59%) and 0.13% (95% CI: 0.03–0.29%) of the studied cases respectively. More detailed results regarding the number of PA can be found in Table 4. Obturator artery was found to be the most common origin artery for the accessory (second or third) PA with a pooled prevalence of 43.12% (95% CI: 22.82–64.59%). Accessory PAs were found to originate from internal pudendal artery in 36.26% of the studied cases (95% CI: 23.48–50.08%). More detailed results regarding the origin of the accessory PA can be found in Table 5.

Any anastomosis of the PA was found to occur in 45.20% of the cases (95% CI: 31.39–59.38%). The most common type of a PA anastomosis was found to be the one with an internal pudendal artery as it occurred in 47.26% of the studied cases (95% CI: 9.66–86.46%). PA was found to have an anastomosis

Table 5. Statistical results of this meta-analysis regarding the origin of the accessory (second or third) PA.

Origin of the accessory PA	N	Pooled prevalence	LCI	HCI	Q	I^2
Obturator artery	50	43.12%	22.82%	64.59%	2.27	55.91
Internal pudendal artery	50	36.26%	23.48%	50.08%	0.00	0.00
Internal iliac artery	50	18.79%	0.00%	46.46%	4.86	79.44
Inferior gluteal artery	50	2.96%	0.00%	8.53%	0.74	0.00

HCI – higher confidence interval; LCI — lower confidence interval; Q — Cochran's Q; PA — prostatic artery.

Table 6. Statistical results of this meta-analysis regarding the anastomoses of the PA.

Category	N	Pooled prevalence	LCI	HCI	Q	I^2
Prevalence of any anastomosis of the PA	1300	45.20%	31.39%	59.38%	82.76	95.17
Type of anastomosis						
Anastomosis of PA with internal pudendal artery	375	47.26%	9.66%	86.46%	250.64	97.61
Anastomosis of PA with intra-prostatic or contra-lateral PA	375	13.81%	0.00%	38.23%	152.33	96.06
Anastomosis of PA with vesicular arteries	375	8.99%	0.74%	22.93%	56.03	89.29
Anastomosis of PA with seminal vesicular arteries	375	8.70%	0.00%	28.53%	137.51	95.64
Anastomosis of PA with lateral accessory pudendal arteries	375	3.54%	0.00%	14.15%	81.79	92.66
Anastomosis of PA with lateral sacral artery	375	0.73%	0.00%	2.23%	9.48	36.74
Area vascularized by an anastomosis						
Rectum	217	65.83%	22.73%	100.00%	136.01	96.32
Penile	217	18.47%	0.00%	55.00%	121.66	95.89
Bladder	217	10.57%	0.00%	28.91%	50.58	90.11

HCI – higher confidence interval; LCI — lower confidence interval; Q — Cochran's Q; PA — prostatic artery.

Table 7. Statistical results of this meta-analysis regarding the presence of the corkscrew pattern of the PA.

Category	N	Pooled prevalence	LCI	HCI	Q	I^2
Presence of the corkscrew pattern	904	20.12%	5.49%	39.93%	29.43	96.60

HCI – higher confidence interval; LCI — lower confidence interval; Q — Cochran's Q; PA — prostatic artery.

with intra-prostatic or contra-lateral PA in 13.81% of the patients (95% CI: 0.00–38.23%). Rectal area was found to be the most common one vascularized by a PA anastomosis (65.83%; 95% CI: 22.73–100.00%). More detailed results regarding the anastomoses of the PA can be found in Table 6. The corkscrew pattern of the PA was found to occur in 20.12% of the studied cases (95% CI: 5.49–39.93%). More detailed results regarding the corkscrew pattern can be found in Table 7.

DISCUSSION

The variations of the origin of the PA have been extensively studied due to their clinical significance in various procedures involving the prostate gland. Major anatomical textbooks state that the PA originates mainly from the internal iliac artery and/or the inferior vesical artery [27]. A number of previous publications have supported this claim, such as the study conducted by Garcia-Monaco et al. [16] which demonstrated that the PA originates from the anterior division of the internal iliac artery in 56.5% of the cases. However, various studies have stated that the most frequently observed origin of the said vessel is from the internal pudendal artery [3, 7, 29]. Interestingly, some reports have stated that the gluteal-pudendal trunk was the most frequently observed origin [10]. These variations in the origin of the PA can have significant implications for surgical procedures such as prostatectomy or PAEs. For instance, in prostatectomy, knowledge of the precise origin of the PA can aid in preserving the blood supply to the neurovascular bundle, which is crucial for preserving erectile function [41]. Similarly, in embolization procedures, an accurate understanding of the origin and course of the PA may help prevent unintended embolization of other arteries, which can lead to complications such as ischemia or infarction of the pelvic organs [28]. The present meta-analysis demonstrates that the most prevalent origin of PA is the internal pudendal artery (28.81%), followed by the obturator artery (14.35%). Although rare, it is crucial to keep in mind that the PA may also originate from the middle anorectal artery (0.99%) and the inferior and superior gluteal arteries (0.75% and 0.20%, respectively), amongst others.

