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VASCULAR-INTERVENTIONAL

Prostatic arterial supply: demonstration by multirow detector Angio CT and Catheter Angiography

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Abstract
Objectives To evaluate the prostatic arterial supply with multidetector Angio CT and Digital Subtraction Angiography (DSA).
Methods DSA was performed in 21 male patients (7 of these also underwent Pelvic Angio CT); a further 4 patients only underwent Angio CT. Prostatic arteries were classified according to their origin, direction, number of pedicles, termination and anastomoses with surrounding arteries in 50 pelvic sides.
Results The most frequent origin was the internal pudendal artery (n = 28; 56%) with the common gluteal-pudendal trunk the next commonest (n = 14; 28%). Less frequent origins were the obturator artery (n = 6; 12%) or the inferior gluteal artery (n = 2; 4%). Two separate vascular pedicles were found in 12 pelvic sides (24%). There were anastomoses with the termination of the internal pudendal artery in 24% of cases (n = 12), with the contra-lateral prostatic arteries in 6 cases (12%), and to the superior vesical artery in 4 cases (8%).
Conclusions Defining prostatic artery origin and direction is paramount to allow selective catheterisation. Angio CT is very useful as a pre-intervention tool. The number of independent vascular pedicles and the presence of anastomoses with surrounding arteries should be taken into account when planning prostatic arterial embolisation.

Keywords Prostatic artery · Anatomy · Prostatic arterial vascularisation · Angio CT · Catheter Angiography

Introduction

The prostatic arterial supply was described by Clegg [1, 2] using gross cadaveric specimens. Other studies using cadaveric specimens have shown the presence of a prostatic artery with variable origins, ranging from the anterior (gluteal-pudendal) trunk, umbilical artery, internal pudendal artery, inferior gluteal artery or the obturator artery [1–3]. In most cases (41.5%–74.3%) the prostate gland is supplied by a common arterial trunk (prostate-vesical) that gives rise to the inferior vesical artery and the prostatic artery [1].

These findings are all based on cadaveric specimens. There are currently no in vivo studies documenting the imaging findings of the prostatic artery anatomy published in the literature. Prostatic arterial supply has gained interest as prostatic arterial embolisation (PAE) to treat benign prostatic hyperplasia (BPH) may follow uterine artery embolisation for fibroids [4, 5].

Urinary tract infection, strictures, postoperative pain, incontinence or urinary retention, sexual dysfunction and blood loss are complications associated with the surgical treatments for BPH. There is a need for innovative

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technologies to continue to improve outcomes and minimise patient discomfort and morbidity when managing BPH [6]. Case reports in humans and animal studies have shown that PAE might be able to reduce prostate size and improve symptoms related to BPH with less associated morbidity [5, 7–9].

Detailed knowledge of prostatic arterial anatomy is necessary in general, and in patients undergoing embolization for BPH in order to allow identification and selective catheterisation before embolisation, minimizing the risks of untargeted embolization with ischemic complications to the bladder or other pelvic organs.

The purpose of this study was to evaluate the prostatic arterial supply using multirow detector Pelvic Angio CT and Catheter Angiography before embolisation to treat symptomatic BPH. The main study goals were identification of the prostatic arteries, their origin and direction, the definition of intra-prostatic branches and possible anastomoses with surrounding arteries.

Materials and methods

The study was approved by the Hospital Ethics Committee and informed consent for PAE as an alternative treatment for BPH was signed by all participants.

