Original Article

Acta Vet Eurasia 2022; 48(3): 200-210

Examination of the Course and Branching of the *Arteria iliaca interna* in New Zealand Rabbit (*Oryctolagus cuniculus L.*)

Özden ÇAVDIR, Erkut TURAN

Department of Anatomy, Aydın Adnan Menderes University, Faculty of Veterinary Medicine, Aydın, Turkey

Cite this article as: Çavdır, Ö., & Turan, E. (2022). Examination of the course and branching of the arteria iliaca interna in New Zealand rabbit (*Oryctolagus cuniculus L.*). *Acta Veterinaria Eurasia*, 48(3), 200-210.

ORCID IDs of the authors: Ö.Ç. 0000-0003-3522-7195, E.T. 0000-0003-4037-8297.

Abstract

Rabbit is an experimental animal that is widely used to understand the etiology, progression, and treatment strategies of diseases related to the circulatory system. The creation of disease models related to vascular system is particularly preferred in performing surgeries and invasive ex,periments for education purpose. Though rabbit's iliac arteries and their branches are vessels mostly encountered in these procedures, yet there are limited resources on the course and distribution of *arteria (a.) iliaca interna*. Therefore, seven male and seven female New Zealand rabbits have been used to elucidate the detailed ramification patterns of branches from the *a. iliaca interna* using the latex injection method. The *a. iliaca interna* ramified into *a. umbilicalis*, *a. obturatoria*, *a. iliolumbalis*, *a. glutea cranialis*, *a. ovarica or a. prostatica*, *a. glutea caudalis*, *a. pudenda interna, a. perinealis ventralis,* and *a. caudalis lateralis*. The branching pattern of the *a. iliaca interna* showed five variations. According to the findings of the recent study, the vessels supplying the pelvic wall were not originating from the *a. glutea caudalis* rather both visceral and parietal divisions were branching off the *a. iliaca interna*. So, it can be said that among domestic mammals, *a. iliaca interna* of the New Zealand rabbit is similar to ruminant and sus, that is, short pudendal type branching in terms of course and divisions. Hopefully, the information obtained in this study will make a contribution to future anatomical, interventional, and surgical studies using the New Zealand rabbit.

Keywords: Arteria iliaca interna, New Zealand rabbit, ramification pattern, variations

Introduction

Rabbit is an experimental animal that is widely used to understand the etiology, progression, and treatment strategies of diseases related to the circulatory system. The creation of disease models related to circulatory system is particularly preferred in the performing surgeries and experimental invasions (Balastegui et al., 2014; Fuster et al., 2012; Getz & Reardon, 2012; Hong et al., 2001; Nagata et al., 1998). For researches on atherosclerosis, the New Zealand rabbit (*Oryctolagus cuniculus L.*) is the most frequently used animal species (Fuster et al., 2012) after the mouse (Getz & Reardon, 2012). It has been stated that rabbit is the fitting model for the experimental application of deep artery angioplasty in human atherosclerosis (Balastegui et al., 2014).

There are many studies that reveal the anatomy of the rabbit's circulatory system and the distribution and variations of the vessels (Balastegui et al., 2014; Ding et al., 2006; Ekim & Dursun, 2011; Mohamed, 2014; Nagata et al., 1998; Nur et al., 1995; Singh, 1982; Yang & Morris, 1998). Though iliac arteries are vessels used in interventional and experimental surgery in rabbits (Abe et al., 2012; Hong et al., 2001; Kakuta et al., 1998; Nagata et al., 1998; Pai et al., 2005), there are limited resources on the course and distribution of *arteria* (*a.*) *iliaca interna* (Barone, 2011; Barone et al., 1973; Craigie, 1948; El-Karmoty et al., 2017; McLaughlin & Chiasson, 1990; Orsi et al., 1979; Popesko et al., 1992; Wingerd, 1985). The information given in these sources is not detailed enough. Moreover, there are some dissimilarities in the available literature regarding the origin, branching, and naming of the vessels that originated from the *a. iliaca interna* (Craigie, 1948; McLaughlin & Chiasson, 1990).

The main purpose of this study was (1) to examine the main branches of *a. iliaca interna* macroanatomically and to determine the dissimilarities in these branches and (2) to provide anatomical details in depth that might have been missing about the *a. iliaca interna*. Hopefully, the information obtained in this study will make a contribution to future anatomical, interventional, and surgical studies using the New Zealand Rabbit.

Corresponding Author: Erkut TURAN • **E-mail:** eturan@adu.edu.tr or terkut@yahoo.com

Received: February 22, 2022 • **Accepted:** July 1, 2022 • DOI: 10.5152/actavet.2022.22013

Available online at actavet.org

Methods

The study was approved by the Local Ethics Committee on Animal Experiments of the Aydın Adnan Menderes University (no. 2017/021). A total of 14 (7 females and 7 males) adult healthy New Zealand rabbits (*Oryctolagus cuniculus L.*) were used. Weighing average of rabbits was 2113 ± 299.70 g (range: 1774–2660 g). The rabbits were purchased from a unit that has the work permit of the experimental animal producer and supplier with approved by the Ministry of Agriculture.

The general anesthesia was induced with a combination of 5 mg/kg xylazine (Rompun; Bayer) and 35 mg/kg ketamine (Ketanes; Alke), intramuscularly. The anticoagulant (Nevparin; Mustafa Nevzat, 500 IU/kg) was given through the ear vein to prevent blood clotting in the vessels. Then, the rabbit's thorax was opened and the apex of the heart was incised to drain out the blood. After discharging the blood, the plastic catheter was inserted into the arcus aortae via the left ventriculus and, vessels were washed with 0.9% NaCl solution. The rabbits were fixed by injecting 10% formalin through the same pathway, and the abdominal cavity was split along the linea alba. The catheter placed in the *arcus aorta* was pushed to the end of the *aorta abdominalis* and was ligated. For the dissection and follow-up of the branches of *a. iliaca interna*, colored latex with red India ink was perfused manually with the aid of a syringe from a catheter into the *aorta abdominalis*. Then, the entire body of these rabbits was fixed with 10% formalin and stored at +4°C in the cold cabinet. The last part of the large intestine was removed from the cavum abdominis and was ligated from just in front of the beginning of the rectum and ligated just 2 cm behind the first ligation to

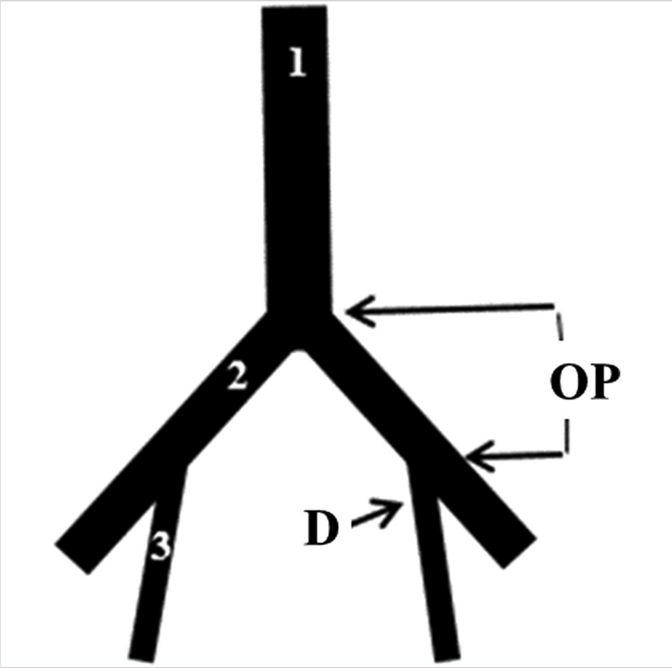

Figure 1.
Measurement of Diameter and Origin Point Distance of a. iliaca interna. 1. Aorta abdominalis, 2. a. iliaca communis, 3. a. iliaca interna. OP = Origin point distance measurement; D = Diameter measurement point.

