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Anatomy

Arterial supply to the rabbit male genital organs

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ABSTRACT. The improvement of veterinary care has prolonged the lifespan of rabbits, and the number of rabbits suffering from age-related, male genital disorders may increase in the near future. This could result in increased opportunities for male genital surgery, requiring knowledge of their arterial anatomy, which, however, has not been sufficiently studied. Therefore, the arteries supplying the genitals were observed in 20 male New Zealand White rabbits. The testis was supplied by the testicular artery originating from the abdominal aorta. The right testicular artery usually emerged at a more cranial level than the left artery (65%). The testicular artery encircled the testis in the sagittal plane and bifurcated (95%) or trifurcated (5%) at the caudal extremity of the testis before entering the parenchyma. The epididymis was supplied by the epididymal branches, either from only the testicular artery (75% of the right and 80% of the left halves) or from both the testicular artery and aorta. The deferent duct was supplied in all halves by the dorsal and ventral branches of the deferential artery, which usually arose from the umbilical artery. The accessory genital glands were supplied by the dorsal branch of the deferential artery and the prostatic artery. The latter, which emerged from the internal iliac artery, exhibited 3 branching types. The most frequent type (55% of the right and 45% of the left halves) had 3 branches supplying the accessory genital glands. These findings will help improve rabbit genital surgery.

KEY WORDS: angiology, deferential artery, prostatic artery, rabbit, testicular artery

Improvement of the breeding environment and veterinary care has prolonged rabbit life expectancy [19]. Male genital diseases, such as testicular tumors, prostatic abscesses and prostatomegaly for example, occur with aging [2, 3, 7, 11, 19]. Therefore, with the expected increase in the number of older rabbits, one can assume that, in the near future, surgery of the male genital organs will be more commonly performed in veterinary practice to cure male genital disorders. For most testicular tumors, surgical removal is curative [2, 7], and for prostatic diseases, excision of the prostate or surgical marsupialization are effective [11]. However, because of the lack of knowledge about genital diseases in male rabbits, the therapeutic options for male genital diseases may be applied based on those for other pet animals [11, 19]. To extrapolate the surgical procedure precisely, the differences in the arterial supply to the male genital organs between the rabbit and other mammals must be borne in mind. Furthermore, knowledge of not only the arterial supply to each male genital organ in the rabbit but also individual arterial variations is important to avoid unexpected bleeding, which may lead to a life-threatening condition during the surgery. Therefore, detailed descriptions of the arteries supplying the rabbit male genital organs are beneficial for refining rabbit surgery.

In prior studies in rabbits, the arterial supply to the rabbit male genital organs, such as the testis, epididymis, deferent duct, and accessory genital organs, was poorly described [1, 4, 5, 10, 13, 14, 18]. The testis is supplied by the testicular artery, which emerges from the abdominal aorta. The combination of the craniocaudal branching level of the right and left testicular arteries is described inconsistently. For example, Rajtová and Danko [14] reported that the right testicular artery originated at a more cranial level than the left one, while Krause [10] reported that the left testicular artery arose at a more cranial level than the right one. Moreover, Arredondo *et al*. [1] reported cases where the right testicular artery emerged at a more cranial level than the left one (83%), cases where the left testicular artery emerged at a more cranial level than the right one (10%), and cases where the right and left testicular arteries originated at the same branching level (7%).

As to the pattern of the arterial supply to the epididymis and deferent duct, prior studies only described the origin of the artery supplying these organs [4, 5, 10, 13, 14, 18]. It has been reported that the epididymis receives its arterial supply via the epididymal branches that emerge only from the testicular artery [4], from the testicular and deferential arteries [5], or from the testicular and

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external pudendal arteries [18], and the ductus deferens is supplied by the deferential artery that emerges from the umbilical artery [4, 10, 13, 18]. However, the detailed ramifications and distribution patterns of the epididymal branches and deferential artery have not been reported in prior studies.

The rabbit has unpaired vesicular, proprostate, and prostate glands and paired paraprostate and bulbourethral glands, all of which are supplied mainly by the prostatic artery [4, 10, 13, 17, 18]. Barone [4] reported that the prostatic artery emerged from the internal iliac artery and distributed to the vesicular, prostate, paraprostate, and bulbourethral glands, but he did not mention the arterial supply to the proprostate gland. Moreover, Orsi *et al*. [13] reported that the prostatic artery (=their urogenital artery) was absent in 20% of cases, and in such cases, the umbilical artery supplied the prostate gland.

