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# Comparison of the blood vessel complexes of the human and bovine male gonads

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*The aim of the study was to compare the blood vessel network of the human and bovine male gonads, paying special attention to differences resulting from mediastinum testis localisation.*
*Two groups of specimens were compared. Each group consisted of 50 corrosive die casts of the testicular and spermatic cord vessels of bovine and human gonads respectively. In each group 20 gonads had only the arterial vessels injected, another 20 only the veins, while in 10 gonads both arteries and veins were injected. The die casts were examined with a stereoscopic binocular as well as an optic microscope.*
*The different testicular vascular patterns in humans and bulls were observed. In humans the intratesticular arteries branch off the arterial network of the tunica albuginea and mediastinum testis. The former runs centripetally, the latter centrifugally. Analogically, the intratesticular veins emptying into the tunica albuginea venous network run centrifugally and those emptying into the mediastinum testis plexus run centripetally. In bulls the arterial vessels run centripetally, later forming a helical, screw-like layer to give off centrifugal branches. Venous vessels run centrifugally and empty into the venous plexus of the tunica albuginea.* (Folia Morphol 2008; 67: 179–185)

**Key words: arteries, veins, human testis, bovine testis, comparative morphology**

## INTRODUCTION

Despite many general similarities, the morphologies of human and bovine testes differ significantly. Quantitative differences include the volume and weight of the organ, which is more than ten times greater in bulls. This is related to the differences in total body weight of the species. The average human testis weighs 15–19 g [27, 32], while the bovine testis weighs 250–395 g [1]. Qualitative differences are mostly connected with the topography of the mediastinum testis. In humans the mediastinum testis is located at the posterior margin of the gonad in its proximal part [2, 23, 26, 29]. In bovines the mediastinum testis is located in the central part of the gonad [3, 12, 22, 25]. In this respect the human testis is similar to the gonads of the rat, mouse, hamster, stallion and apes, while the bovine testis is considered to be a model of gonads with a centrally located mediastinum, similar to those of the zebu, buffalo, buck and ram [2, 3, 12, 13, 22, 23, 26, 29]. The difference in mediastinum testis topography implies differences in the vascular pattern of the human and bovine male gonad. In bulls the blood carried by the testicular arteries to the mediastinum has to pass the gonad centripetally, while in humans it can be also distributed directly through

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the arterial network of the tunica albuginea. Opinion on this is, however, divided. Studies on the bovine testicular arterial network report the presence of both centripetal and centrifugal arteries. The former come out of the tunica albuginea network and the latter out of the mediastinum testis [11, 16, 17, 30, 31]. Some studies have confirmed the presence of centrifugal arteries in the human testis, although their origin remains a matter of dispute [5, 20, 21]. In contrast, descriptions of the testicular venous network in both humans and bovines have been consistent in the majority of recent studies [12, 13, 16–18, 21, 30].

The subject of the study was the vascular complex, including both the arterial and venous networks, of the male gonads of two species: human (*Homo sapiens*) and bovine (*Bos taurus*). The different localisations of the mediastinum make comparison of the chosen species potentially useful in studies of its role in the vascularisation of the testis. Additionally, there is still no consistency of opinion concerning the testis blood vessel complex, especially with regard to the human arterial network. Studies have usually been performed on a relatively small group of gonads, which could be one explanation for the lack of agreement in the conclusions reached by various authors [11, 16, 30, 31]. Some results of studies made of animals are still being applied directly to the humans, which is unjustified, as even the gross morphology of the human testis differs significantly from that of many other mammals [10, 16].

The goal of the study was to describe, analyse and compare the blood vessel complex of the human and bovine testis using a modern, reliable corrosive method [16, 30, 31] applied to a higher number of gonads than previously reported [5, 6, 11, 19]. The method is as accurate as the microangiographic method of vascular studies [9, 21] and more suitable for long-term preservation of the specimens. The study focuses on the intratesticular angioarchitecture as well as on the testicular arteries and veins. The similarities and differences between species were of special interest of the authors.