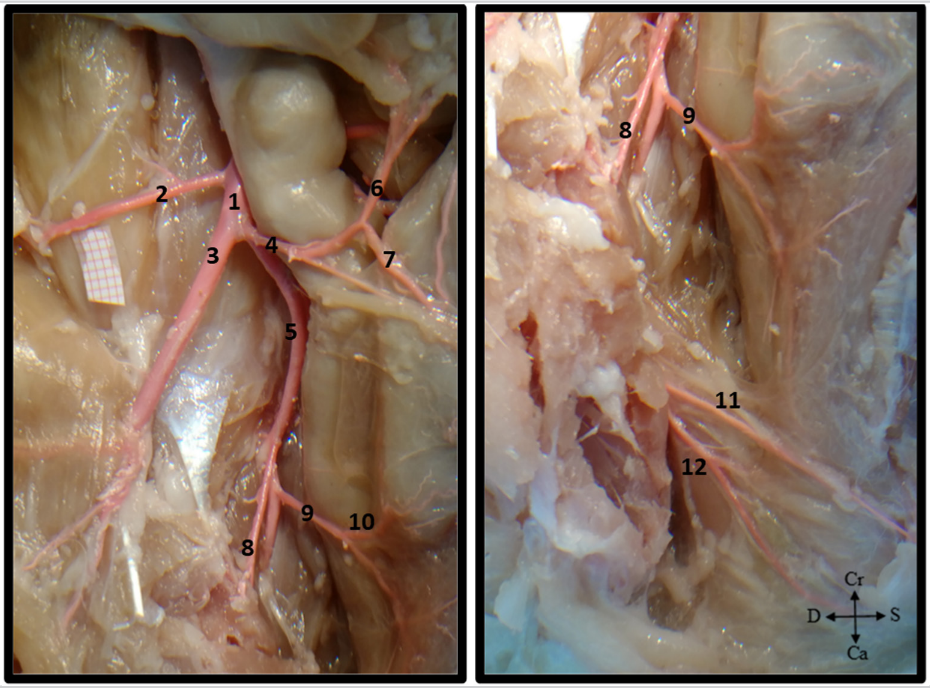

Figure 2.
Course and Branching of a. iliaca interna dextra in the Same Specimen, Ventral View (Female). The Left Image Shows the Cranial Portion of the arteria iliaca interna, While the Right Image Shows the Caudal Portion. 1: A. iliaca communis dextra, 2: a. circumflexa ilium profunda, 3: a. iliaca externa, 4: a. umbilicalis, 5: a. iliaca interna, 6: a. uterina, 7: a. vesicalis cranialis, 8: a. obturatoria, 9: a. vaginalis, 10: a. vesicalis caudalis, 11: a. perinealis ventralis, 12: a. caudalis lateralis. Cr = cranial; Ca = caudal; D = dexter; S = sinister.

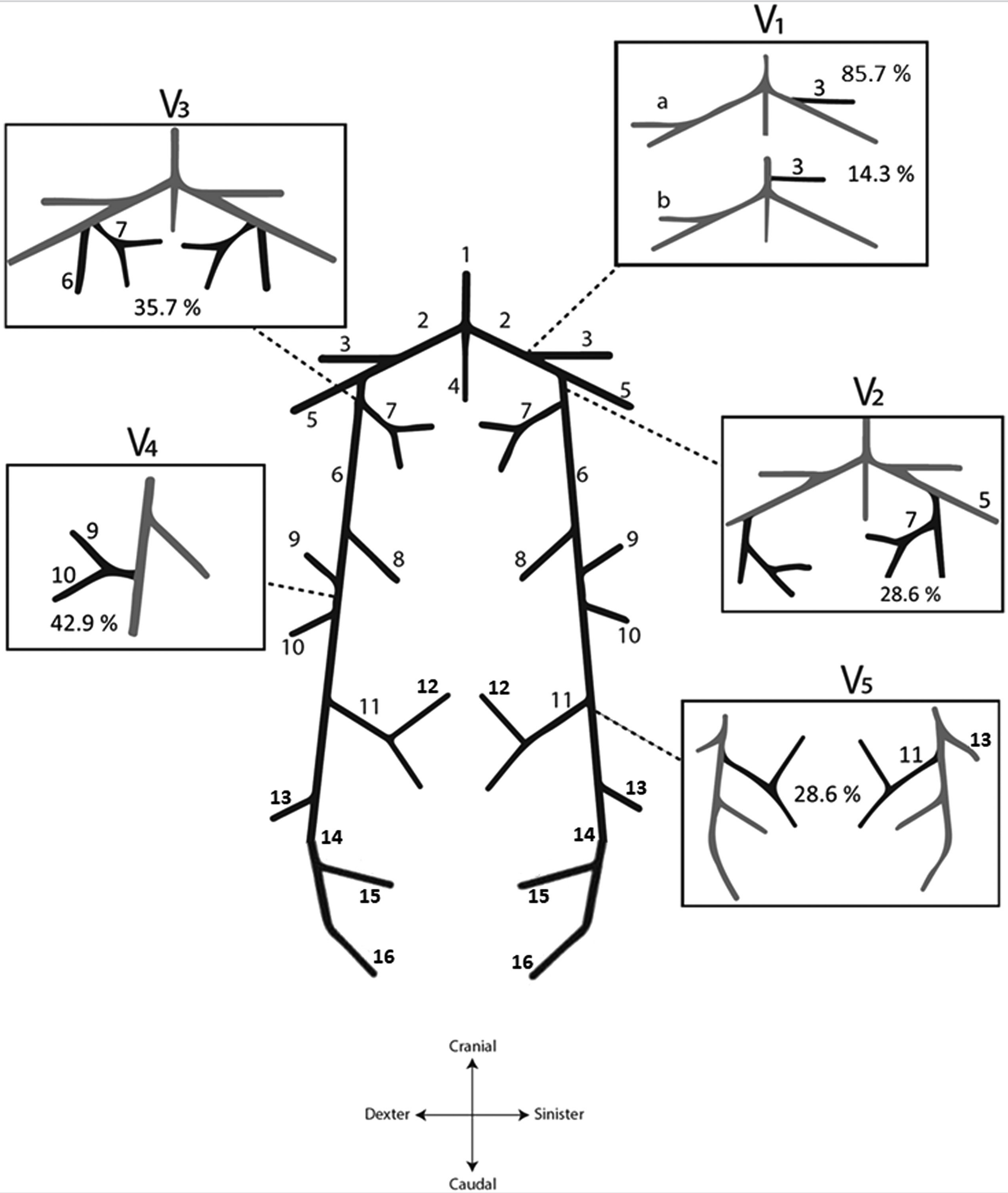

Figure 3.
Schematic Drawings of Ramification Patterns of the a. iliaca interna in a Ventral View. 1: Aorta abdominalis, 2: a. iliaca communis, 3: a. circumflexa ilium profunda, 4: a. sacralis mediana, 5: a. iliaca externa, 6: a. iliaca interna, 7: a. umbilicalis, 8: a. obturatoria, 9: a. iliolumbalis, 10: a. glutea cranialis, 11: a. vaginalis or a. prostatica, 12: a. vesicalis caudalis, 13: a. glutea caudalis, 14: a. pudenda interna, 15: a. perinealis ventralis,16: a. caudalis lateralis.

avoid contamination of the dissection site with feces. The intestinal contents were washed and cleaned via an anal catheter. The connective tissues and fasciae around the vessels were dissected out until *a. iliaca externa* and *a. iliaca interna* were seen. After revealing the *a. iliaca interna*, exploration of the main branches separated from the *a. iliaca interna* was made under dissection loupe. Photographs of the dissected arteries were taken with a digital camera (Canon, EOS 550D). Figures and schematic drawings were prepared using Microsoft PowerPoint 2016.

Diameter measurements were taken at the origin of *a. iliaca interna*. The distance between the *a. iliaca communis* and the onset of the *a. iliaca interna* was measured bilaterally (Figure 1). A micrometric caliper (Mitutoyo series 500 digital caliper) was used for these measurements. The nomenclature of the vessels was based on Nomina Anatomica Veterinaria (NAV, 2017).