As described above, the pattern of the arterial supply to the rabbit male genital organs has been insufficiently described and still needs to be studied. Therefore, in the present study, the aim was to elucidate the detailed arterial supply pattern to the male genital organs and its individual variations in the rabbit.

MATERIALS AND METHODS

This study was approved by the Research Ethics Committee for Animal Experimentation of Tokyo University of Agriculture and Technology (No. 28–20, 30–43).

In this study, 20 male New Zealand White rabbits (13–14 weeks old, weighing 2.5–3.0 kg), purchased from Tokyo Laboratory Animal Science Co. (Tokyo, Japan), were dissected. Sixteen male rabbits were newly used for the present study, and the remaining 4 rabbits were used in our previous studies [8, 9]. The experimental procedures were similar to those used in our previous studies [8, 9]. In brief, all rabbits were euthanized with intraperitoneal injection of sodium pentobarbital (60 mg/kg) and perfused transcardially with saline followed by 10% formalin or 4% paraformaldehyde. Then, for better visualization of the arteries, 3–8 m*l* of latex (Neoprene latex 601A or 842A; Showa Denko, Kawasaki, Japan) colored with red poster coloring (Turner Colour Works Ltd., Osaka, Japan) or red acrylic paint (Liquitex; Bonny Colart Co., Ltd., Tokyo, Japan) were injected through a cannula inserted into the thoracic or abdominal aorta. The specimens were fixed for more than 7 days in 10% formalin before dissection. The arteries supplying the male genital organs were observed with the naked eye or under the surgical microscope (L-0950SDP, Inami & Co., Ltd., Tokyo, Japan) and photographed with a digital camera (Nikon D5500, Nikon Corp., Tokyo, Japan). The contrast and resolution of the photographs were adjusted with Adobe Photoshop (Adobe Systems, San Jose, CA, USA), and Adobe Illustrator (Adobe Systems) was used to prepare the schematic drawings.

Regarding terminology, the artery supplying the proximal portion of the deferent duct is referred to as the "ventral branch" of the deferential artery and the artery supplying the distal portion of the deferent duct is referred to as the "dorsal branch". The nomenclature of the other arteries and related structures was based on the Nomina Anatomica Veterinaria [12].

RESULTS

The rabbit testis, epididymis, deferent duct, and accessory genital glands received their arterial supplies via the testicular, deferential, and prostatic arteries (Fig. 1). The pattern of arterial supply to these organs showed frequent individual variations without any clear correlation between the vascularization pattern of each organ. To distinguish the branching type of the epididymal branch and the prostatic artery, the branching type of the epididymal branch is referred to as "Ep-Type", and that of the prostatic artery is referred to as "Pro-Type".

Arterial supply to the testis

The testis was supplied by the testicular artery that emerged from the abdominal aorta (Fig. 1). In 13 cases (65%), the right testicular artery emerged at a more cranial level than the left one, while in 7 cases (35%), the left testicular artery arose at a more cranial level than the right one. After originating from the abdominal aorta, each testicular artery ran caudolaterally and passed through the inguinal canal to distribute to the testis. The testicular artery circled around twice on the testis in a sagittal plane (Figs. 1 and 2). That is, after reaching near the cranial extremity of the testis, the testicular artery ran toward the caudal extremity along the epididymal border and then turned ventrally around the caudal extremity to run cranially along the free border. The testicular artery again went back toward the caudal extremity along the epididymal border medial to the first course and divided into 2 or 3 terminal branches near the caudal extremity (Fig. 2). Each of these branches ran to the cranial extremity along the free border to enter the testicular parenchyma there. In 19 halves each on the right and left sides (95%) (Fig. 2), the testicular artery divided into 2 terminal branches, and in the remaining 1 half each on the right and left side (5%), the testicular artery divided into 3 terminal branches.