The inclusion criteria were male patients with age greater than 50 years and diagnosis of BPH with moderate to severe lower urinary tract symptoms refractory to medical treatment for at least 6 months, with sexual dysfunction or accepting the risk of developing sexual dysfunction after treatment, and/or with peak urinary flow rate (Qmax) inferior to 12 mL/s or with acute urinary retention. Malignancy (evaluated by PSA, physical examination, transrectal ultrasound in all patients and by prostatic biopsy in suspicious cases) and advanced atherosclerosis and tortuosity of iliac arteries were exclusion criteria. The patients were not randomized. PAE was not proposed when surgery was indicated for other reasons (secondary renal insufficiency due to prostatic obstruction, hematuria, bladder diverticula or stones). All patients were informed about the embolization technique used and the experimental nature was clearly indicated. The patients were allowed to choose freely between PAE and transurethral resection of the prostate (TURP), open surgery or laser surgery. Imaging evaluation was performed in 25 male patients. Digital Subtraction Angiography (DSA) was performed in 21 male patients. Seven male patients were evaluated by Pelvic Angio CT before DSA. Four patients were only evaluated by Pelvic Angio CT and were considered poor candidates for Digital Angiography because of extensive atherosclerotic lesions in the iliac arteries. All patients were Caucasian, with a mean age of 72.3 years (range 57–83 years). One patient had a partial prostatectomy 14 years before and 6 patients had bladder catheters at the time due to acute urinary retention.

Pelvic Angio CT examinations were performed using a 16 spiral GE® system in 11 patients in the supine position. Power settings were 100–120 kV and 200–300 mA, matrix 512 × 512 pixels, collimation 16 × 1.25 mm (slice thickness 0.5 mm) and pitch 1.3. Iodine contrast agent injection of 150 cc (at a concentration of 350 mg/mL iodine), at an injection rate of 5 mL/s using bolus triggering in the abdominal aorta (above the renal arteries) was performed in every patient. Post-processing using maximum intensity projections (MIP) and volume rendering with 3D reconstructions were performed.

Digital subtraction angiography was performed in 21 patients by a single femoral approach, usually the right hand side, using a cobra-shaped catheter (C2F5) and non-ionic Visipaque contrast medium (Iodixanol, 320 mg I/ml; GE Healthcare, New Jersey, USA). DSA was first performed in the aorta to visualise both pelvic sides and the common iliac arteries (injection volume 30 mL, injection rate of 15 mL/s). Afterwards the contra-lateral (usually the left) internal iliac artery was selectively catheterised and DSA (injection volume 15 mL, injection rate of 8 mL/s) was performed in the artery origin in a neutral position and repeated with left anterior oblique projection (35°) and caudal-cranial angulation (10°). After identifying the left prostatic arteries, selective catheterisation with a 3 F-microcatheter (Progreat; Terumo, Tokyo, Japan) was performed and selective angiography was performed manually with 3–5 mL of contrast medium in neutral and left anterior oblique projections. The contralateral internal iliac artery (usually the right) was selectively catheterised after performing the Waltman loop on the catheter with the same side (usually the right) anterior oblique projection (35°) and caudal-cranial angulation (10°). Prostatic arteries on the right hand side were selectively catheterised in the same way. After confirming the position of the catheter in the ostium of the prostatic artery, embolization was performed with nonspherical polyvinyl alcohol (PVA) particles 200 μm (Cook). The end point chosen for embolization was slow flow or "near stasis" in the prostatic vessels with interruption of the arterial flow and prostatic gland opacification.

Prostatic arteries were identified and classified according to their origin, direction, number of pedicles, termination and anastomoses with surrounding arteries.

Results

The origin of the prostatic artery was identified in all patients (n = 25), with a total of 50 male pelvic sides

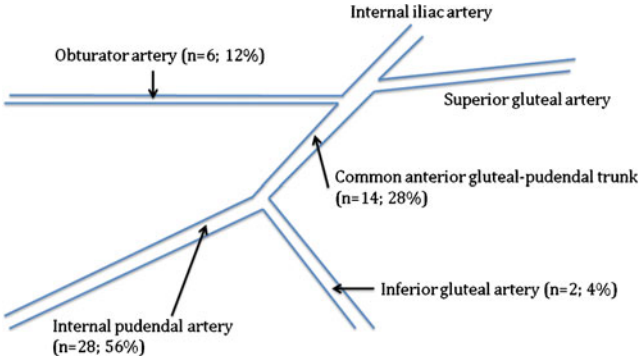

Fig. 1 Schematic drawing of the different sites from which the prostatic artery can arise (n = 50 male pelvic sides)

studied (Fig. 1 and Table 1). The most frequent origin was as a collateral branch of the internal pudendal artery (Fig. 2) above the sciatic notch (n = 28; 56%). The second most frequent prostatic artery origin was more proximal and superior, as a collateral branch of the common anterior gluteal-pudendal trunk (n = 14; 28%). Other less frequent origins were as a collateral branch of the obturator artery (n = 6; 12%) or as a collateral of the inferior gluteal artery (n = 2; 4%).

