Distribution of the arterial supply to the lower urinary tract in the domestic tom-cat (*Felis catus*)

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ABSTRACT: This study was aimed at determining the arterial supply and gross vascular architecture of the urinary bladder in the male cat. For this purpose, the urinary bladders of 10 cats were evaluated. Organ vascularization was investigated using the latex injection technique. The feline urinary bladder was found to be supplied by the prostatic artery, which stemmed from the internal pudendal artery and the umbilical artery that originated from the internal iliac artery. The umbilical artery extended caudally to form the cranial vesical artery, which was later distributed into the corpus and apex of the urinary bladder. The feline prostatic artery divided into the artery of the deferent duct and a slim branch, which supplied the prostate gland. The artery of the deferent duct gave off a caudal vesical artery which gave off slim branches to the preprostatic urethra. On the surfaces of the urinary bladders examined, the cranial and caudal vesical arteries followed varying courses, which reflected individual variations. In all samples, the blood vessels generally divided into two or three branches on the surface of the urinary bladder, whilst in only one sample, the caudal vesical artery was observed to be of the ladder type. Moreover, the cranial and caudal vesical arteries anastomosed with each other on the surface of the urinary bladder. This study constitutes a model for comparison with other species and provides morphological contributions to anatomy training and surgical interventions since there is a lack of literature on species-specific vascular morphology in the field of veterinary urology in contrast to the abundance of studies on humans and rodents.

Keywords: arterial supply; urinary bladder; tom-cat

The major arterial supplies to the organs in the pelvic cavity are the internal iliac artery, internal pudendal artery, and the umbilical and prostatic/vaginal arteries stemming from the former two arteries (Nickel et al., 1981; Constantinescu, 2004). The arterial organisation may, to different extents, vary between different species, whereas arterial variations may also be observed among animals of the same species. Such morphological approaches, relevant to vascular architecture, are considered to be useful for both surgical interventions and training in anatomy.

A multitude of studies (Nitschke and Preuss, 1971; Ventura et al., 1995, 1996) have been conducted to date that explore the arterial supply to organs in the pelvic cavity. These studies, which have been carried out in both animals and humans (Carvalho et al., 1990; Lopez-Fuster et al., 1993; Fatu et al., 2006), have demonstrated the distribution of the internal iliac artery and the internal pudendal artery in the pelvis, and most were aimed at revealing the generalized supply pattern. Therefore, the present study was designed in view of the availability of only a limited number of elaborate studies on the arterial supply of the feline urinary bladder. Furthermore, studies (Wyrost et al., 1991; Stefanov, 2004; Holub et al., 2005) aimed at a detailed investigation of the vascular organisation of the neighbouring organs of the urinary bladder, including the prostate gland and other accessory genital glands, the deferent duct and uterus, have also touched upon the vascularization of the urinary bladder due to their common supplying arteries. It should additionally be noted that animal studies demonstrating the distribution of blood vessels on the surface of the urinary bladder, apart from main blood vessels, are also limited in number.

While gross anatomical evaluations of the vascularization of the urinary bladder are available, electron microscopy studies demonstrating the microvascularization of the organ in carnivores (Stefanov, 2004), rodents (Inoue and Gabella, 1991), lagomorphs (Orsi et al., 1979; Hossler and Monson, 1995) and humans (Miodonski and Litwin, 1999) have also been conducted. Furthermore, physiological parameters related to blood flow in the arteries supplying the urinary bladder have also been investigated (Brading et al., 1999). Another area of investigation was vascular structure and angiogenesis in urinary bladder carcinomas (Miodonski et al., 1998).

Although the incidence of lower urinary tract infections in cats is low, the proportional morbidity rate is quite high (Chew et al., 1999). Unfortunately, since the urinary tract can respond to insult in only a limited number of ways, clinical signs are rarely indicative of a particular disease. While there are many conditions that can result in signs of feline lower urinary tract disease, the vast majority of cases are idiopathic (Gunn-Moore, 2003). This phenomenon contributes to the popularity of clinical studies (Gerber et al., 2005; Hostutler et al., 2005; Forrester and Roudebush, 2007) on feline urinary tract diseases. It is considered that the success of pathological evaluations and surgical approaches is closely related to the knowledge available on the normal anatomical features, arterial organisation and vascular variations of the lower urinary tract.