## MATERIAL AND METHODS

One hundred male gonads (50 human and 50 bovine) were included in the study. The human testes were taken in the two days following death from donors aged from 18 to 82 years. The bovine testes were taken up to 9 hours after the animal had been slaughtered for butchering. The animals aged from 2.5 to 3 years. None of the organs in either group showed any signs of pathological alteration or disease. The testes were taken together with their coverings. No attempt was made in the morphological studies to match the age of the donor or side of the gonad (left or right) and the material was analysed uniformly. The spermatic cord was isolated and prepared in order to find access to the testicular artery and testicular vein or plexus pampiniformis, if present. In each group 20 specimens were prepared for access to the arterial vessels and study of the arterial network study, 20 for venous network study and 10 for both arterial and venous vessels access and study. A corrosive die cast of the chosen vessels was obtained by the following process:

- 0.9% NaCl solution was injected into the chosen vessel and perfusion was maintain for 10–20 s in order to flush out possible clots;
- saline perfusion was followed by injection of 10 mL of 3% glutaraldehyde solution, in cocadylate buffer (pH 7.4);
- the vessels were filled with one of follow synthetic resins: Mercox, Kallocyl M, Plastogen G or Batson 17, and these were stained with appropriate pigments
- the gonad was left for 24 hours in warm (20°C) water in order to toughen the resin;
- after toughening, the specimen was placed in 40% KOH solution (50°C) for the next 24 hours to dissolve the organic parts;
- the remnants of dissolved tissues were removed by continuous warm water flush for 24 hours;
- the cleaning of die cast was continued by a short wash with water with a small amount of standard washing liquid and a final flush of distilled water;
- the die casts were later dried out by air flow at room temperature for a suitable time.

The corrosive die casts were examined visually by macroscopic observation with a stereoscopic binocular as well as an optic microscope. Digital photographic documentation was collected for macroscopic and microscopic studies for each specimen. The images were saved in jpeg format and later digitally transformed and analysed using CorelDRAW Graphics Suite 12 software.

## RESULTS

In the study the topographies of the human and bovine vessels were seen to differ. The differences

**Table 1.** Terminal division of the testicular artery in humans

| Type of division | Frequency |
|---|---|
| One major terminal branch | 18% |
| Two terminal branches of similar diameter | 74% |
| Three to five terminal branches | 8% |

**Table 2.** Terminal division of the testicular artery in bulls

| Type of division | Frequency |
|---|---|
| One smaller and one larger terminal branch | 26% |
| Two terminal branches similar in size | 61% |
| Three terminal branches | 13% |

were related to the testicular arteries and intratesticular vessels, both arterial and venous networks being involved.

### Testicular arteries

In both groups the testicular artery, while branching off the spermatic cord, runs along the posterior margin of the testis. However, the terminal division of the testicular artery differs significantly. In humans it is located on the level of the mediastinum testis, whereas in bulls it is located more inferiorly, close to the inferior end of the testis and to the tail of the epididymis. The most typical type of terminal division is that into two terminal branches, although other types were observed in both groups (Table 1, 2). In four bovine gonads a testicular artery branch was observed. The vessel originated from the straight part of the testicular artery on the posterior margin of gonad. No similar observation was reported in previous studies [12, 13, 17, 30].

### Superficial arterial vessels

In both groups the terminal branches of the testicular artery form a superficial vascular network, which is related to the tunica albuginea. The way these contribute to the network differs according to the species. In humans the terminal branches of the testicular artery run straight on as the major arterial trunks, passing from the posterior to the anterior margin of the testis close to the inferior end of the testis. In this way the vessels form an oval-like loop surrounding the gonad (Fig. 1). The loop is open superiorly, while the terminal branches do not