Statistical analyses were performed using Statistical Package for the Social Sciences software 19.0 (IBM/SPSS, Armonk, New York, United States) for Windows. Mean values, standard deviations, and 95% CI were calculated for the parameters. The Shapiro–Wilk test was used to test the distribution of measurements for normality. The paired samples *t*-test was used to compare the right and left side measurements. The independent *t*-test was used to make a comparison between measurements of the male and female rabbits. Significance was established at $p < .05$.

Results

Aorta abdominalis were divided into *arteriae* (*aa.*) *iliaca communis dextra et sinistra*. It was observed that *aa. iliaca communis sinistra et dextra* were branched into *aa. circumflexa ilium profunda dextra et sinistra*. Then, *a. iliaca* communis was continued and divided into *a. iliaca* externa and *aa. iliaca interna* on both sides. The *a. sacralis mediana* was found as a direct continuation of the *aorta abdominalis* exactly on the midline. The first branch originating from the *a. iliaca interna* was *a. umbilicalis*. From this artery, *a. ductus deferentis* (males) and *a. uterina* (females) were seen branching, cranially. Next arterial branch separated from *a. umbilicalis* and headed backward was *a. vesicalis cranialis*. Then, the second main vessel leaving *a. iliaca interna* and advancing toward *foramen obturatum* was found to be *a. obturatoria*. After *a. obturatoria*, at the level of *incisura ischiadica major*, first branch was *a. iliolumbalis* and then *a. glutea cranialis* was witnessed. Immediately after these vascular branches, *a. iliaca interna* was continued as *a. vaginalis* or prostatica in the pelvic region. The branch separated from *a. vaginalis* or *a. prostatica* and headed forward was *a. vesicalis caudalis*. After the separation of *a. vaginalis* or *a. prostatica*, *a. iliaca interna* was found dumping below *musculus cocygeus* and vanished. But just before heading under the *musculus cocygeus* dorsally, it gave another branch at the level of *incisura ischiadica minor* called *a. glutea caudalis*. It was determined that the branch after *a. glutea caudalis* was the *a. pudenda interna*. *A. pudenda interna* became visible again after passing under

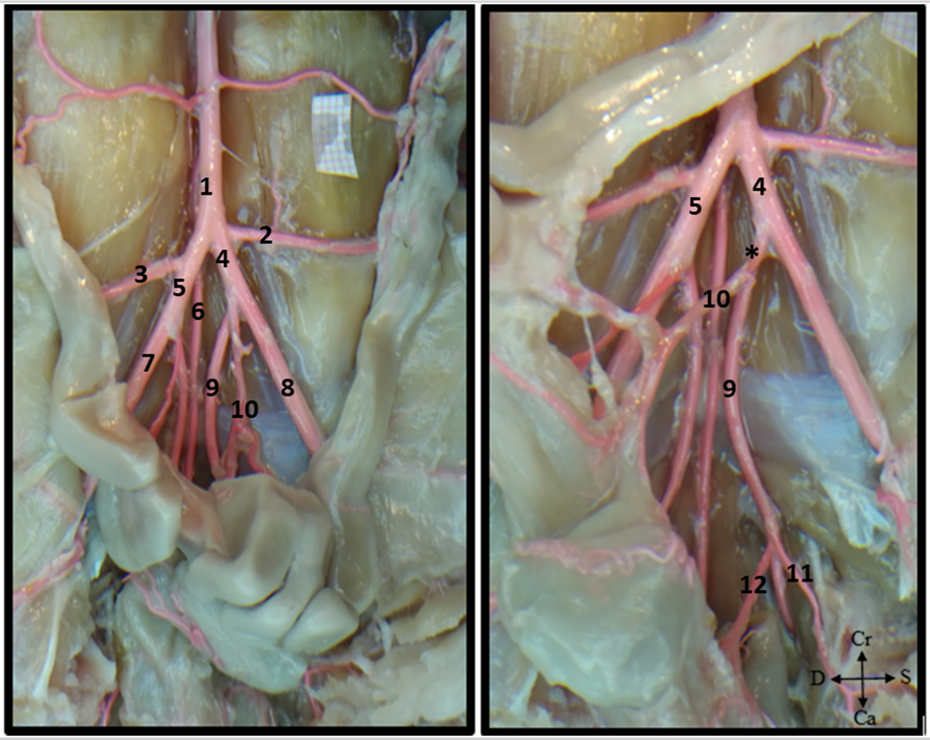

Figure 4.
*Asymmetry Observed at the Origin of a. circumflexa ilium profunda and a. iliaca interna. *a. umbilicalis Originates from a. iliaca interna (Variation 1A, Variation 2) Ventral View (female). 1: Aorta abdominalis, 2: a. circumflexa ilium profunda sinistra, 3: a. circumflexa ilium profunda dextra, 4: a. iliaca communis sinistra, 5: a. iliaca communis dextra, 6: a. sacralis mediana, 7: a. iliaca externa dextra, 8: a. iliaca externa sinistra, 9: a. iliaca interna sinistra, 10: a. umbilicalis sinistra, 11: a. obturatoria, 12: a. vaginalis.*

the musculus coccygeus, giving *a. perinealis ventralis* division and was finally ended as the *a. caudalis lateralis* (Figure 2).

In dissection findings of the rabbit, *a. iliaca interna* and its main branches generally advanced as mentioned above, but there were variations in the research materials other than this general distribution. Variations were grouped as described below.

Variation 1A
Aa. circumflexa ilium profunda sinistra et dextra originated from the *a. iliaca communis*. In 12 cadavers (6 females, 6 males), *aa. circumflexa ilium profunda sinistra* was found to be separated earlier than *a. circumflexa ilium profunda dextra* (85.7%) (Figure 3, 4).

Variation 1B
In two cadavers (two males), *a. circumflexa ilium profunda sinistra* was seen originating directly from *aorta abdominalis* while *a. circumflexa ilium profunda dextra* was found to be initiated from *a. iliaca communis* (14.3%) (Figure 3, 5).

Variation 2
Asymmetry was detected between the origin points of *aa. iliaca interna sinistra et dextra*. In four cadavers (one female, three males), the origin of *a. iliaca interna sinistra* was found to be more cranial (28.6%) (Figure 3, 4).

In the remaining ten cadavers, the exit point of the vessel on the right and left sides was almost in line (71.4%) (Figure 3).

Variation 3
It was observed that *a. umbilicalis* originated on both sides of *a. iliaca* communis in five cadavers (three females, two males, 35.7%) (Figure 3, 6).

Whereas in the left over nine cadavers, *a. umbilicalis* commenced from *a. iliaca interna* (64.3%) on both sides (Figure 3).

Variation 4
A. iliolumbalis and *a. glutea cranialis* started from a common root and branched into two in six cadavers on both sides (three females, three males) (42.9%) (Figure 3, 7).

In the remaining eight cadavers, these two vessels were seen originating as separate vessels from the *a. iliaca interna* on both sides (57.1%) (Figure 3, 8).

Variation 5
In four cadavers, the origin of *a. vaginalis* (three females) or *prostatica* (one male) started from *a. pudenda interna;* it was caudal than the *a. glutea caudalis* (28.6%) on both sides (Figure 3, 9).

In the remaining ten cadavers, *a. vaginalis* (four females) or *prostatica* (six males) began just after the *a. obturatoria* (71.4%) on both sides (Figure 3).

No statistically significant differences were found in the lengths and diameters of the right and left sides and between male and female rabbits (Table 1) (Figure 10).