After its origin, the prostatic artery has a tortuous trajectory and courses obliquely downwards, forwards and medially towards the bladder base. During its course it gives rise to branches to the bladder base (inferior vesical artery) and terminates near the posterior-superior and lateral aspect of the prostatic base, terminating with numerous prostatic branches. The length of the prostatic artery is very variable, according to its origin; the further away from the prostate (proximal origins near the common anterior gluteal-pudendal trunk or inferior gluteal artery), the longer the artery length. When the origin is in the internal pudendal artery or in the obturator artery, the artery is shorter, because the origin is nearer to the prostatic base.

Before or just after reaching the prostate it is common to observe a bifurcation of the prostatic artery with 2 separate vascular pedicles, which was found in 12 pelvic sides (24%). A posterior pedicle that surrounds the seminal vesicles and deferent canals reaching the prostate base (the so-called vesicle-deferential arteries) and an anterior pedicle that surrounds the lateral borders of the prostate with an inferior trajectory, reaching the prostate apex, giving branches to the bladder base (inferior vesical artery) and continuing as an anterior capsular prostatic branch (prostate-vesical artery) that runs downwards into the perineum (Fig. 3). These 2 vascular pedicles may have independent origins or origins in a common trunk that bifurcates. However, in most cases only one vascular pedicle was found on each pelvic side.

The superior vesical artery (or umbilical artery) was found to have a common proximal origin with the prostatic artery in 6 cases (12%).

After reaching the prostatic capsule, the prostatic artery gives rise to numerous perforating branches to the gland, with apparent penetration made at the 2 and 10 o'clock positions for the antero-lateral pedicles and at 5 and 7 o'clock positions for the posterior-lateral pedicles.

In most cases the prostatic artery termination was isolated from the surrounding arterial systems with no significant anastomoses (Fig. 4 and Table 2). However, in 24% of cases (n = 12) it was possible to demonstrate inferior continuation of the anterior capsular prostatic branches with anastomoses with the termination of the internal pudendal artery near the perineum. These anastomoses may be to the dorsal artery of the penis or to the anal artery of the same side and/or contra-lateral side. Also, anastomoses with the contra-lateral prostatic arteries were found in 6 cases (12%), and to the superior vesical artery (on the same or contra-lateral side) in 4 cases (8%).

Discussion

The prostatic artery supply was evaluated regarding its origin, trajectory and termination in 50 pelvic sides using pelvic Angio CT and/or Digital Angiography with super-selective prostatic catheterisation. The most frequent prostatic artery origin was as a collateral branch of the internal pudendal artery above the sciatic notch (n = 28; 56%). The second most frequent origin was as a collateral branch of the common anterior gluteal-pudendal trunk (n = 14; 28%), with a more superior/proximal origin and thus longer arterial length. These findings are somewhat different from the reported literature, which documented the common anterior gluteal-pudendal trunk as the most frequent prostatic artery origin (in 41.5%–74.3% of cases), with the internal pudendal artery giving rise to the prostatic artery in only 26.4% of cases [1–3, 10, 11]. As previously reported, the prostatic artery, the inferior vesical artery and the vesicle-deferential arteries showed frequent common trunks and origins in the anterior gluteal-pudendal trunk. Other origins (from the obturator or inferior gluteal arteries)

Table 1 Prostatic Artery Origin: 25 patients (50 pelvic sides)

	Internal pudendal artery	Gluteal-pudendal trunk	Obturator artery	Inferior gluteal artery
Prostatic Artery Origin	28 (56%)	14 (28%)	6 (12%)	2 (4%)