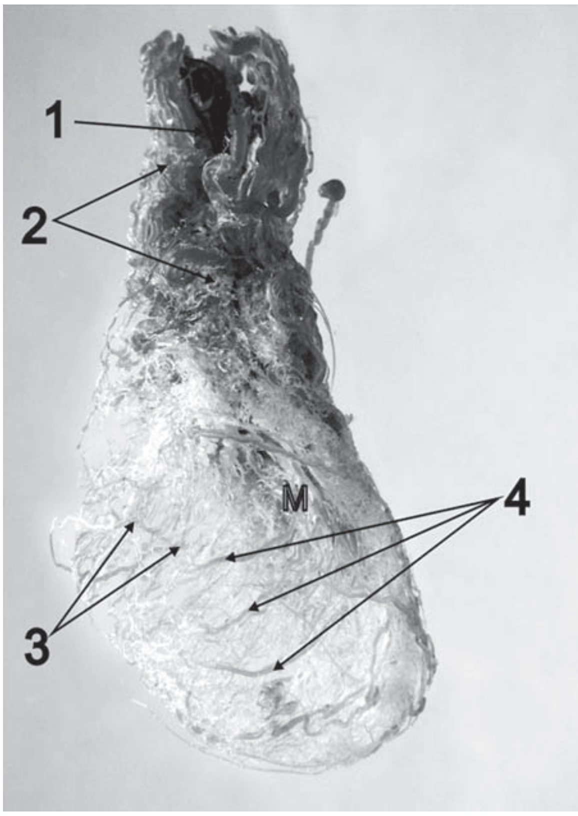


**Figure 1.** Corrosive die cast of human vessels: 1 — a. testicularis, 2 — veins of the plexus pampiniformis, 3 — arteries of the tunica albuginea network, 4 — terminal branches of the testicular artery, M — the mediastinum testis.

anastomose with the testicular artery in the superior part of testis. The dense arterial network of the tunica albuginea is formed mainly by minor arterial vessels, which spread perpendicularly off the terminal branches of the testicular artery. Where there are more than two terminal branches of the testicular artery, two of them follow the typical course and the other one(s) spreads over the medial or lateral surface of the gonad. In bulls the terminal branches of the testicular artery divide to consequent vessels, which form the arterial network of the tunica albuginea (Fig. 2). These winding arteries are named the rami tunicales maiores and the rami tunicales minores, with respect to their diameters [13]. The terminal branches of the testicular artery in bulls are shorter and more winding than those in humans.

### Intratesticular arterial vessels including the mediastinum testis network

The most significant differences between the groups concern the intratesticular vessels. In humans

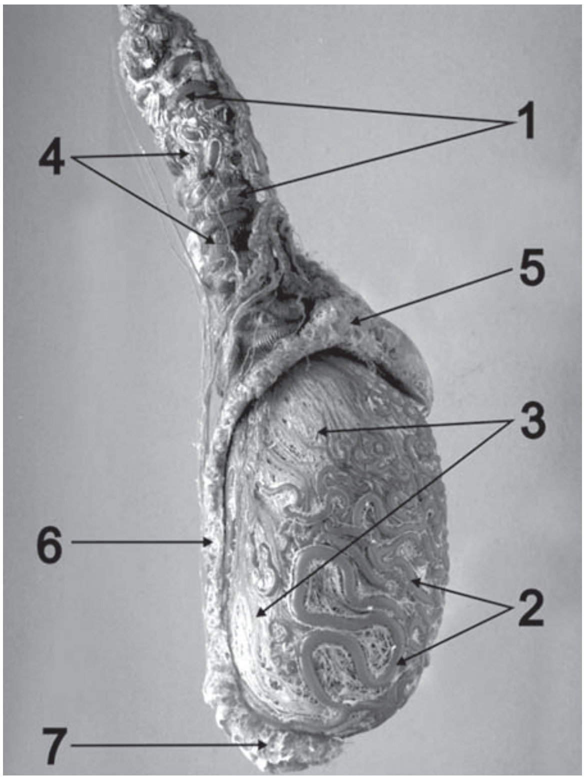


**Figure 2.** Corrosive die cast of bull's vessels: 1 — a. testicularis, 2 — arteries of the tunica albuginea network, 3 — veins of the tunica albuginea network, 4 — veins of the plexus pampiniformis, 5 — epidymidis (head), 6 — epidymidis (body), 7 — epidymidis (tail).