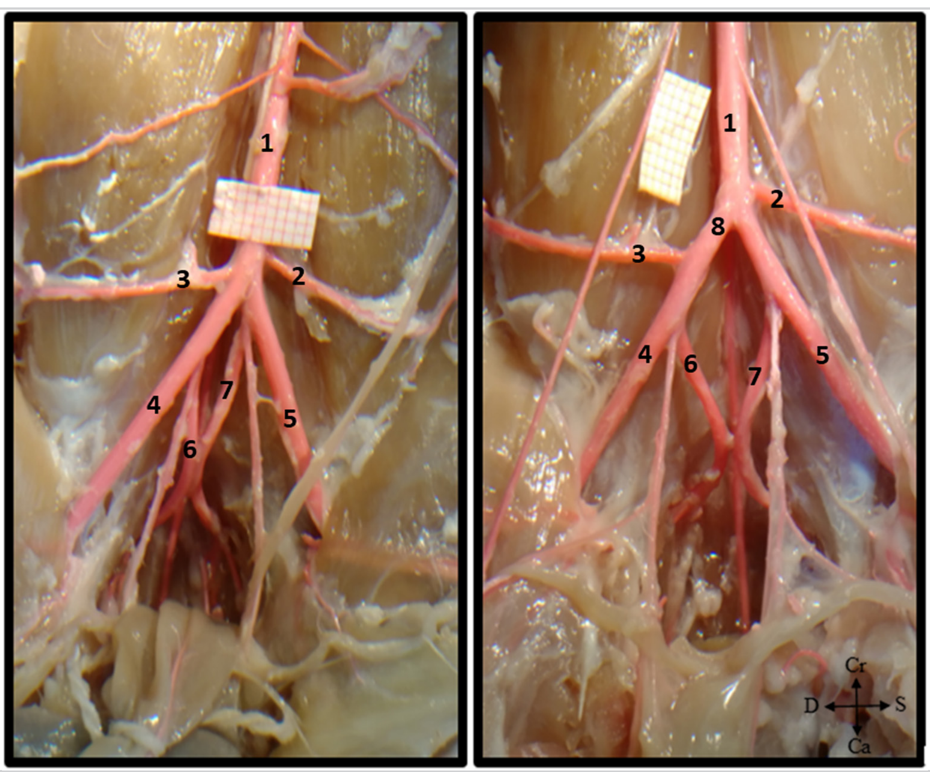

Figure 5.
A. circumflexa ilium profunda sinistra (2), Originates from aorta abdominalis (1) and a. circumflexa ilium profunda dextra (3) Originates from a. iliaca communis dextra (8) (Variation 1B). Ventral View (Male). 1: Aorta abdominalis, 2: a. circumflexa ilium profunda sinistra, 3: a. circumflexa ilium profunda dextra, 4: a. iliaca externa dextra, 5: a. iliaca externa sinistra, 6: a. iliaca interna dextra, 7: a. iliaca interna sinistra, 8: a. iliaca communis dextra.

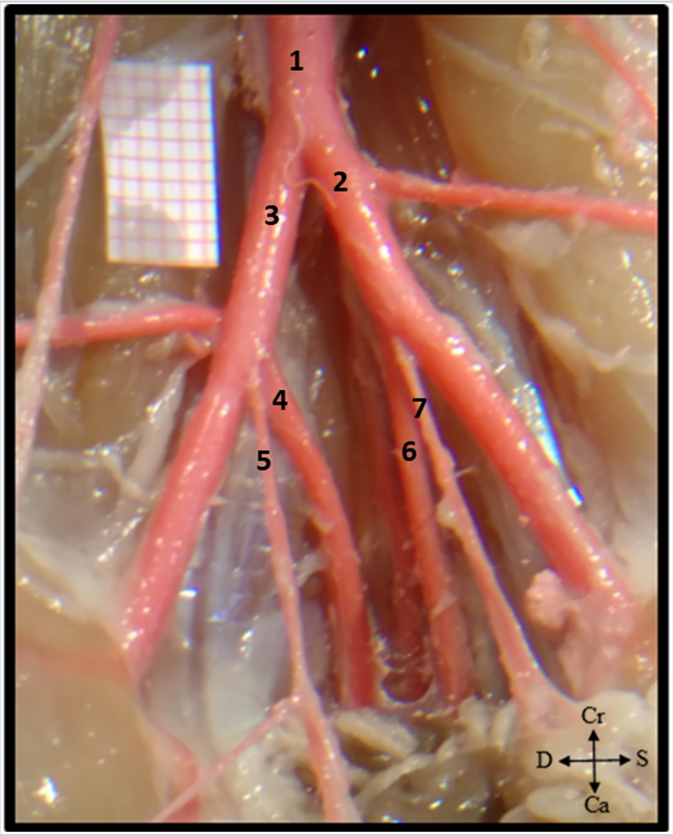

Figure 6.
Aa. umbilicales (5, 7) Originated from aa. iliaca communes (2, 3) (Variation 3). Ventral View (Male). 1: Aorta abdominalis, 2: a. iliaca communis sinistra, 3: a. iliaca communis dextra, 4: a. iliaca interna dextra, 5: a. umbilicalis dextra, 6: a. iliaca interna sinistra, 7: a. umbilicalis sinistra.

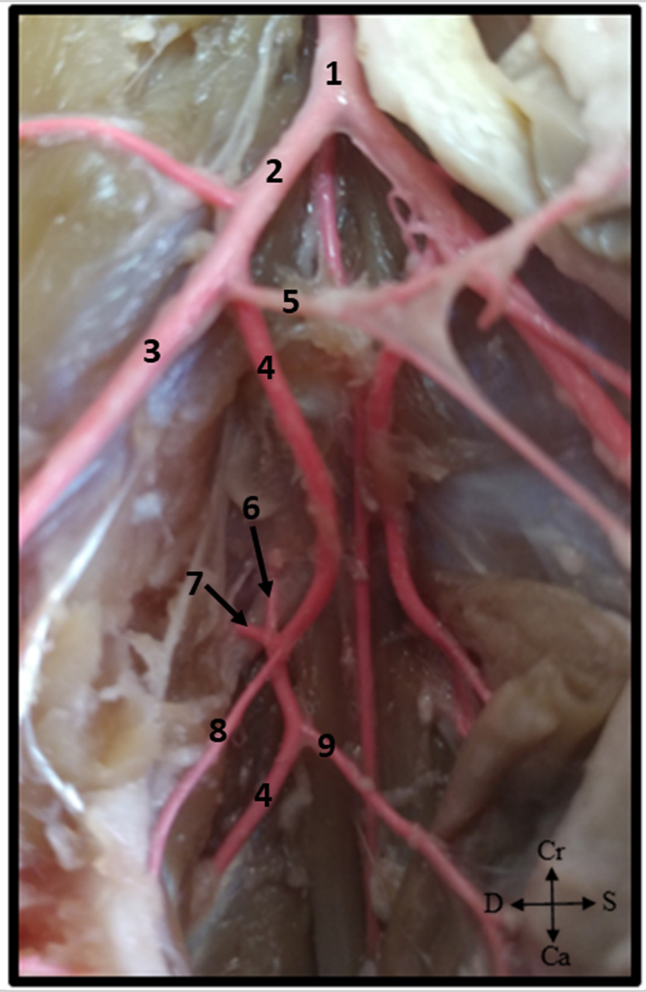

Figure 7.
Dispersion of a. iliolumbalis (6) and a. glutea cranialis (7) as separate roots from a single root (Variation 4). Ventral view (male). 1: Aorta abdominalis, 2: a. iliaca communis dextra, 3: a. iliaca externa dextra, 4: a. iliaca interna dextra, 5: a. umbilicalis dextra, 6: a. iliolumbalis dextra, 7: a. glueta cranialis dextra, 8: a. obturatoria dextra, 9: a. prostatica dextra.

Discussion

In comparison to human medicine, there are very limited studies evaluating the branching pattern and variations of *a. iliaca interna* in veterinary sciences (only dogs and cats) (Avedillo et al., 2015, 2016a, 2016b; Gonzalez et al., 2015). To our knowledge, only two research articles (El-Karmoty et al., 2017; Orsi et al., 1979) described ramification patterns of pelvic visceral arteries of the rabbit but descriptions of ramification patterns variations were not comprehensive in these studies. In rabbit, the information given in classical veterinary anatomy textbooks about *a. iliaca interna* is also not in depth plus the information presented there is having greater dissimilarities. This might be the first detailed report to show the remarkable individual variations and their incidences in the ramification patterns of the arteries that originate from the *a. iliaca interna* in the New Zealand rabbit. Nevertheless, the study might have a limitation regarding the number of animals used. In fact, when this limitation is taken into consideration, the authentication of the findings obtained in the study increased as less number of animals corresponded to the obtained variations. Moreover, in some of the studies (El-Karmoty et al., 2017; Kigata & Shibata, 2020a) investigating the *a. ilica interna* and its branches in rabbits, the number of animals was seen smaller (10–20 samples). This is also especially important in the 3R rule regarding the use of experimental animals. The greater the number of animals used, the greater will be the overall costs in terms of animal suffering. Therefore, the number of animals used should be the minimum that is consistent with the aims of the experiment (Zurlo et al., 1996).