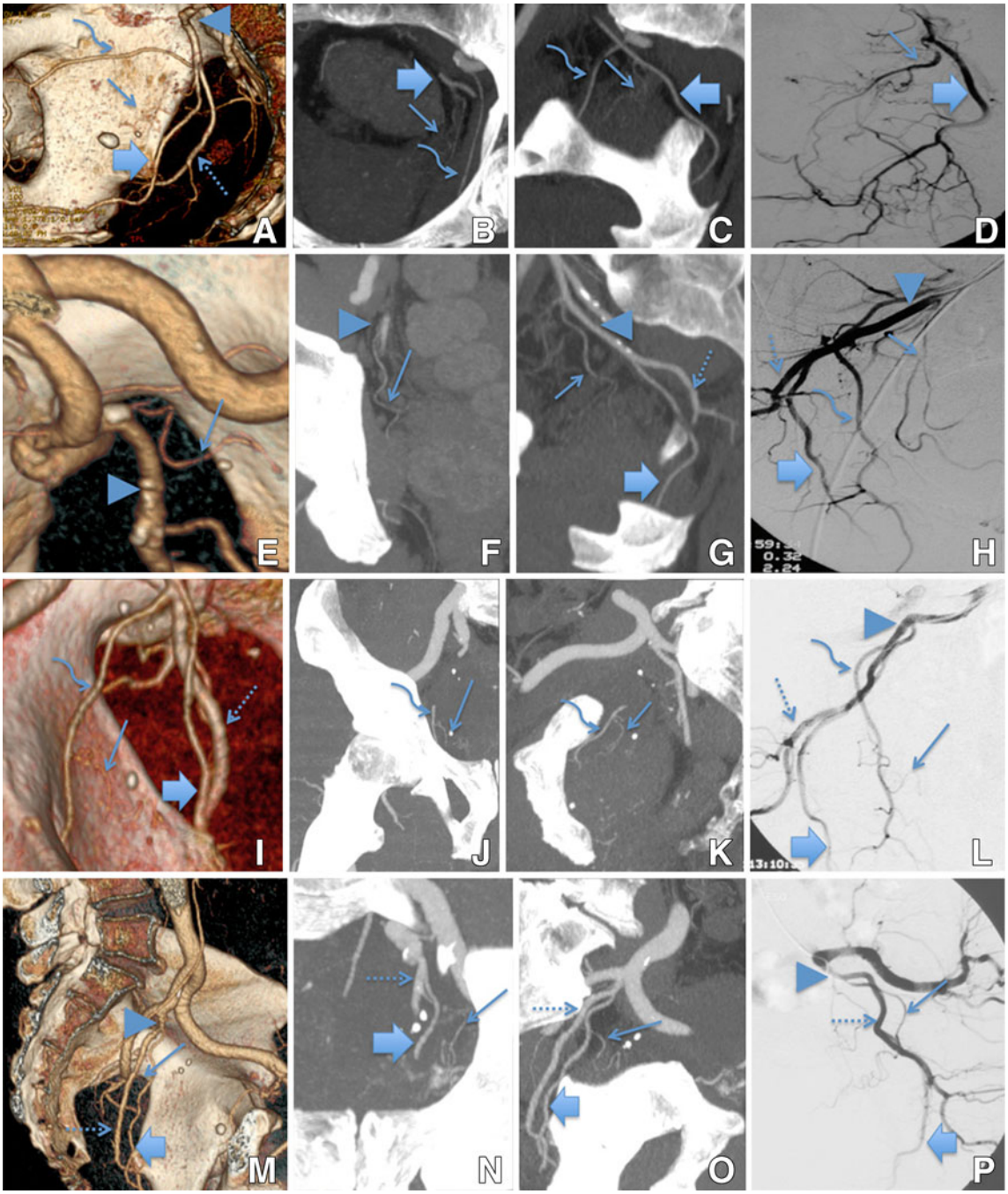

Fig. 2 Prostatic artery (*straight small arrow*) origin. **a**–**d** as a collateral branch of the internal pudendal artery (*straight large arrow*) above the sciatic notch. **e**–**h** with a longer trajectory and length as a collateral branch of the common anterior gluteal-pudendal trunk (*arrowhead*) with a proximal/superior origin. **i**–**l** as a collateral branch of the obturator artery (*curved arrow*). **m**–**p** with a longer trajectory and length as a collateral branch of the inferior gluteal artery (*dotted arrow*). **a**; **e**; **i**; **m**—Pelvic Angio CT with 3D reformats. **b**; **f**; **j**; **n**—Pelvic Angio CT with coronal MIP reformats. **c**; **g**; **k**; **o**—Pelvic Angio CT with sagittal MIP reformats. **d**; **h**; **l**; **p**—Pelvic DSA with selective catheterisation of the internal iliac arteries. Straight small arrow—prostatic artery. *Straight large arrow*—internal pudendal artery. *Curved arrow*—obturator artery. *Dotted arrow*—inferior gluteal artery. *Arrowhead*—common anterior gluteal-pudendal trunk