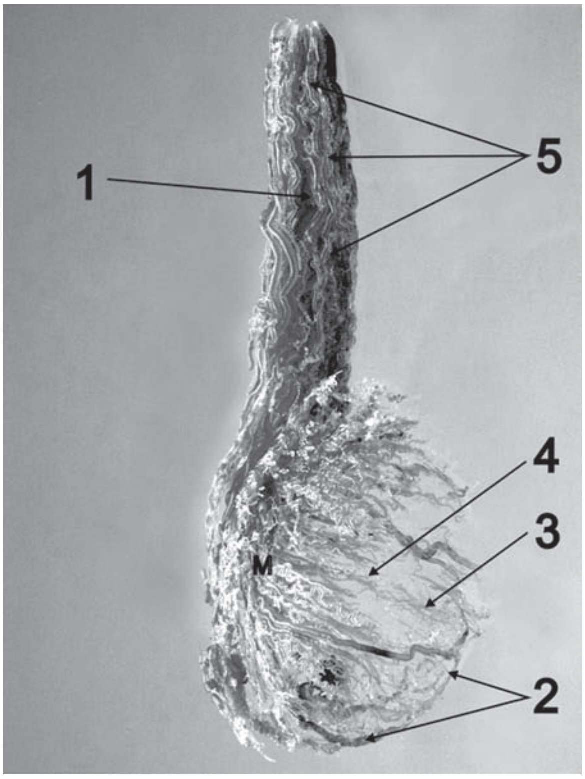


**Figure 3.** Corrosive die cast of human vessels: 1 — a. testicularis, 2 — arteries of the tunica albuginea network, 3 — centripetal arteries, 4 — centrifugal arteries, 5 — veins of the plexus pampiniformis, M — the mediastinum testis.

the intertesticular arteries originate from the tunica albuginea network running centripetally, as well as from the mediastinum testis network running centrifugally. The centripetal arteries come off the tunica albuginea and run towards the mediastinum testis. The centrifugal arteries, parallel to the centripetal ones, come off the mediastinum testis and head towards the tunica albuginea (Fig. 3). The arterial network of the mediastinum testis is formed by some of the superficial branches of the terminal branches of the testicular artery. As a consequence, the blood supply of the testicular tissue is provided by two relatively independent sources. In bulls the intratesticular arteries come off the tunica albuginea network perpendicularly and head towards the mediastinum testis, running centripetally. Some of them reach the mediastinum testis and form screw-like helicoids or knot-like vascular conglomerations. These structures do not anastomose with each other. Each conglomeration is an originating structure for between 3 and 20 centrifugal arteries parallel to the centripetal ones (Fig. 4). The centrifugal arteries do not anastomose with the arterial network of the tunica albuginea. As a consequence, the blood supply of the testicular tissue is provided by one consequent system of arterial vessels.


**Figure 4.** Corrosive die cast of bull's arterial vessels: 1 — a. testicularis, 2 — ramus maior, 3 — ramus minor, 4 — centripetal arteries, 5 — arterial conglomerations in the mediastinum testis, 6 — centrifugal arteries, M — the mediastinum testis.

### The intratesticular venous vessels

In both groups there are more intratesticular veins than arteries. Additionally, the veins are straighter in comparison with the respective arteries. In humans the intratesticular veins run centripetally and centrifugally. The centripetal vessels empty into the venous network of the mediastinum testis, while the centrifugal vessels empty into the network of the tunica albuginea (Fig. 5). Both venous networks pass directly into the vessels of the plexus pampiniformis. In bulls the intratesticular veins are exclusively centrifugal. They are straight and run in the direction of the tunica albuginea network, finally emptying perpendicularly into its vessels (Fig. 6). No structures similar to the venous network of the mediastinum testis in humans were observed in bulls. The absence of the mediastinum testis venous network and centripetal veins in bulls is the most significant difference between the two groups concerning the intratesticular venous pattern.

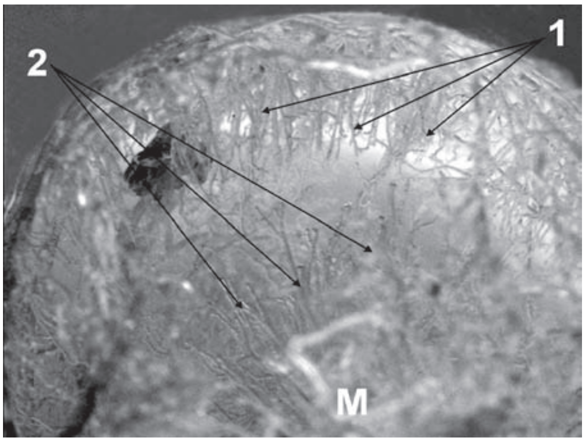


**Figure 5.** Corrosive die cast of human venous vessels: 1 — centrifugal veins, 2 — centripetal veins, M — the mediastinum testis.