Arterial supply to the epididymis

The epididymis received its arterial supply via the epididymal branches that emerged from only the testicular artery, or from both the testicular artery and the abdominal aorta (Figs. 1 and 3). Furthermore, the tail of the epididymis close to the initial part of the deferent duct was supplied by the deferential artery (Fig. 4C and 4D). The epididymal branches originated from the testicular artery at up to 5 different levels along the proximodistal axis of the testicular artery depending on each half of the specimen, the level of the inguinal canal, the level just proximal to the convoluted portion of the testicular artery, the level of the convoluted portion of the testicular artery, the level proximal to the bifurcation or trifurcation of the testicular artery at the caudal extremity of the testis,

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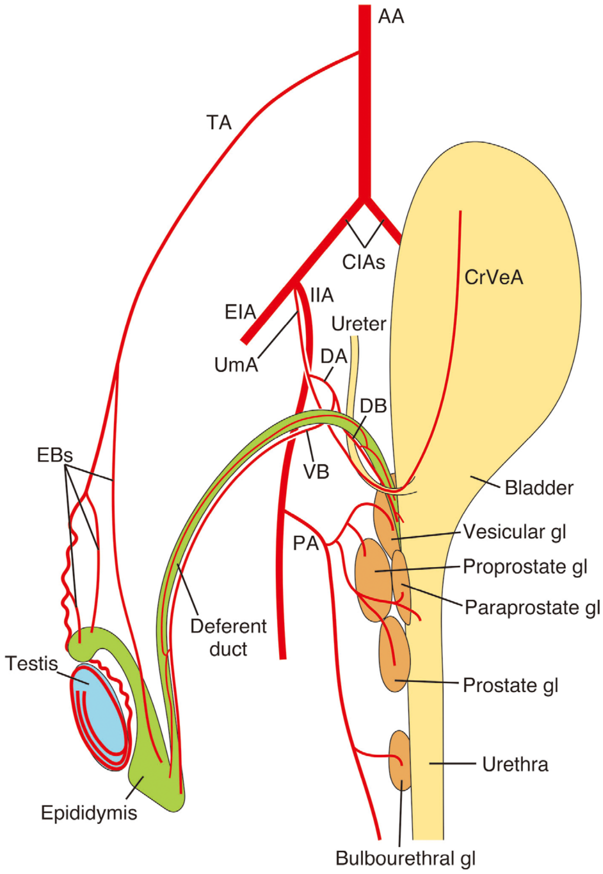

Fig. 1. Schematic drawing of the ramification patterns of the testicular, deferential, and prostate arteries in the ventral view. Abbreviations used in this figure and Figs 2–5: AA, abdominal aorta; BuB, branch to the bulbourethral gland; CIA, common iliac artery; CrVeA, cranial vesical artery; DA, deferential artery; DB, dorsal branch of the deferential artery; EB, epididymal branch; EIA, external iliac artery; gl, gland; IIA, internal iliac artery; PA, prostatic artery; ParaPB, branch to the paraprostate gland; PB, branch to the prostate gland; ProPB, branch to the proprostate gland; TA, testicular artery; UmA, umbilical artery; UrB, urethral branch; VB, ventral branch of the deferential artery; and VesB, branch to the vesicular gland.

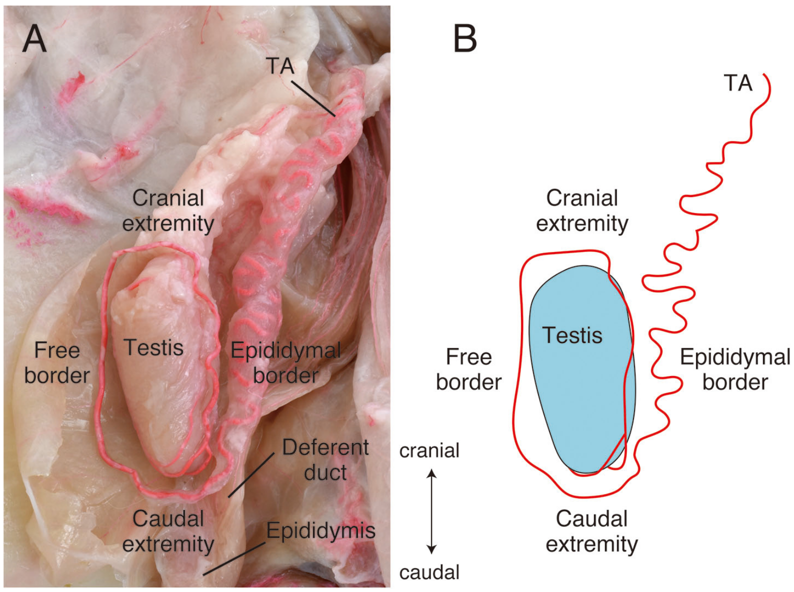

Fig. 2. A: Photograph of the testicular artery that circles twice around the right testis. Medial view. To show the course of the testicular artery, the epididymis is detached from the testis, and the testicular artery is displaced. The original course of the testicular artery is shown in Figs. 1 and 3. B: Schematic drawing of A.