MATERIAL AND METHODS

Ten adult male cats which died because of traumas such as traffic accidents were used in this study. Animals were non-pedigreed domestic cats and the average weight of the animals was approximately 2600–3500 g. The latex injection method was used to observe the vascularization of the urinary bladder. Ten urinary bladders and their arteries were evaluated by dissection of the pelvic region. For this purpose, after the apex of the heart was cut, a urinary catheter was inserted into the left ventricle of the heart and fixed by placing a ligature on the ascending aorta. Red-coloured latex (30–40 cm^3) was injected into arterial system through the catheter until the blood vessels in extremities became apparent. The cadavers were kept in cold water for one day to ensure fixation of the latex. Materials which were dissected under a dissection microscope (ScanOptics-SO5800) were photographed with a digital camera (Canon SX1-IS).

RESULTS

It was observed that the feline urinary bladder was basically supplied by the prostatic artery (*a. prostatica*), which stemmed from the internal pudendal artery (*a. pudenda interna*) and umbilical artery (*a. umbilicalis*) that originated from the internal iliac artery (*a. iliaca interna*). The umbilical artery, which stemmed from the internal iliac artery in the first place, formed the vesical cranial artery at the level of the last lumbal vertebra (Figure 1). The umbilical artery had its origin at a short distance from the origin of the internal iliac artery and reached the ureter at the level of the internal opening of the inguinal canal. The umbilical artery passed the deferent duct and ureter diagonally from above, and extended caudally, from a wide angle, through a mass of fat tissue, to form the cranial vesical artery (*a. vesicalis cranialis*), which was later distributed into the corpus and apex of the urinary bladder (Figure 1). The same artery terminated at the caudolateral border of the urinary bladder in the form of the lateral ligament (*lig. vesicae laterale*) of the organ.

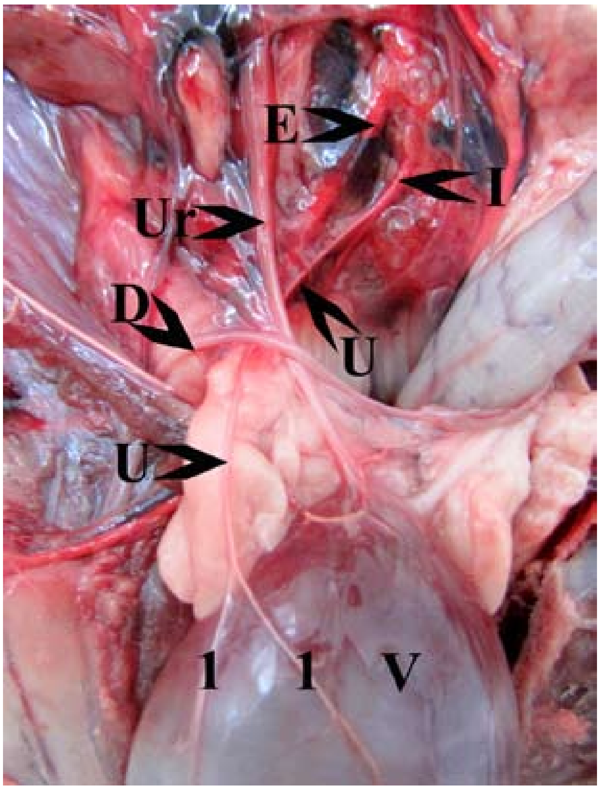

Figure 1. Origin and course of the umbilical artery (U). E = external iliac artery, I = internal iliac artery, Ur = ureter, D = deferent duct, V = urinary bladder; 1 = cranial vesical artery