were found rarely as previously reported, however we found no cases of prostatic arteries originating in the middle rectal artery, directly from the internal iliac artery, or from the umbilical artery (although some authors may consider this situation in cases where the superior vesical artery has a common origin with prostatic arterial branches) [1–3].

Contrary to a previous report [1] we found considerable differences between prostatic artery origin, trajectory and

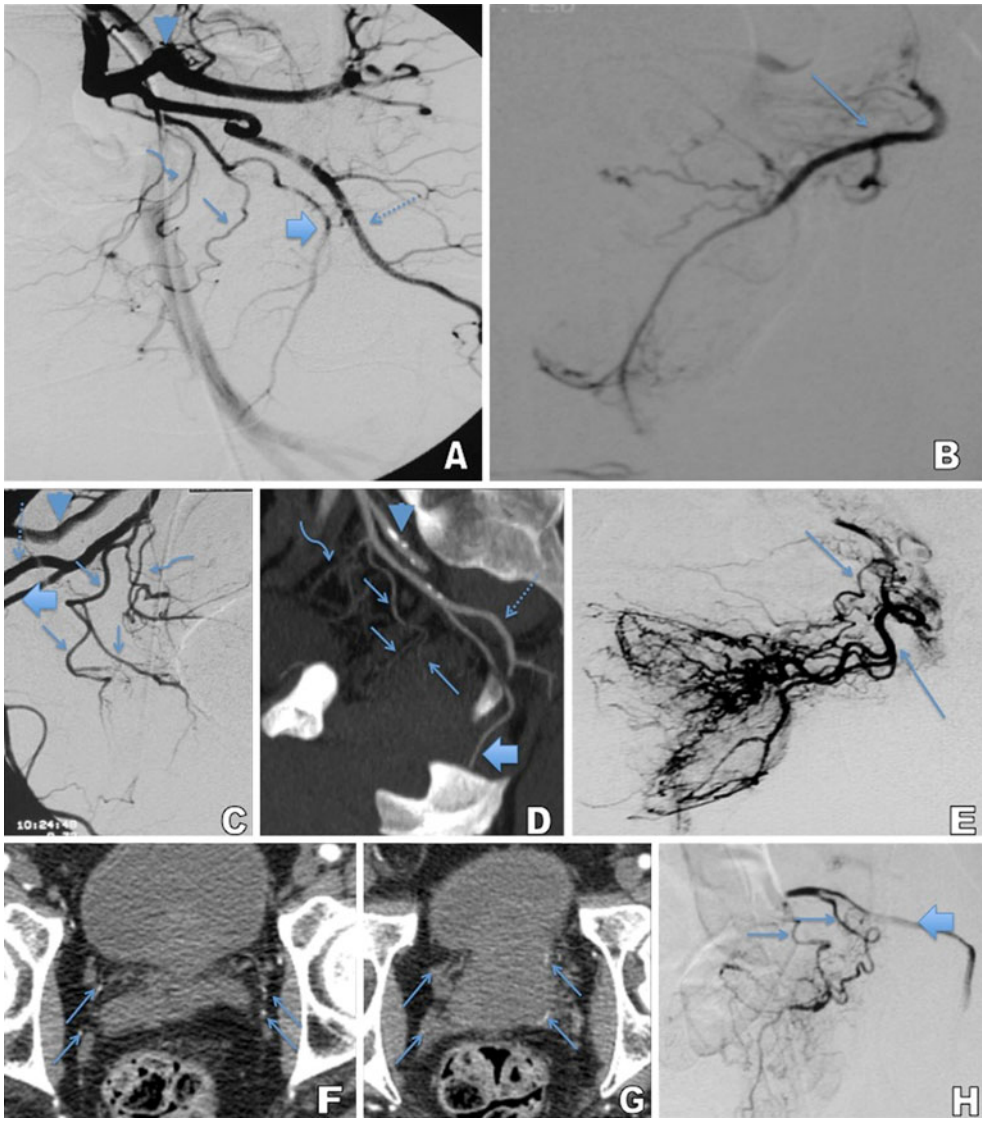

Fig. 3 Prostatic artery (*straight small arrow*) with a single vascular pedicle. **a** DSA of the left internal iliac artery showing a single prostatic artery vascular pedicle (*straight small arrow*) arising from the internal pudendal artery (*straight large arrow*) after the superior vesical artery (*curved arrow*). **b** DSA of the left prostatic artery after selective catheterisation. Prostatic artery with 2 vascular pedicles arising from a common trunk. **c** DSA of the right internal iliac artery showing the prostatic artery bifurcating into 2 vascular pedicles (*straight small arrow*). **d** Pelvic Angio CT with sagittal MIP reformats on the same patient side as in C. **e** DSA after selective catheterisation of the left prostatic artery showing 2 vascular pedicles. Prostatic artery with 2 vascular pedicles arising independently. **f** and **g** Axial Angio CT showing perforating branches to the prostatic gland (*straight small arrow*), with apparent penetration made at