and the level distal to the bifurcation or trifurcation. In the cases where the epididymal branch emerged from the abdominal aorta, the branch issued between the branching levels of the ipsilateral renal and testicular arteries.

The branching pattern of the epididymal branch was divided into 2 major types based on the number of parent arteries that gave rise to the epididymal branches (Fig. 3). Ep-Type 1 included the cases where the epididymal branch emerged from only

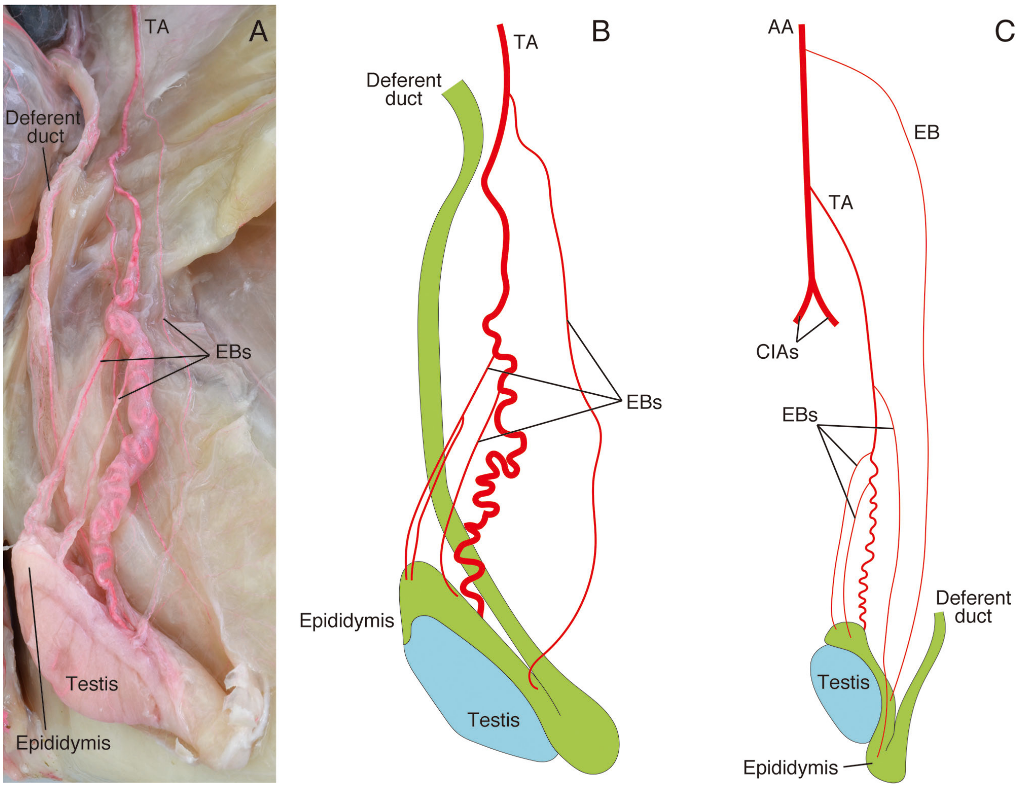

Fig. 3. A: Photograph of the branching pattern of the epididymal branch categorized into Ep-Type 1c. Lateral view of the left testis. B: Schematic drawing of A. C: Schematic drawing of the ramification pattern of the epididymal branch categorized as Ep-Type 2d.

the testicular artery (Fig. 3A and 3B), while Ep-Type 2 included the cases where the epididymal branch emerged from both the testicular artery and the abdominal aorta (Fig. 3C). Moreover, in each type, the cases that had 1 to 5 epididymal branches were, respectively, categorized into subtypes a to e. The number of cases included in each subtype is summarized in Table 1. In any type, the epididymal branches distributed to the head, body, and tail of the epididymis with frequent individual variations.