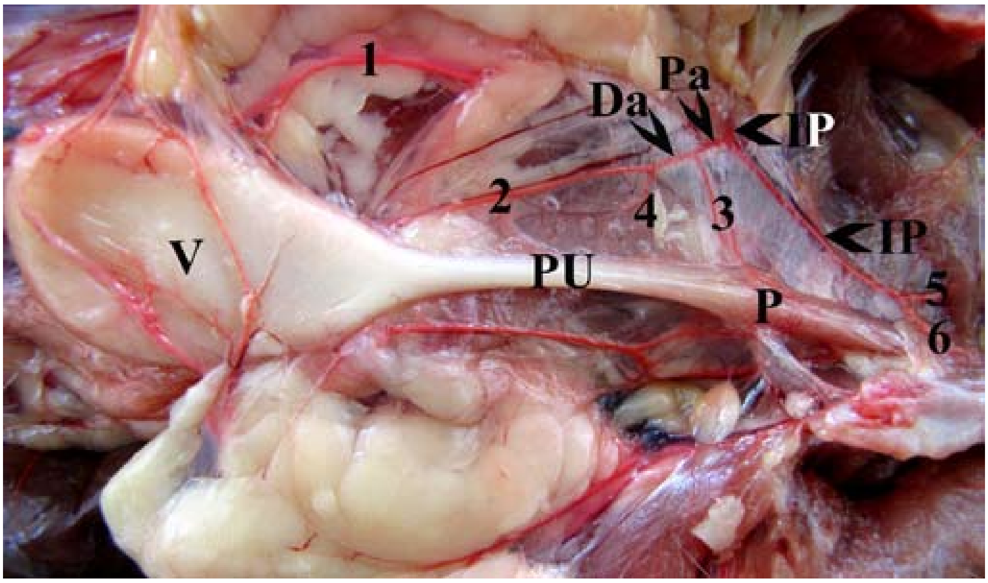

Figure 2. Arterial branches originating from the prostatic artery (Pa) and the structures supplied by this artery. Da = deferential artery, V = urinary bladder, PU = preprostatic urethra, P = prostate, IP = internal pudendal artery; 1 = cranial vesical artery, 2 = caudal vesical artery, 3 = branch of prostate, 4 = branches of deferent duct, 5 = ventral perineal artery, 6 = artery of penis

Another supplying artery of the urinary bladder, namely the prostatic artery, stemmed from the internal pudendal artery, approximately at the level of the sacrum. Immediately after being given off from internal pudendal artery, the feline prostatic artery extended cranioventrally along the lateral wall of the pelvic cavity and divided into the artery of the deferent duct and a slim branch, which supplied the prostate gland. The artery of the deferent duct gave off the caudal vesical artery (*a. vesicalis caudalis*). It was observed that the caudal vesical artery was larger than the branches which supplied the deferent duct and prostate gland. Furthermore, the caudal vesical artery gave off urethral branches to the preprostatic urethra (Figure 2). Along its caudal course and prior to giving off the ventral perineal artery and artery of the penis, the internal pudendal artery contributed to the blood supply of the postprostatic urethra with slim branches, referred to as the urethral artery (Figure 3). Furthermore, it was observed that the cranial vesical artery gave off ureteral branches (*rami uretericus*) to the pelvic part of the ureters, which were situated in proximity to the urinary bladder (Figure 4). In only one of the patterns, the deferential artery (*a. ductus deferentis*), apart from its thinner branches supplying the deferent duct, prostate gland and urinary bladder, also gave off a very large urethral branch supplying the preprostatic urethra. Moreover, the prostatic artery directly ramified into branches which supplied the urinary bladder, deferent duct and prostate gland through medial iliac lymph nodes on the intersection of the internal pudendal artery and prostatic artery in one of the animals.