the 2 and 10 o'clock positions for the antero-lateral pedicles and at the 5 and 7 o'clock positions for the posterior-lateral pedicles. **h** DSA after left internal pudendal artery catheterisation showing 2 independent prostatic vascular pedicles (*straight small arrow*). *Straight small arrow*—prostatic artery. *Straight large arrow*—internal pudendal artery. *Curved arrow*—superior vesical artery. *Dotted arrow*—inferior gluteal artery. *Arrowhead*—superior gluteal artery

length in the same patient between pelvic sides. Thus, each pelvic side should be considered separately when performing selective catheterisation or during the Angio CT post-processing. Also, we did not find 2 symmetric vascular pedicles on each pelvic side in most cases.

After reaching the prostate surface, a prominent feature of the arterial branches is their tortuosity with a "corkscrew" pattern [1], with contra-lateral anastomoses according to some authors [10, 12] or with few contra-lateral anastomoses [1]. Additional arterial supplies from the middle rectal or the vesicle-deferential arteries have also been documented [1]. In this study the prostatic artery trajectory also showed a "corkscrew" pattern/trajectory in many cases, terminating with branches to the bladder base (inferior vesical artery) and prostatic branches near the lateral, posterior and superior aspect of the prostatic base. There are frequently 2 vascular pedicles to the prostate, one posterior to the superior aspect of the gland and another