Ep-Type 1 was observed in 15 halves on the right (75%) and 16 halves on the left (80%). One right half (5%) was categorized as Ep-Type 1a, 5 right halves (25%) and 8 left halves (40%) were included in Ep-Type 1b, and 7 right halves (35%) and 6 left halves (30%) were categorized as Ep-Type 1c, which was the most frequent type observed in the present study (Fig. 3A and 3B). Ep-Type 1d included 2 halves on the right (10%) and 1 half on the left (5%), and the remaining 1 half on the left side (5%) was included as Ep-Type 1e (Table 1).

Ep-Type 2 included 5 halves on the right (25%) and 4 halves on the left (20%), which had 3 to 5 epididymal branches. Therefore, in Ep-Type 2, there were Ep-Types 2c to 2e only, where only 1 epididymal branch originated from the abdominal aorta, and the remaining 2 to 4 branches emerged from the testicular artery (Fig. 3C). Ep-Type 2c was observed in 2 halves each on the right and left sides (10% each), Ep-Type 2d included 1 half on the right side (5%) and 2 halves on the left side (10%) (Fig. 3C), and the remaining 2 halves on the right side (10%) were categorized as Ep-Type 2e (Table 1).

Arterial supply to the deferent duct

The deferent duct was supplied by the deferential artery, whose origin varied in each specimen. In 18 halves on the right (90%) and 19 halves on the left (95%), the deferential artery emerged from the umbilical artery, which usually emerged from the common iliac artery (Figs. 1 and 4). The deferential artery also originated directly from the common iliac or internal iliac artery in each 1 half on the right side (5% each), and from the external iliac artery in the remaining 1 half on the left side (5%). In all halves, the deferential artery was divided into the dorsal and ventral branches near the crossing of the deferent duct and ureter (Figs. 1 and 4). The dorsal branch ran medially to distribute to the distal portion of the deferent duct (Fig. 4A and 4B), and in 8 halves on the right (40%) and 9 halves on the left (45%), the dorsal branch anastomosed to a branch from the prostatic artery near the terminal portion of the deferent duct. The ventral branch ran along the deferent duct and passed through the inguinal canal to distribute to the proximal portion of the deferent duct and the tail of the epididymis close to the initial portion of the deferent duct (Fig. 4C and 4D).

Arterial supply to the accessory genital glands

The vesicular, proprostate, prostate, paraprostate, and bulbourethral glands were usually supplied by both the dorsal branch of the deferential artery and the prostatic artery (Figs. 1, 4 and 5).