The cranial and caudal vesical arteries, which were distributed on the surface of the urinary blad-

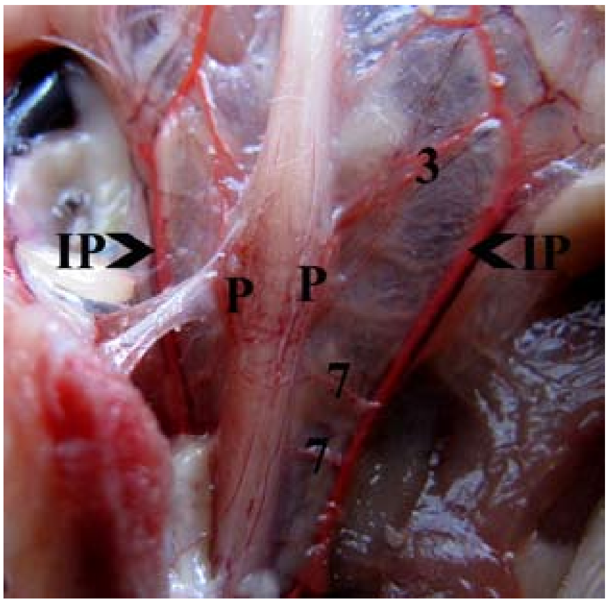

Figure 3. Arterial supply of the prostate (P) and postprostatic urethra. IP = bilateral internal pudendal arteries; 3 = branches of prostate, 7 = urethral arteries

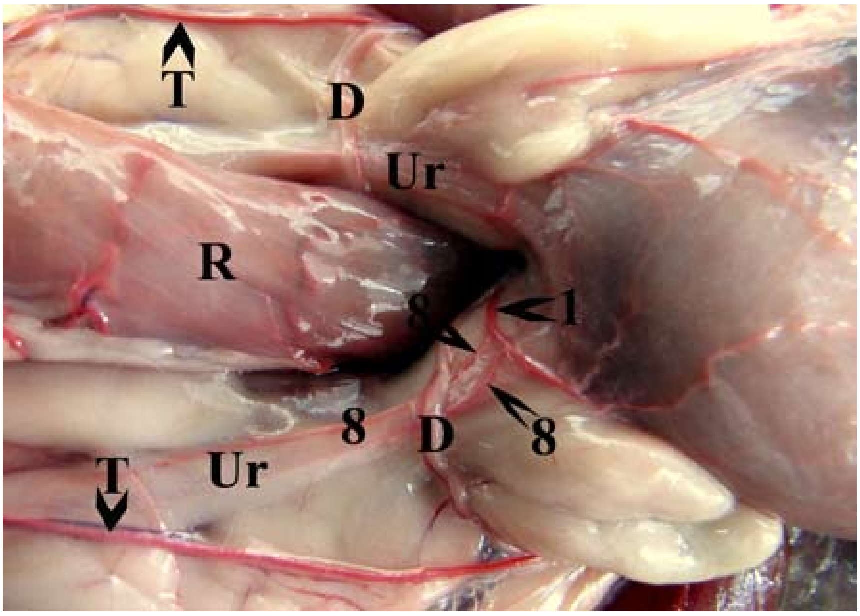

Figure 4. Ureteral branches (8) originating from cranial vesical artery (1). R = rectum, Ur = ureters, D = deferent ducts, T = testicular arteries

der, did not display a single and standard pattern of distribution. On the surfaces of the urinary bladders examined, the arteries followed varying courses, which reflected individual variations (Figures 1, 2, and 4). In all samples, the blood vessels generally divided into two or three branches on the surface of the urinary bladder, whilst in only one sample, the caudal vesical artery was observed to be of the ladder type. In some cases, it was observed that the cranial vesical artery and caudal vesical artery anastomosed with each other on the surface of the urinary bladder.

DISCUSSION

The urinary bladder is mainly supplied by the caudal vesical artery and cranial vesical artery (Nickel et al., 1981; Constantinescu, 2003). Similarly, in the dog, the origin of the cranial vesical artery has been reported as the umbilical artery, whilst it has been indicated that the caudal vesical artery originates from the urogenital artery formed by the end of the visceral branch of the internal iliac artery (Miller, 1993). Campos et al. (1985) described a middle vesical artery, which gave off branches to the prostate gland and urethra. Such an artery has neither been observed nor identified in tom-cats.