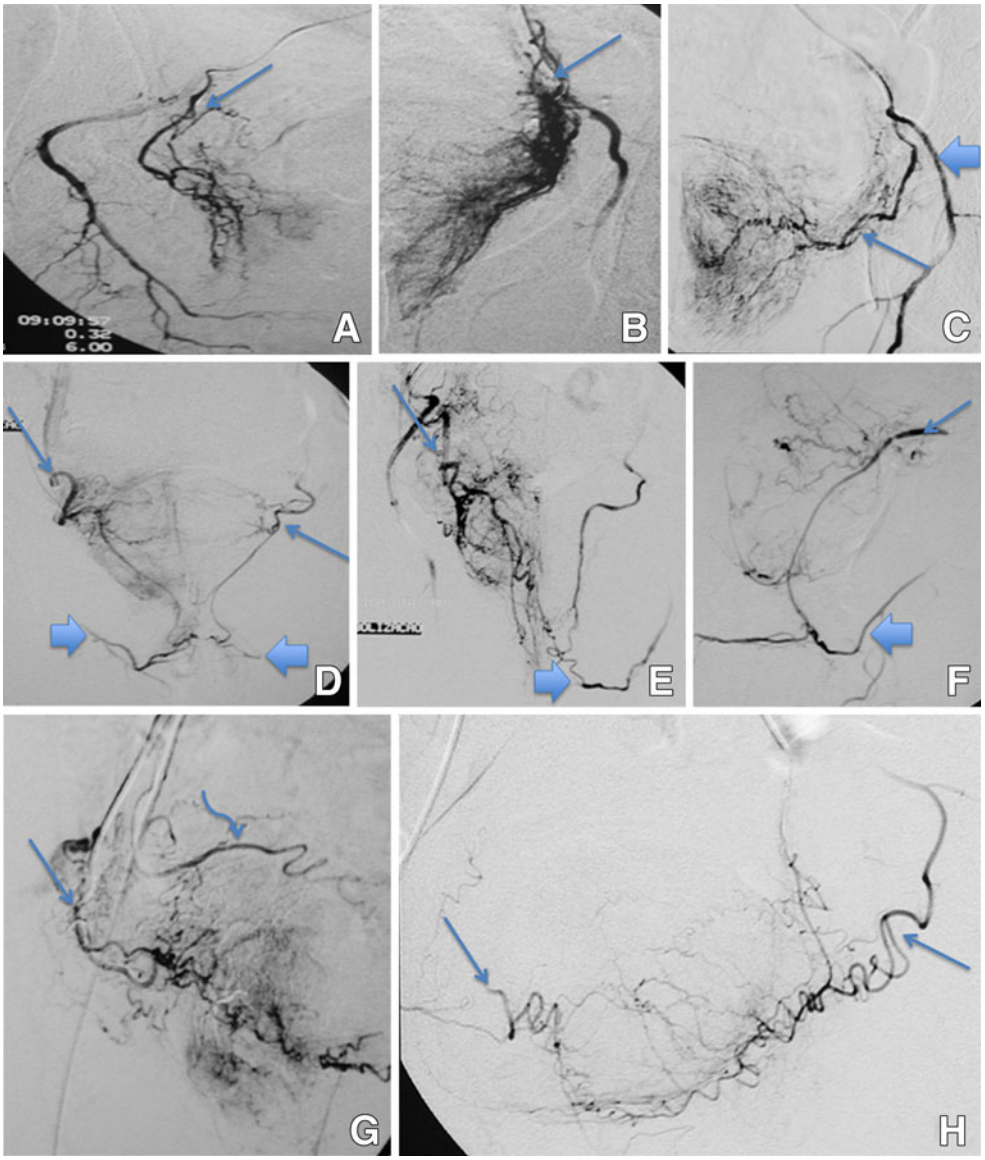

Fig. 4 Prostatic artery (*straight small arrow*) with no anastomoses to the adjacent arterial systems. **a** DSA of the right prostatic artery after selective catheterisation. **b** and **c** DSA of left prostatic artery after selective catheterisation. Prostatic artery (*straight small arrow*) with anastomoses to the same side and the contra-lateral internal pudendal arteries (*straight large arrow*). **d** DSA of the right prostatic artery after selective catheterisation (also note anastomoses to the contra-lateral prostatic artery). **e** DSA of the right prostatic artery after selective catheterisation. **f** DSA of left prostatic artery after selective catheterisation. **g** Anastomoses to the same side superior vesical artery (*curved arrow*). DSA of the right-hand-side prostatic artery after selective catheterisation. **h** Intra-prostatic arterial anastomoses to the contra-lateral prostatic artery. DSA of the left prostatic artery after selective catheterisation. *Straight small arrow*—prostatic artery. *Straight large arrow*—internal pudendal artery. *Curved arrow*—superior vesical artery

anterior and lateral to the inferior aspect of the prostate. These inferior branches may have anastomoses with perineal branches of the internal pudendal artery and with the middle rectal or anal arteries [10]. After reaching the prostate the main source of prostatic microvascularisation are 3 groups of arteries (capsular, intermediate and periurethral) [11]. The capsular branches are arranged on the surface in a posterior and anterior group with antero-lateral and posterolateral subgroups. After passing the capsule usually at the 1, 5, 7 and 11 o'clock positions, vessels create the intermediate and peri-urethral arteries [12–14]. In our study the presence of 1 or 2 vascular pedicles arising in a common trunk or independently was very variable. We found 2 prostatic arterial vascular pedicles in 12 pelvic sides (24%), which is similar to the previously reported rates [1, 2]. When 2 vascular pedicles are present, the anterior (prostate-vesical) gives rise to the vesical and anterior-inferior prostatic arteries, while the