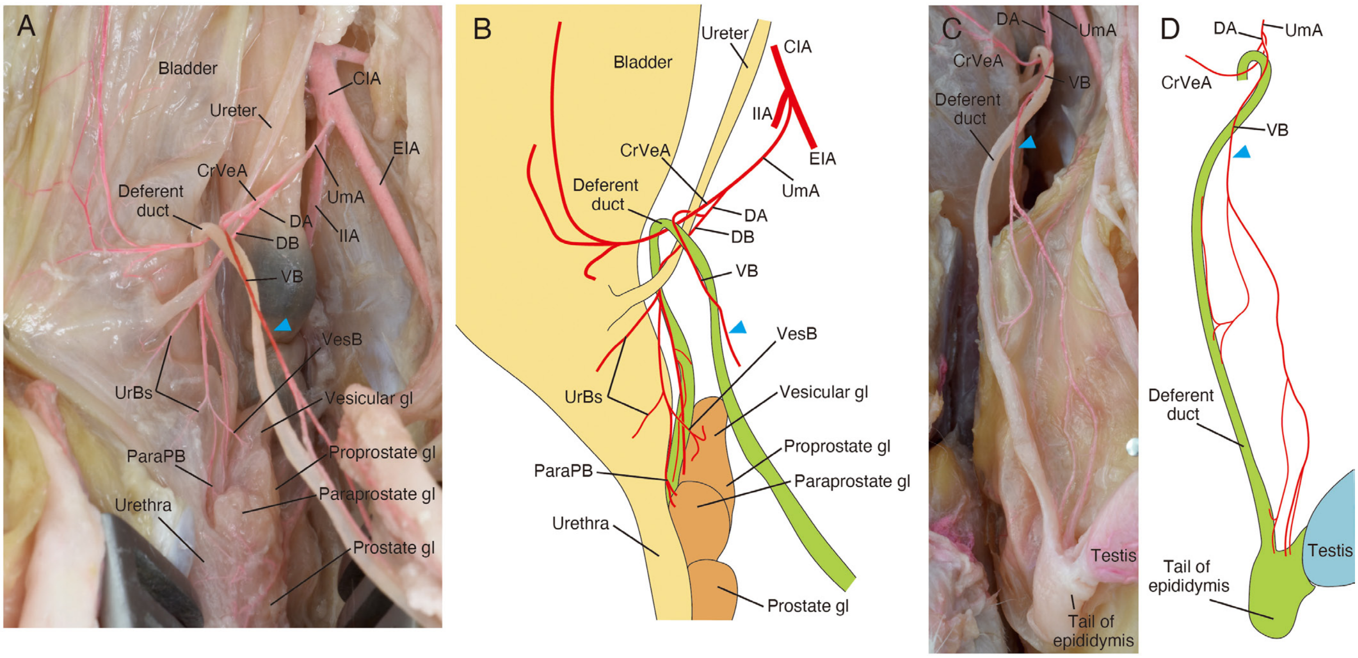

Fig. 4. Photographs and schematic drawings of the dorsal (A and B) and ventral (C and D) branches of the deferential artery. Arrowhead in each panel indicates the same ventral branch of the deferential artery. A: Photograph showing the ramification pattern of the dorsal branch of the deferential artery from a left ventrolateral view. B: Schematic drawing of A. The distal portion of the ventral branch is not illustrated. C: Photograph showing the ramification pattern of the ventral branch of the deferential artery in the medial view. D: Schematic drawing of C.

Table 1. Number of cases in each subtype of Ep-Types 1 and 2

		Subtype				
		a	b	c	d	e
Ep-Type 1	Right	1 (5%)	5 (25%)	7 (35%)	2 (10%)	
	Left		8 (40%)	6 (30%)	1 (5%)	1 (5%)
Ep-Type 2	Right			2 (10%)	1 (5%)	2 (10%)
	Left			2 (10%)	2 (10%)	

Ep-Types 1 and 2, respectively, include the cases where the epididymal branch emerges from only the testicular artery or from both the testicular artery and abdominal aorta. Subtypes a to e, respectively, have 1 to 5 epididymal branches.

The dorsal branch of the deferential artery distributed to the vesicular, proprostate, and paraprostate glands with frequent individual variations (Fig. 4A and 4B), but in 1 half on the right (5%) and 2 halves on the left side (10%), this branch did not supply the accessory genital glands. In 10 halves on the right (50%) and 13 halves on the left (65%) (Fig. 4A and 4B), the dorsal branch of the deferential artery distributed to the vesicular and paraprostate glands. In other halves, this branch supplied the vesicular gland (2 halves on the right [10%] and 4 halves on the left [20%]), the paraprostate glands (4 halves on the right [20%]), the paraprostate and proprostate glands (2 halves on the right [10%] and 1 half on the left [5%]), and the vesicular and proprostate glands (1 half on the right [5%]).

The prostatic artery emerged from the internal iliac artery and ran caudoventrally to supply the accessory genital glands. The ramification pattern of the arterial branches to the accessory genital glands was categorized into 3 types based on the number of branches that originated directly from the prostatic artery to the accessory genital glands (Fig. 5). There were 2 to 4 branches, and in all halves, the most distal branch supplied the bulbourethral gland and the other branches distributed to the vesicular, proprostate, prostate, and paraprostate glands with frequent individual variations.

Pro-Type 1 (Fig. 5A), having 2 branches that emerged from the prostatic artery, was observed in 4 halves on the right (20%) and 2 halves on the left side (10%). Pro-Type 2 (Fig. 5B and 5C), having 3 branches that emerged from the prostatic artery, included 11 halves on the right (55%) and 9 halves on the left (45%). This was the most frequent type observed in the present study. Pro-Type 3 (Fig. 5D) was observed in 5 halves on the right (25%) and 9 halves on the left (45%), where 4 branches emerged from the prostatic artery.