As reported by Nickel et al. (1981), in male mammals, the prostatic artery, which stems from the internal iliac artery, first divides into three branches. Of these, two branches continue with their course as arteries of the deferent duct and prostate artery, and are distributed into the prostate gland and deferent duct, whereas the third branch, namely, the caudal vesical artery, divides into ureteral (*ramus uretericus*) and urethral branches (*ramus urethralis*). Similarly, it has been reported that, in carnivores, the umbilical artery, which originates from the internal iliac artery, forms the cranial vesical artery and supplies the cranial portion of the urinary bladder, whereas the caudal vesical artery has been determined to stem from the prostatic artery (Smith, 1999). The prostatic artery divides into two branches in the dog, after being given off by the internal pudendal artery. The branch, which extends in a caudal direction, later bifurcates into the urethral and prostatic branches, whereas the branch that extends cranially divides into the artery of the deferent duct and the caudal vesical artery and supplies the deferent duct and urinary bladder (Smith, 1999). The findings obtained in the present study are similar to those reported in the dog, but display slight differences. Accordingly, the prostatic artery first gives off branches, which supply the prostate gland, and continues with its course as an artery of the deferent duct, which gives off the caudal vesical artery and deferential branches. In contrast to canine vascularization, the blood vessels supplying the feline preprostatic urethra originate from the caudal vesical artery. In agreement with the present study, Miller (1993) reported that the caudal vesical artery originated from the artery of the deferent duct, which stemmed from the prostatic artery in the dog. He also reported that both the urethral and ureteral branches were given off by the caudal vesical artery (Miller, 1993).

Vascularization in equine animals (Budras et al., 2003) is partly similar to that of cats. Accordingly, the internal pudendal artery gives off a small artery near its origin, which supplies the deferent duct in males. However, the equine internal pudendal artery also gives off the umbilical artery, which later forms the cranial vesical artery and ends as the lateral ligament on the bilateral surface of the urinary bladder in both sexes which is in contrast to cats. As is the case in other mammalian species, the equine prostatic artery (vaginal artery in females) ramifies visceral branches, which supply most of the pelvic organs.

Miller (1993) reported that in the dog, the cranial vesical artery and the controlateral caudal vesical artery anastomosed with each other on the surface of the urinary bladder. In the present study, such anastomoses were observed in some of the cats. Yet, the anastomosis of the terminal branches of the testicular artery with the branches of the caudal vesical artery, as observed in the dog, was not observed in any of the feline urinary bladders examined.

It was observed that in the llama (Graziotti et al., 2003), the umbilical artery, which was given off at a distance of 1–2 cm from the origin of the internal iliac artery, extended caudoventrally and continued with its course as the cranial vesical artery, which gave one or more twigs to the cranial part of the urinary bladder. In the llama (Graziotti et al., 2003), this branch was not determined to give off a branch to either the uterus or the deferent duct. In cats, the umbilical artery, which formed the cranial vesical artery, did not supply these organs either. However, it was observed that this artery gave off slim branches to the ureter. It has also been reported that the internal pudendal artery extends caudoventrally along the lateral wall of the pelvic cavity, that the internal iliac artery is the most ventrally situated terminal branch, and that the prostatic artery in males and the vaginal artery in females ramify near their origin in llamas (Graziotti et al., 2003). Along its course to the prostate gland and the postprostatic urethra, the prostatic artery gives off two collateral branches. One of these branches is the artery of the deferent duct and gives off the caudal vesical artery and ureteral branches, whilst the other is the urethral artery, which ends at the preprostatic urethra (Graziotti et al., 2007). In agreement with the findings of the present study, it was observed that in llamas (Graziotti et al., 2003, 2007), the internal pudendal artery gave off urethral branches prior to its terminal bifurcation, and later divided into the ventral perineal artery and artery of the penis. On the other hand, it was observed that in the boar (Trappe, 1984), the prostatic artery also contributed to the supply of the perineal region. In a study conducted in cattle (Wyrost et al., 1991), it was determined that, the ejaculator ducts, the initial part of the urethra, urinary bladder, vesicular glands and prostate gland, were supplied by the deferential branches (*ramus deferentis*) of the prostatic artery.