We observed that in some such sources, which are related to the anatomy of the rabbit, there is no uniformity in the terminology used in naming the vessels (Craigie, 1948; McLaughlin & Chiasson, 1990). Likewise, certain terms in the sources belongs to two-legged mammals while others are related to four-legged mammals. In the current study, the vessels are named in accordance with the areas of vascularization described in domestic mammals.

There were no statistically significant differences in origin point distance and diameters of the right and left *a. iliaca interna* between male and female rabbits (Table 1). The data of distance and diameter

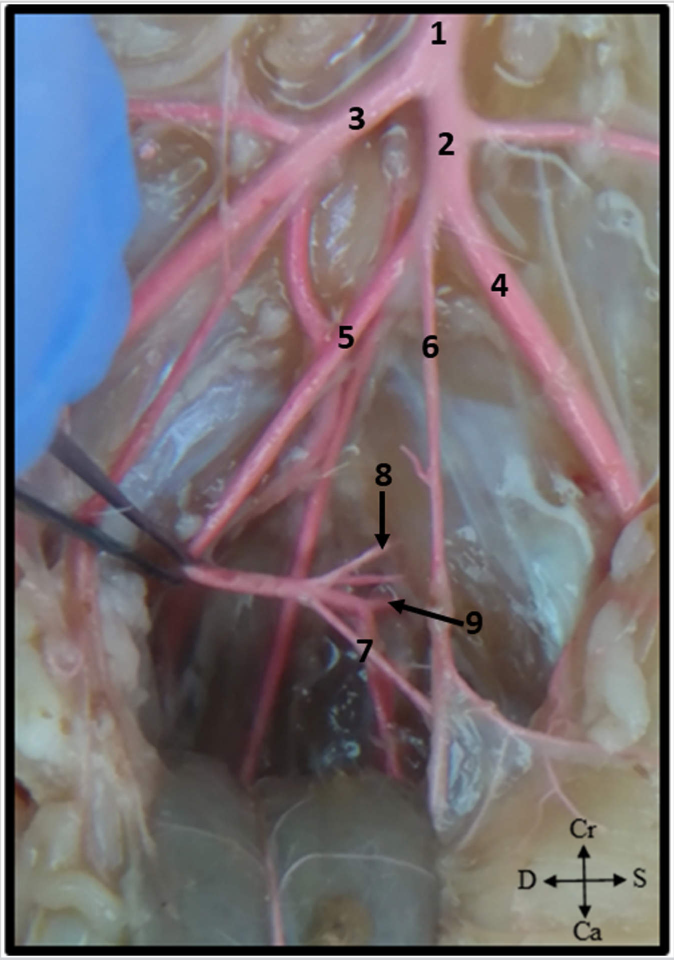

Figure 8.
The Separate Branching of a. iliolumbalis (8) and artreia glutea cranialis (9) from a. iliaca interna. (Variation 4) Ventral View (Male). 1: Aorta abdominalis, 2: a. iliaca communis sinistra, 3: a. iliaca communis dextra, 4: a. iliaca externa sinistra, 5: a. iliaca interna sinistra, 6: a. umbilicalis sinistra, 7: a. obturatoria sinistra, 8: a. iliolumbalis sinistra, 9: a. glutea cranialis sinistra.

measurements can be important for experimental catheterization and ligation.

In domestic mammals, the ramification pattern of the branches from the *a. iliaca interna* is categorized based on the origin of the *a. umbilicalis*, *aa. glutea carnialis et caudalis*, and *a. pudenda interna*, all of which are thought to be the principal branches of the *a. iliaca interna* in domestic mammals. The origin of these principal branches differs among domestic species. In particular, the origin and branching pattern of the *a. pudenda interna* root two different nomenclatures. In ruminants and sus, *a. iliaca interna* runs backward through the pelvis and gives branches supplying blood to the pelvic wall and organs (short pudendal type). In equidae and canis, *a. pudenda interna*, originating as a strong single vessel from the *a. iliaca interna*, provides vascularization to the intrapelvic organs (long pudendal type) (Nickel et al., 1981). In two previous research articles, it was reported that the rabbit has a long pudendal branching pattern, unlike classical anatomy textbooks (El-Karmoty et al., 2017; Orsi et al., 1979).

In this long pudendal branching system, three main branches originate from *a. iliaca intena* named *a. glutea caudalis*, *a. pudenda interna*, and *a. umbilicalis*. Among these vessels, *a. glutea caudalis* is the chief subdivision that provides branches for the pelvic wall (Avedillo et al., 2015; Nickel et al., 1981). According to the findings of the recent study, the vessels that supply the pelvic wall were not originating from the *a. glutea caudalis* rather visceral and parietal branches of the pelvis were branching off the *a. iliaca interna*. So, it can be said that among domestic mammals, the New Zealand rabbit's *a. iliaca interna* is similar to ruminant and sus, that is, short pudendal type branching in terms of course and branching.

In rabbit *a. circumflexa ilium profunda* starts from *a. iliaca communis* (Barone, 2011; Barone et al., 1973; Bavaresco et al., 2012; McLaughlin & Chiasson, 1990; Popesko et al., 1992). However, Craigie (1948) named this branch, that is, named *a. circumflexa ilium profunda* in other rabbit sources, as *a. iliolumbalis*. That is why, in this study, the origin of *a. circumflexa ilium profunda* was observed with great attention. *A. circumflexa ilium profunda* is a branch that participates in the nutrition of the lateral and lower walls of the abdomen (Nickel et al., 1981). Examination of the rabbit showed that the region nourished by vessel originating from *a. iliaca communis* was *a. circumflexa ilium profunda* instead of *a. iliolumbalis.* It had been observed that this branching pattern was compatible with other domestic mammal species. Dissection findings of *a. circumflexa ilium profunda* revealed that the left branch protrudes more cranially (85.7%) than the right even though 14.3% showed that the vessel originates directly from *aorta abdominalis* on the left side. Only 7.1% of both branches of the right and left sides originated at the same level symmetrically. Balastegui et al. (2014) reported that asymmetry between right and left *a. circumflexa ilium profunda* was 73.3% in New Zealand rabbits.

The first vessel to leave the *a. iliaca interna* was *a. umbilicalis* (Barone, 2011; Craigie, 1948; El-Karmoty et al., 2017; McLaughlin & Chiasson, 1990). On the contrary, according to Popesko et al. (1992), the first vessel originating from *a. iliaca interna* was *a. iliolumbalis*. According to Popesko et al. (1992), *a. obturatoria* is the fourth vein originating from the *a. iliaca interna* after *a. umbilicalis*, *a. iliolumbalis*, and *a. glutea cranialis.* Orsi et al. (1979) reported that *a. umbilicalis* gave one branch as *a. vesicalis cranialis* and the other branch in the caudal direction (pelvic region) nourishing the urogenital organs and rectum. In addition, as rats are phylogenetically closely related to rabbits, *a. umbilicalis* was found starting from *a. iliaca communis* (97%), in 1% from *a. iliaca externa*, in 1% from *a. iliaca interna,* and was absent in 1 case (1%) only (Kigata & Shibata, 2019). However, the results of this study exposed that *a. umbilicalis* was the first leaving branch from *a. iliaca interna* on the basis of organs it feeds. This vessel was compatible in terms of course and distribution in other domestic mammalian species like *a. ductus deferentis* (males) or *a. uterina* (females) were seen as its branches. This branch is continued to the cranial part of the urinary bladder in both sexes as *a. vesicalis cranialis*. According to this study, *a. umbilicalis* was originating from *a. iliaca interna* in 64.3%, while in 35.7%, it was found as the branch of the *a. iliaca communis*.