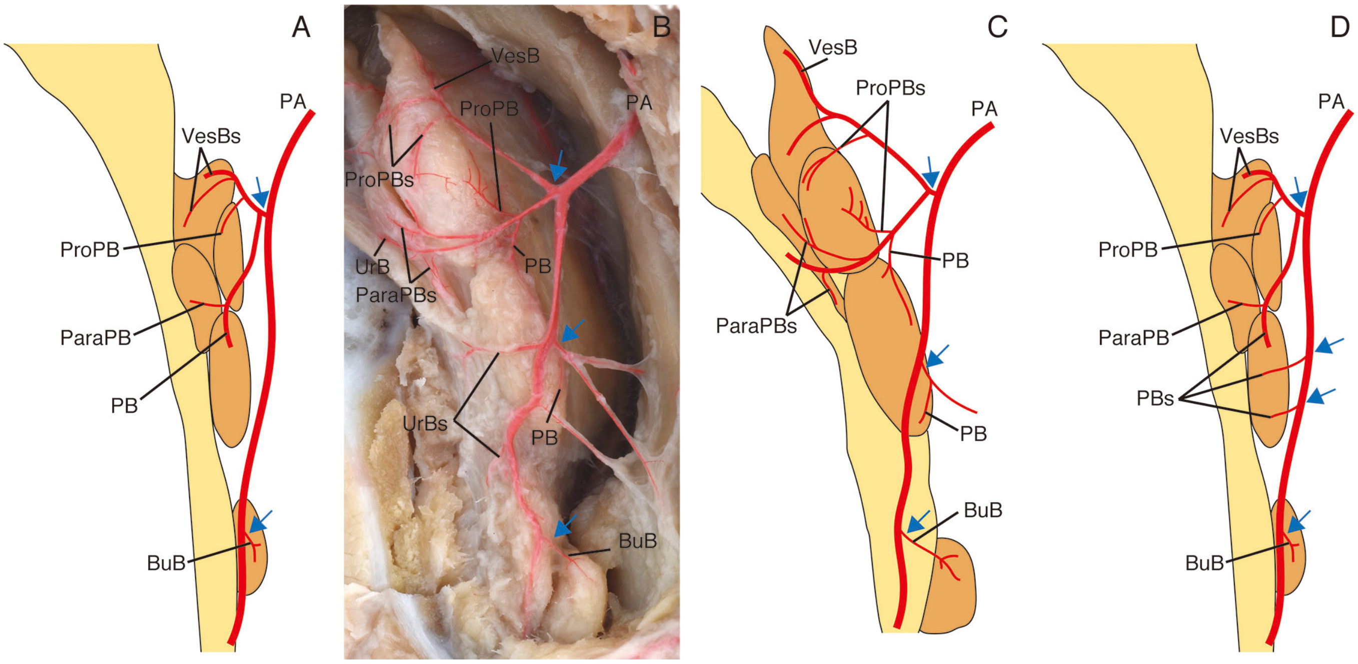

Fig. 5. Photograph and schematic drawings of the pattern of the arterial supply to the accessory genital glands in the left lateral view. Arrows indicate the branches from the prostatic artery to the accessory genital glands. In A, C and D, only the branches to the accessory genital glands are illustrated. A: Pro-Type 1. B: Photograph of Pro-Type 2. C: Schematic drawing of B. D: Pro-Type 3.

DISCUSSION

The present study elucidated the detailed ramification patterns of the arteries supplying the rabbit testis, epididymis, deferent duct, and accessory genital glands, and this is the first study showing individual variations in the pattern of the arterial supply to these genital organs.