In domestic mammals such as the bull, stallion and boar (Nickel et al., 1981), it was seen that, apart from the cranial vesical artery, the umbilical artery also gave off branches supplying the ureter and deferent duct. Furthermore, in the indicated animal species, the prostatic artery, after giving off a branch to the prostate gland, also ramified branches supplying the ureter (*ramus uretericus*), urinary bladder (*a. vesicalis caudalis*) and urethra (*rami urethralis*). A similar vascularization pattern was observed in the tom-cats examined in the present study. It was also determined that the ureteral branches originated from the cranial vesical artery, although no mention was made regarding other domestic mammals (Nickel et al., 1981). However, it should be noted that the level of origin of the arteries may to varying extents differ between different species. Nickel et al. (1981) and Barone (1996) have suggested classifying the internal iliac artery under two groups, namely, the "long iliac type" in ruminants and swine, and the "short iliac type" in carnivores, and have reported that the indicated artery gives off visceral intrapelvic and parietal branches. The ramification of the feline iliac artery was in compliance with the short iliac type model suggested for carnivores (Nitschke and Preuss, 1971). Graziotti et al. (2003) reported that in the llama, the iliac artery could display features of the long type internal artery, as is the case in other ruminants, yet, also showed that the intrapelvic visceral branches originated from the internal pudendal artery. That the ramification pattern of the internal pudendal artery supplying the urinary bladder was the same in the cats examined in the present study as in llamas suggests that the classification of arteries as long or short types may not always be valid. Findings reported by Graziotti et al. (2003) are supportive of this proposition. The results of the present study, which was conducted in domestic tom-cats, suggest that vascular organisation may not always be related to phylogenetic closeness between species. For instance, Graziotti et al. (2003) also reported that the internal iliac artery of the llama presented a greater similarity to the artery of the cat, which belongs to the carnivore type. The origins of the parietal and visceral branches were similar in both species. Graziotti et al. (2007) argued that the similarity of the llama and camel (Kadhim et al., 2001) with respect to the distribution of the internal pudendal artery and the internal iliac artery was strong evidence of a common phylogenetic origin.

The pelvic arterial system has also been investigated in talpid species (Ventura and Lopez-Fuster, 1998), and the differences in these species from other insectivores and mammalian orders were evaluated. In talpid species, similar to several domestic mammals (Nickel et al., 1981), it was also observed that the prostatic artery, which originated from the internal pudendal artery, displayed a visceral distribution composed of ureteric branches, the caudal vesical artery and branches to the deferent duct. In cases where the cranial vesical artery did not exist, it was reported that starting from the neck of the urinary bladder the caudal vesical artery extended cranially along the lateral border and vascularised the entire organ. Similar to the findings in tom-cats, it was determined that the internal pudendal artery finally divided into the ventral perineal artery and the artery of the penis. The vascularization of talpid species and the cat also display close similarities. It was reported in the guinea pig that similar to talpid species, the prostatic artery gave off ureteral branches (Aharinejad et al., 1990). However, it has been determined that in tom-cats, these branches originate from the vesical artery and supply the pelvic part of the ureter.

The findings made in the present study may constitute a reference for the interpretation of the vascular connection of the urinary bladder with its neighbouring organs as well as for further morphological studies and training in anatomy. Also, they may contribute to clinical studies and inform surgical interventions of lower urinary system disorders, while underlining the great significance of arterial supply for urinary system oncology, which may aid in the evaluation of pathological cases arising from neovascularization.

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