After *a. umbilicalis*, the branch that separated from the *a. iliaca interna* and contributed to the nutrition of the pelvic wall was *a. obturatoria* (Barone, 2011; Craigie, 1948; McLaughlin & Chiasson, 1990). Craigie (1948) reported that *a. circumflexa femoris medialis* originated from

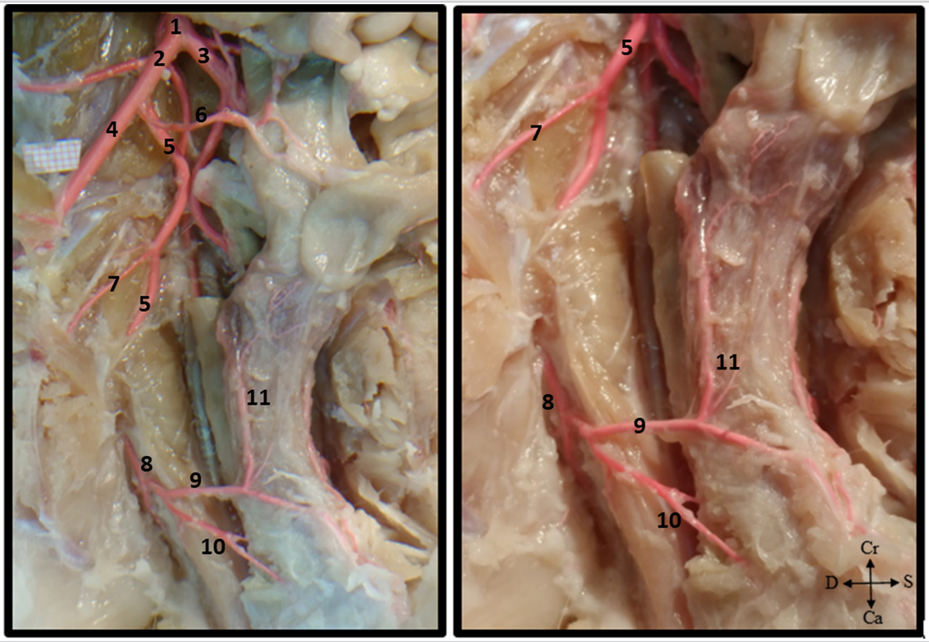

Figure 9.
A. pudenda interna (8) is not in the Immediate Near of a. obturatoria (7); Originating from Caudally (Variation 5). Ventral View (Female). 1: aorta abdominalis, 2: a. iliaca communis dextra, 3: a. iliaca communis sinistra, 4: a. iliaca externa dextra, 5: a. iliaca interna dextra, 6: a. umbilicalis dextra, 7: a. obturatoria dextra, 8: a. pudenda interna dextra, 9: a. vaginalis dextra, 10. a. perinealis ventralis dextra, 11. a. vesicalis caudalis

a. iliaca interna almost at the same point as *a. obturatoria* extending to thigh muscles. However, in rabbits, *a. circumflexa femoris medialis* had been reported as branch of *a. femoralis* (Popesko et al., 1992). In other domestic mammals, the same vessel originates from *a. profunda femoris* (one of the main branches of *a. iliaca externa*) (Dursun, 1994; Nickel et al., 1981). According to McLaughlin and Chiasson (1990), *a. haemorrhoidalis media* was the vessel diverging just after the origin of the *a. obturatoria*, and it was the other name for *a. rectalis media* (Tecirlioğlu, 1986). The information available in the sources showed that there was a significant difference in the origin and naming of these blood vessels. According to dissection findings of the current study, the second main branch leaving the *a. iliaca interna* was *a. obturatoria*, moving toward *foramen obturatum*. At the level of *incisura ischiadica major*, near caudal to *a. obturatoria*, first *a. iliolumbalis* and then *a. glutea cranialis* branches were seen. *A. iliolumbalis* and *a. glutea cranialis* started from a common root in 42.9% and branched out by dividing into two. However, in 57.1%, they had been observed to originate from the *a. iliaca interna* as two separate branches. In a dog, *a. iliolumbalis* and *a. glutea cranialis* originate from a common root of *a. iliaca interna* in 1.72% (Avedillo et al., 2015). In addition, in rats, *a. glutea cranialis* was found as branching from *a. ilica communis* in (80%) or from *a. iliaca intera* in (10%). But there were also reports that it started from *a. iliaca communis* as a common root (10%) together with *a. pudenda interna* (Kigata & Shibata, 2019).

It is observed that there are variances in the sources about the next branches given by *a. iliaca interna*. Popesko et al. (1992) stated that the first branch leaving *a. iliaca interna* was *a. glutea caudalis* and then *a. pudenda interna* and *a. caudalis lateralis* were leaving, respectively. According to Barone (2011), after *a. obturatoria*, *a. vaginalis or a. prostatica*, *a. glutea caudalis,* and *a. pudenda interna* originated, respectively. Craigie (1948) found that after the origin of *a. obturatoria* and *a. circumflexa femoris medialis*, *a. haemorrhoidalis media* started little caudally. *A. iliaca interna* was leaving the pelvic cavity as *a. ischiadica* and ended by dividing into branches two branches called *a. pudenda interna* and *a. caudalis lateralis*. In 64% of rats, *a. glutea caudalis* and *a. pudenda interna* started with a common stem from *a. iliaca interna* but in 36%, they started from *a. iliaca communis* (Kigata & Shibata, 2019). In this study, *a. vaginalis or a. prostatica* was seen originating from

Table 1.
The Diameter and Origin Point Distance Measurements [(Mean ± SD (95% CI)] of arteria iliaca interna

	N	Diameter Right (mm)	Daimeter Left (mm)	*p*	Origin Point Distance Right (mm)	Origin Point Distance Left (mm)	*p*
Female	7	1.19 ± 0.22 (0.99–1.39)	1.26 ± 0.24 (1.03–1.49)	.590	8.92 ± 1.13 (7.88–9.96)	7.17 ± 1.89 (5.42–8.93)	.730
Male	7	1.23 ± 0.31 (0.95–1.52)	1.29 ± 0.27 (1.04–1.53)	.140	8.37 ± 1.50 (6.98–9.75)	7.15 ± 2.32 (4.99–9.30)	.590
p		.785	.838		.450	.980	

Note: SD = standard deviation.

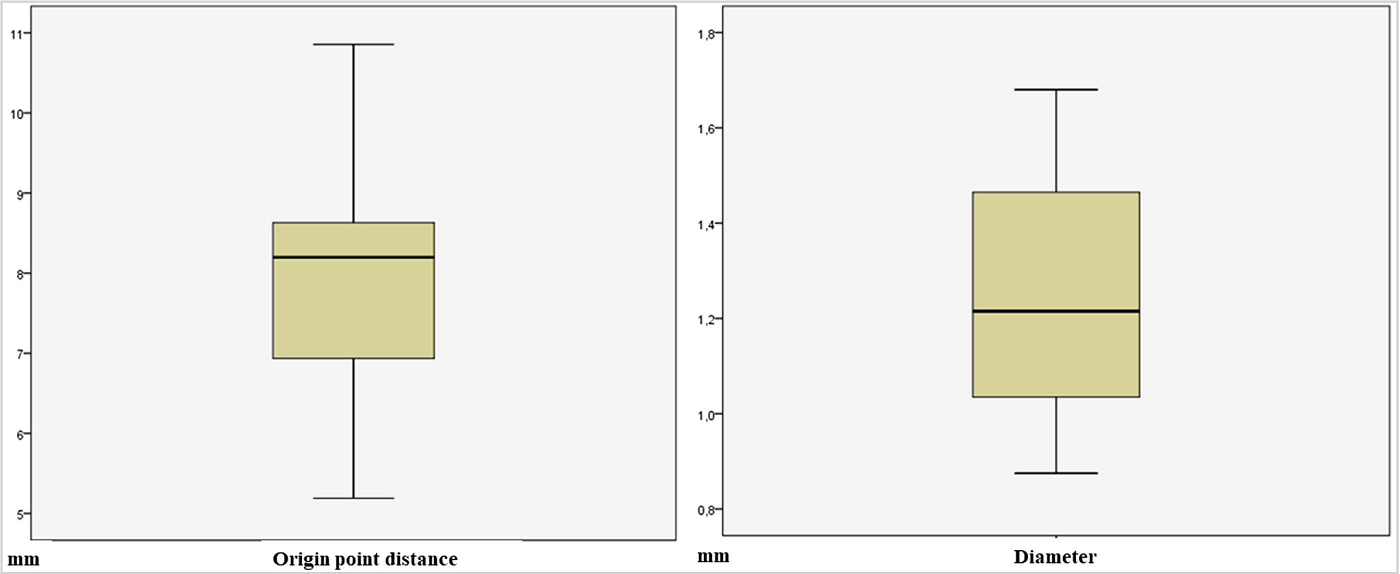

Figure 10.
Box Plotting of the Diameter and Origin Point Distance Measurements in 14 Rabbits. ⊤, maximum; ⊥, minimum; —, median. The Box Includes 50% of the Values.