Table 2 Prostatic Artery anastomoses with surrounding arteries: 25 patients (50 pelvic sides)

	None	Internal pudendal artery	Contra-lateral prostatic artery	Superior vesical artery
Anastomoses	28 (56%)	12 (24%)	6 (12%)	4 (8%)

posterior (vesicle-deferential and prostatic) gives rise to the arteries supplying the posterior-superior aspect of the prostate. In these situations, the anterior pedicle may have an inferior continuation alongside the anterior aspect of the prostate terminating at the base of the perineum with anastomoses to the internal pudendal arteries. Thus, in almost ¼ of situations there may be anastomoses between prostatic arteries and the internal pudendal artery (with the dorsal artery of the penis or the anal artery). These anastomoses should be taken into consideration before embolisation in order to avoid unwanted, untargeted embolisation. In some cases the vesicle-deferential and prostatic arteries had common origins. However, the inferior vesical artery almost always had a common origin with the prostatic artery. When catheterising the prostatic arteries it is of utmost importance to analyse how many vascular pedicles exist and to visualise whether they have common or separate origins. Proximal embolisation should be avoided in order to spare inferior vesical branches to the bladder base. However, embolisation that is too distal may leave behind prostatic vascular pedicles. Also, the superior vesical artery (or umbilical artery) was found to have a common proximal origin with the prostatic artery in 6 cases (12%), and should always be avoided to prevent bladder ischaemia.

The capsular arteries were found to perforate the capsule at approximately the 2 and 10 o'clock positions for the anterior-lateral branches and at the 5 and 7 o'clock positions for the posterior-lateral branches, as previously reported [11–14].

Intra-prostatic contra-lateral anastomoses were documented in 6 cases (12%), and to the superior vesical artery in 4 cases (8%). The anastomoses to the superior vesical artery should be carefully inspected and avoided to prevent untargeted bladder embolisation. As these anastomoses between the prostatic arteries and the internal pudendal or superior vesical arteries are very small, DSA may be the best imaging modality to detect them.

Angio CT was very useful as a pre-intervention tool allowing planning of the intervention, and was able to detect small vessels such as the prostatic arteries. Angio CT allows definition of the iliac artery trajectory and atherosclerotic changes that might preclude selective catheterisation. Also, under DSA, it may sometimes be difficult to be sure which artery is selectively supplying the prostate. Angio CT depicts which pelvic branches provide arterial supply to the prostate, their origin, trajectory and number of vascular pedicles, allowing treatment planning before DSA.

Regarding the post-processing and the interpretation of Angio CT, the visualisation of the prostatic arteries is mandatory in an axial plane, complemented by sagittal and coronal MIP reformatations where the prostatic artery origin may be best depicted. The 3-D CT reformats are very useful to understand and depict the branching patterns of male internal iliac arteries and to demonstrate the prostatic artery trajectory.

There are experimental animal studies using pigs and dogs that showed that PAE can induce prostatic volume reduction and that it is safe, with no associated sexual dysfunction [7, 8]. Prostatic embolization has been performed in human subjects to control severe hemorrhage with success in different case series [15, 16]. There are 2 case reports with a total of 3 patients with severe symptomtic BPH treated with success by arterial embolization [5, 9]. However, PAE is still considered an experimental technique with no studies to date reporting the results in a large series of patients. Our preliminary results are promising. Prostatic arterial embolisation is a feasible procedure, with minimal complications. Our preliminary results and short term follow-up suggest good symptom control without sexual dysfunction in suitable candidates, associated with a reduction in prostate volume. However data referring to medium and long-term results are still lacking. Also, future studies with larger series of patients, comparing different treatment techniques are warranted.

Defining prostatic artery origin and direction is paramount to allow selective catheterisation before embolisation. Definition of the number of independent vascular pedicles should be clarified in order to allow complete prostatic embolisation. Anastomosis with surrounding arteries should be taken into account before embolisation in order to avoid untargeted embolisation.

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All authors had full access to all of the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis.

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