PAE is a relatively new embolization technique for treating lower urinary tract symptoms caused by BPH and represents an alternative to classic surgical procedures such as transurethral resection of the prostate (TURP) [19]. A relatively recent systematic review and meta-analysis conducted by Knight et al. [24] showed that the subjective symptom improvement was similar between TURP and PAE. However, PAE was associated with fewer adverse events and shorter hospitalization times. It is clear that having appropriate knowledge about the complete anatomy of the PA may help to decrease potential complications further when performing PAEs. Specifically, acknowledging the morphometric values of the PA, especially its diameter, is of great importance when choosing an appropriately-sized catheter when performing PAEs. The present meta-analysis shows that the mean diameter of the main trunk of the PA is 1.52 mm.

The prevalence of accessory PAs and their clinical significance have also been discussed in the literature. In a cadaveric study conducted by Garcia-Monaco et al. [17], it was stated that in 78% of the analysed hemipelvises, a single dominant PA was present. However, the rest of the specimens had multiple PAs supplying the prostate gland. Boeken et al. [8] presented similar results, with a prevalence of double accessory PAs in 15.6% of the cases. Interestingly, Wang et al. [37] presented a considerably lower frequency of accessory PAs (7.4%). The present meta-analysis demonstrates that a single PA is present in the majority of the cases (76.43%) (Table 4). However, accessory PAs may occur; double PAs are relatively common, with a frequency of 23.18%, and the presence of triple PAs is remarkably rare (0.13%). Moreover, our study shows, that the most common origin of the accessory PAs is from the obturator artery (43.12%), followed by the internal pudendal artery (36.26%).

Potential anastomoses between the PA and the adjacent arteries are important to take into consideration when performing endovascular procedures in the pelvis. Their prevalence, topography, and areas which the said anastomoses supply have been greatly discussed in the literature. The present study shows that the PA most commonly forms anastomoses with the internal pudendal artery (47.26%); however, other arteries may also be involved, such as the inferior vesical artery or the lateral sacral artery. Furthermore, the overall prevalence of considerable anastomoses formed by the PAs and their adjacent vessels is 45.20%.

The present study is not without limitations. Due to the nature of the research, the accuracy of the established results is conditioned by the quality of the primary studies. Some of the analyses could not have been performed due to insufficient amount of consistent data in the literature. Additionally, the most of the PAs were studied in Asia, therefore the results of the present study may reflect more an Asian population rather than the global one. Although not without limitations, our meta-analysis attempts to establish the detailed anatomy of the PA based on the data from the literature that meet the requirements of evidence-based anatomy.

CONCLUSIONS

In conclusion, the authors of the present study believe that this is the most accurate and up-to-date analysis regarding the highly variable anatomy of the PA. The PA originates most commonly from the internal pudendal artery (28.81%); however, it may also originate from other pelvic arteries, including the middle anorectal or the superior gluteal arteries. Moreover, accessory PAs may occur, yet, a single main PA supplying the prostate gland is most frequently observed (76.43%). The PA may also form anastomoses with the adjacent arteries (pooled prevalence of 45.20%), which may create a complex vascular network in the pelvis. It is hoped that the current meta-analysis may help to decrease the potential complications that may emerge from diverse endovascular and urological procedures.

ARTICLE INFORMATION AND DECLARATIONS

Ethics statement

Not applicable.

Author contributions

Kyrylo Shafarenko: literature search, extraction, data collection, statistical analysis, writing, figures, tables. **Michał Bonczar:** statistical analysis, writing, figures. **Patryk Ostrowski:** writing, tables, literature. **Mateusz Michalczak:** literature search, extraction. **Jerzy Walocha:** writing, literature **Mateusz Koziej:** statistical analysis, writing.

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Conflict of interest

The authors declare no potential conflicts of interest with respect to the research, authorship, and//or publication of this article.

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