In all rabbits examined, the testis received its arterial supply via the testicular artery, in agreement with prior studies [1, 4, 5, 10, 14, 18]. In the present study, the right testicular artery arose at a more cranial level than the left artery in 65% of cases, and in the remaining 35% of cases, the left testicular artery emerged at a more cranial level than the right one. Arredondo *et al*. [1] also reported that the right testicular artery emerged more cranially than the left one in 83% of cases, whereas the left testicular artery originated more cranially than the right one in 10% of cases. The incidence of the combination of the right and left testicular arterial branching level in the study of Arredondo *et al*. [1] is almost consistent with the present findings, but they also reported cases (7%) where the right and left testicular arteries arose at the same branching level. The absence of such cases in the present study, as well as in other prior studies [10, 14], leads to the conclusion that the cases where the right and left testicular arteries emerge at the same branching level are rare in the rabbit. In the present study, the testicular artery encircled the testis twice in the sagittal plane, in agreement with the findings of prior studies [5, 14]. Before entering the testicular parenchyma, the testicular artery divided into 2 (95% of halves) or 3 (5% of halves) terminal branches in the present study, whereas in prior studies, the number of terminal branches was always 2. These variations were reported for the first time in the present study.

The epididymis was supplied by the epididymal branches that arose from the testicular artery and sometimes from the abdominal aorta, and by the ventral branch of the deferential artery in the present study. It has been reported that the epididymis is supplied by the testicular artery [4], by the testicular and deferential artery [5], or by the testicular and external pudendal arteries [18]. The present findings are consistent with those of Chubb and Desjardins [5], except that the abdominal aorta also gave rise to the epididymal branch (25% of right and 20% of left halves). However, the present findings are inconsistent with those of Barone [4] and Tsuzaki [18]. Since both of these authors did not mention the number of rabbits observed, the pattern described in their studies may not be the typical one, but rather represent an accidentally observed pattern due to the small number of rabbits. Moreover, the branching pattern of the epididymal branches was categorized into 2 types based on the number of parent arteries that gave rise to the epididymal branches, and then further divided into 5 subtypes based on the number of epididymal branches in the present study. In fact, the present study is the first showing such individual variations in the origin and number of the epididymal branches. The variation in the origin of the epididymal branch may be related to the developmental process of the epididymis and epididymal branches. In humans [6], it has been described that there are several mesonephric arteries on each side, which are the primitive testicular arteries distributing to the future testis and epididymis. Generally, one of these arteries remains and becomes the definitive testicular artery, but in rare cases, more than 1 mesonephric artery persists to supply the testis and epididymis [6]. It is considered that the epididymal branch that emerged directly from the abdominal aorta in the present study may be a remaining mesonephric artery, which underwent a similar developmental process described in humans.

The deferent duct was supplied by the deferential artery, which emerged from one of the umbilical, common iliac, external iliac, or internal iliac arteries. In 90% of right and 95% of left halves, the deferential artery originated from the umbilical artery, consistent with the descriptions in prior studies [4, 10, 13, 18], but the deferential artery that emerges from the common, external, and internal iliac arteries has not been reported in prior studies [4, 10, 13, 18]. Moreover, in all rabbits observed, it was found for the first time that the deferential artery always bifurcated into the ventral and dorsal branches that, respectively, distributed to the proximal and distal portions of the deferent duct. The ramification pattern of the deferential artery is different among species [15, 16]. Given the course and distribution of these branches, the ventral and dorsal branches in the rabbit, respectively, may correspond to the deferential artery and deferential branch of the prostatic artery in the horse, ruminant, and pig [15, 16]. Thus, the rabbit deferential artery has a wider distribution, and the prostatic artery makes a lesser contribution to the arterial supply to the deferent duct in comparison with other mammals [15, 16].

The accessory genital glands were supplied by the prostatic artery and the dorsal branch of the deferential artery. In all rabbits examined, the prostatic artery arose from the internal iliac artery, in agreement with the findings of prior studies [4, 10, 13, 18]. Orsi *et al*. [13] also reported that the prostatic artery was absent in 20% of cases in Norfolk rabbits. Since New Zealand White rabbits were used in the present study, the incidence of the absence of the prostatic artery in Orsi's study may be due to the strain difference. The ramification pattern of the prostatic artery was divided into 3 types based on the number of branches to the accessory genital glands from the prostatic artery. The number of branches was 2 to 4, with 3 being the most frequent (55% of the right and 45% of the left halves). This is the first report to show such individual variations in the ramification pattern of the prostatic artery.

In the present study, the detailed arterial supply to the rabbit male genital organs was shown, and the individual variations in the pattern of the arterial supply to the epididymis and accessory genital glands were divided into 2 and 3 major types, respectively. Such new anatomical knowledge obtained from the present study will be highly beneficial for the refinement of genital surgical procedures in the rabbit.

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