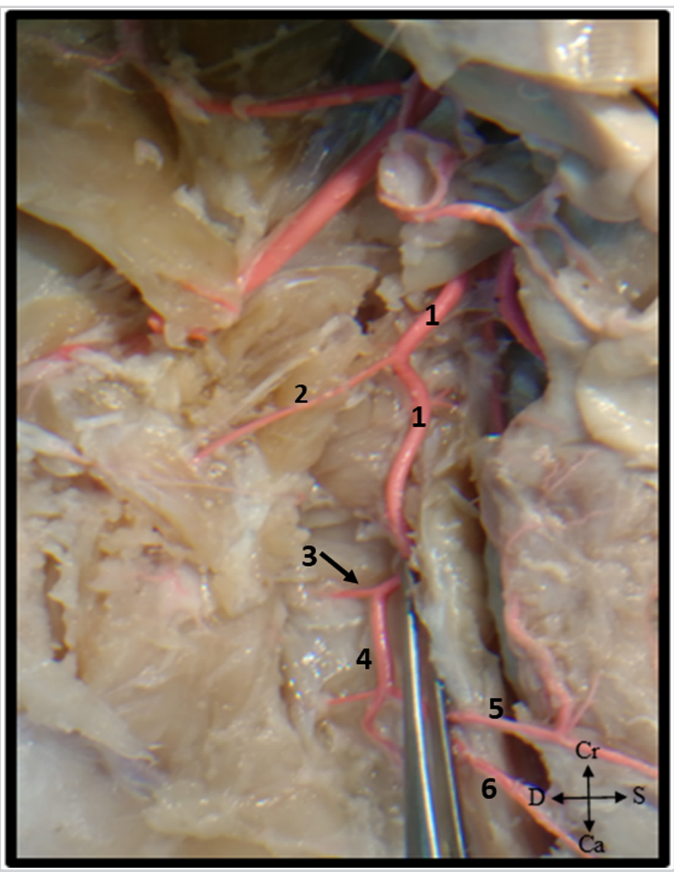

Figure 11.
A. iliaca interna dextra*. 1:* a. iliaca interna dextra*, 2:* a. obturatoria *3:* a. glutea caudalis, *4.* a. pudenda interna, *5.* a. perinealis ventralis, *6.* a. caudalis lateralis*. Ventral View (Female).*

a. iliaca interna very close to *a. obturatoria* in the pelvic region in 71.4%, and its origin from *a. pudenda interna* was later in 28.6% than the origin of *a. glutea caudalis*. According to Kigata and Shibata (2020b), *a. vaginalis arose* from *a. umbilicalis, a. iliaca intena* or *a. pudenda interna* and as to *a. porstatica arose* from *a. iliaca interna* (Kigata & Shibata, 2020a).

Later, *a. iliaca interna* submerged under the *musculus cocygeus* and disappeared. Just before its disappearance, it gave *a. glutea caudalis* dorsally at the level of *incisura ischiadica minor;* after this separation, the next part of the *a. iliaca interna was a. pudenda interna*. *A. pudenda interna* became visible again after passing under the *musculus coccygeus. A. pudenda interna* ended as *a. perinealis ventralis* and *a. caudalis lateralis* (Figure 11). This result about the origin of *a. pudenda interna* was in agreement with Barone (2011) and in disagreement with Popesko et al. (1992).

Adult domestic mammals do not have a vessel called *a. ischiadica*, which was reported by Craigie (1948) as a branch of the *a. ilica interna* (NAV, 2017). However, at some stage in the embryonic life of all vertebrates, a branch developing from *a. iliaca interna* and *nervus ischiadicus* on the caudal surface of the thigh was called *a. ischiadica*. It was reported to terminate as *a. poplitea*. This vessel, which forms the first vascular system of the pelvic limb, regressed and was replaced by *a. iliaca externa* and *a. femoralis* (Funke & Kuhn, 1998; Patten, 1946; Sidawy, 2006). As a developmental disorder in adult humans, it has been reported that *a. ischiadica* could survive at a rate of 0.05% and was found as the main vascularization of the leg. Anatomically, this vessel was coming out of the *incisura ischiadica major* on the caudal of the thigh along with *nervus ischiadicus* and reaching the *fossa poplitea* to unite with *a. poplitea*. However, clinically, these humans experience some important problems with pelvic limb vascularization (Albay et al., 2012; Sidawy, 2006). No similar clinical situation had been reported in domestic mammal species and rabbits.

Conclusion and Recommendations

In conclusion, the main branches of the *a. iliaca interna* in New Zealand rabbits were figured out in the present study and named in accordance with the areas of vascularization described in the domestic mammals. The arterial branches that originate from the *a. iliaca interna* in the New Zealand rabbit showed remarkable individual variations and ramification patterns. At least five differences were observed in ramification patterns of the main branches of the *a. iliaca interna*. Understanding these branching patterns could be especially helpful in performing surgical interventions for a particular structure or muscle of the pelvic region of the New Zealand rabbit. This information can also be beneficial in the apprehension of a chain of events leading to these pathological conditions.

Ethics Committee Approval: The study was approved by the Local Ethics Committee on Animal Experiments of the Aydın Adnan Menderes University (Date: February 27, 2017, no. 2017/021).

Peer-review: Externally peer-reviewed.

Author Contributions: Concept – Ö.Ç., E.T.; Design – Ö.Ç., E.T.; Supervision – Ö.Ç., E.T.; Resources – Ö.Ç., E.T.; Materials – Ö.Ç., E.T.; Data Collection and/or Processing – Ö.Ç., E.T.; Analysis and/or Interpretation – Ö.Ç., E.T.; Literature Search – Ö.Ç., E.T.; Writing Manuscript – Ö.Ç., E.T.; Critical Review – Ö.Ç., E.T.; Other – Ö.Ç., E.T.

Acknowledgments: This research was supported by the Aydın Adnan Menderes University Research Foundation (VTF-17044) and was a part of the unpublished master thesis of first author. The authors would like to thank Dr. Komal KHAN for her supports in the English writing of the article.

Declaration of Interests: The authors declare that they have no conflict of interest.

Funding: The authors declared that this study has received no financial support.

References

Abe, Y., Hotta, Y., Okumura, K., Kataoka, T., Maeda, Y., & Kimura, K. (2012). Temporal changes in erectile function and endothelium-dependent relaxing response of corpus cavernosal smooth muscle after ischemia by ligation of bilateral internal iliac arteries in the rabbit. *Journal of Pharmacological Sciences*, *120*(3), 250–253. [CrossRef]

Albay, S., Kastamoni, Y., & Koyuncu, E. (2012). Embriyonal kalıntı arterler. *Süleymen Demirel Üniversitesi Tıp Fakültesi Dergisi*, *19*(2), 62–67.

Avedillo, L., Martín-Alguacil, N., & Salazar, I. (2015). Anatomical variations of the blood vascular system in veterinary medicine the internal iliac artery of the dog: Part One. *Anatomia, Histologia, Embryologia*, *44*(4), 299–307. [CrossRef]

Avedillo, L., Martín-Alguacil, N., & Salazar, I. (2016a). Anatomical variations of the blood vascular system in veterinary medicine. The internal iliac artery of the dog. Part Two. *Anatomia, Histologia, Embryologia*, *45*(2), 88–99. [CrossRef]

Avedillo, L., Martín-Alguacil, N., & Salazar, I. (2016b). Anatomical variations of the blood vascular system in veterinary medicine: The internal iliac artery of the dog-part three. *Anatomia, Histologia, Embryologia*, *45*(3), 189–196. [CrossRef]

Balastegui, M. T., Ramos-Plá, J. J., Ferrer-Puchol, M. D., Carrillo, J. M., Monteagudo-Franco, S. P., Esteban, E., & Liste, F. (2014). Anatomical variations in the aortic bifurcation in New Zealand white rabbits on arteriography. *Anatomical Record*, *297*(4), 663–669. [CrossRef]

Barone, R. (2011). *Anatomie Comparée des Mammifères Domestiques, Tome 5: Angiologie* (2nd ed). Editions Vigot.

Barone, R., Pavaux, C., Blin, P. C., & Cuq, P. (1973). *Atlas D' Anatomie Du Lapin*. Masson & Cie, Paris.

Bavaresco, A. Z., Culau, P. D. O. V., & Campos, R. (2012). Ramos Colaterais Parietais e Terminais da Aorta Abdominal em Coelhos da Raça Nova Zelândia (Oryctolagus Cuniculus). *Acta Scientiae Veterinariae*, *40*(4), 1–6.

Craigie, E. H. (1948). *Bensley's practical anatomy of the rabbit. An elementary laboratory textbook in mammalian anatomy* (8th ed). The Blakiston Company.

Ding, Y. H., Dai, D., Layton, K. F., Lewis, D. A., Danielson, M. A., Kadirvel, R., Cloft, H. J., & Kallmes, D. F. (2006). Vascular anatomic variation in rabbits. *Journal of Vascular and Interventional Radiology*, *17*(6), 1031–1035. [CrossRef]

Dursun, N. (1994). *Veteriner anatomi II*. Medisan Yayınevi.

Ekim, O., & Dursun, N. (2011). Yeni Zelanda Tavşanı'nda (Oryctolagus Cuniculus L.) Arcus Aortae ve Ilişkili Dallarının Makroanatomisi. *Veteriner Hekimler Derneği Dergisi*, *82*(2), 25–32.

El-Karmoty, A. F., Khalifa, E. F., & Fathi, M. (2017). Comparative study on the arterial supply of the accessory genital glands in adult male domestic rabbit (Oryctolagus cuniculus) and wild fox (Vulpes vulpes). *International Journal of Veterinary Science*, *6*(2), 70–76.

Funke, C., & Kuhn, H. J. (1998). The Morphogenesis of the arteries of the pelvic extremity a comparative study of Mammals with special reference to the Tree Shrew Tupaia be/angeri (Tupaiidae, Scandentia, Mammalia). *Advances in Anatomy, Embryology, and Cell Biology*, *144*, 1–97. [CrossRef]

Fuster, J. J., Castillo, A. I., Zaragoza, C., Ibáñez, B., & Andrés, V. (2012). Animal models of atherosclerosis. *Progress in Molecular Biology and Translational Science*, *105*, 1–23. [CrossRef]

Getz, G. S., & Reardon, C. A. (2012). Animal models of atherosclerosis. *Arteriosclerosis, Thrombosis, and Vascular Biology*, *32*(5), 1104–1115. [CrossRef]

Gonzalez, V. H., Ball, S., Cramer, R., & Smith, A. (2015). Anatomical and morphometric variations in the arterial system of the domestic cat. *Anatomia, Histologia, Embryologia*, *44*(6), 428–432. [CrossRef]

Hong, J. H., Bahk, Y. W., Suh, J. S., Kwak, B. K., Shim, H. J., Kim, J. S., Kim, H. S., Moon, Y. H., Kim, S. J., Chung, J. W., & Park, J. H. (2001). An experimental model of ischemia in rabbit hindlimb. *Journal of Korean Medical Science*, *16*(5), 630–635. [CrossRef]

Kakuta, T., Usui, M., Coats, W. D. Jr., Currier, J. W., Numano, F., & Faxon, D. P. (1998). Arterial remodeling at the reference site after angioplasty in the atherosclerotic rabbit model. *Arteriosclerosis, Thrombosis, and Vascular Biology*, *18*(1), 47–51. [CrossRef]

Kigata, T., & Shibata, H. (2019). Anatomical variations of the arterial branches from the rat iliac arteries. *Journal of Veterinary Medical Science*, *81*(1), 1–8. [CrossRef]

Kigata, T., & Shibata, H. (2020a). Arterial supply to the rabbit male genital organs. *Journal of Veterinary Medical Science*, *82*(3), 254–260. [CrossRef]

Kigata, T., & Shibata, H. (2020b). Ramification pattern of the arteries supplying the rabbit female genital organs. *Anatomical Record*, *303*(5), 1478–1488. [CrossRef]

McLaughlin, C. A., & Chiasson, R. B. (1990). *Laboratory anatomy of the rabbit* (3th ed). McGraw-Hill Higher Education.

Mohamed, R. A. A. (2014). Arterial supply of the intestine of Baladi rabbit. *International Journal of Veterinary Science*, *3*(2), 52–60.

Nagata, Y., Fujiwara, K., Okajima, K., Mitsumori, M., Mizowaki, T., Ohya, N., Hiraoka, M., Abe, M., Ohura, K., & Wataya, S. (1998). Transcatheter arterial embolization for malignant osseous and soft-tissue sarcomas. I. A rabbit experimental model. *Cardiovascular and Interventional Radiology*, *21*(3), 205–207. [CrossRef]

NAV. (2017). *International Committee on Veterinary Gross Anatomical Nomenclature and authorized by the general assembly of the World Association of Veterinary Anatomist* (6th ed). Editorial Committee Hanover.

Nickel, R., Schummer, A., & Seiferle, H. (1981). *The anatomy of the domestic animal*. Verlag Paul Parey.

Nur, İ. H., Karadağ, H., Arı, H. H., & Özüdoğru, Z. (1995). Yeni Zelanda Tavşanlarında Arka Bacak Arteria'aları Üzerine Makroanatomik ve Subgros Araştırmalar. *Yüzüncü Yıl Üniversitesi Veteriner Fakakültesi Dergisi*, *6*(1), 38–45.

Orsi, A. M., Pinto e Silva, P., Fernandes de Abreu, M. A., & Mello Dias, S. (1979). Pelvic visceral arteries of rabbits (Oryctolagus cuniculus). *Acta Anatomica*, *104*(1), 72–78. [CrossRef]

Pai, M., Jamal, W., Mosse, A., Bishop, C., Bown, S., & McEwan, J. (2005). Inhibition of in-stent restenosis in rabbit iliac arteries with photodynamic therapy. *European Journal of Vascular and Endovascular Surgery*, *30*(6), 573–581. [CrossRef]

Patten, B. M. (1946). *Human embryology*. The Blakiston Company.

Popesko, P., Rajtowa, V., & Horak, J. (1992). *A colour atlas of anatomy of small laboratory animals, Vol. I: Rabbit, guinea pig*. Wolfe Publishing Ltd.

Sidawy, A. N. (2006). *Diabetic foot: Lower extremity arterial disease and limb salvage*. Lippincott William & Wilkins.

Singh, A. P., Singh, G. R., Sharma, D. N., Nigam, J. M., & Bhargava, A. K. (1982). Arteriographic anatomy of the abdominal aorta in the goat, dog, pig, and rabbit. *Veterinary Radiology*, *23*(6), 279–281. [CrossRef]

Tecirlioğlu, S. (1986). *Komparatif Anatomi Terimleri* [*Ankara Üniversitesi Veteriner*]. Fakültesi Yayınları.

Wingerd, B. D. (1985). *Rabbit dissection manual*. The John Hopkins University Press.

Yang, D., & Morris, S. F. (1998). Anatomical study of intramuscular arterial patterns in rabbits. *Canadian Journal of Plastic Surgery*, *6*(4), 183–189. [CrossRef]

Zurlo, J., Rudacille, D., & Goldberg, A. M. (1996). The three Rs: The way forward. *Environmental Health Perspectives*, *104*(8), 878–880. [CrossRef]