### Extratesticular venous vessels including the plexus pampiniformis

In both groups the intratesticular veins empty into the tunica albuginea network. The veins of this network pass into the plexus pampiniformis vessels of significantly smaller diameter. In humans, however, the plexus pampiniformis is also made up of vessels of the mediastinum testis network. In both groups the plexus pampiniformis consists of numerous small venous vessels. These vessels are closely related to the testicular artery surrounding it inside the spermatic cord. No valves were observed in the vessels of the plexus either in the intrascrotal or intrainguinal part of it.

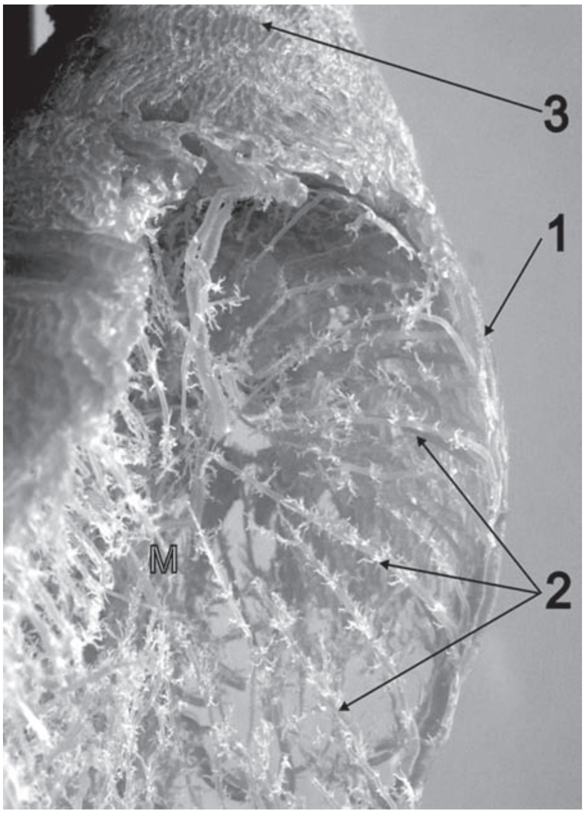


**Figure 6.** Corrosive die cast of bull's venous vessels: 1 — veins of the tunica albuginea network, 2 — centrifugal veins, 3 — veins of the plexus pampiniformis, M — the mediastinum testis.

### Density of the vascular complex

In both groups the superficial and intratesticular vessels form a vascular complex of variable density. In humans a lack of large vessels and a low density of small arteries and veins were observed on the central part of the lateral surface of the gonad in its inferior half. In bovines the lowest vascular density was observed in the middle of the posterior margin of the testis on both sides of the testicular artery.

## DISCUSSION

The differences in the vascular complexes of the human and bovine male gonads observed in the study are significant. In our view the conclusion reached by some authors that the vascular pattern of the human testis is similar to that of the animal is an overgeneralisation [10, 16]. The majority of the differences can be directly linked to the different position of the mediastinum testis in humans, the different arterial supply of the arterial network of the mediastinum testis and the different structure of this network. The extra-centric position of the human mediastinum testis allows a direct connection to be made to the arterial network of the tunica albuginea. Although we have followed many other authors in observing this kind of connecting artery, our finding that the centrifugal intratesticular arteries originate in the mediastinum testis is not consistent with all other studies [5, 21]. In bulls the arterial network of the mediastinum testis is formed by the centripetal intratesticular arteries and their conglomeration. Another consequence of the location of the central mediastinum testis in bulls is a lack of venous network in this part of the gonad. If this network was developed the withdrawal of the blood to the pampiniform plexus would be a topographical problem. However, in *Bubalus bubalus* (Murrah buffalo), a species closely related to *Bos Taurus*, the centrifugal collecting vein (central vein) withdraws venous blood from the central part of testis to the peripherals [4]. As it collects blood from several centripetal veins, it may be suggested that this vessel is analogical in structure to the human mediastinum testis venous network. The absence of the central vein in the bovine masculine gonad, confirmed by many studies [12, 13, 16, 17, 30], can therefore explain the absence of centripetal intratesticular veins and, consequently, the lack of a venous network in the mediastinum testis.

The vascular pattern of the bovine intratesticular vessels described in this study is consistent with previous studies [11–13, 16, 17, 30, 31]. In contrast, the human intertesticular centrifugal arteries are described differently by other authors [5, 20, 21]. Our study demonstrated that most, if not all, the centrifugal arteries originate from the mediastinum testis arterial network, which does not agree with previous descriptions of these arteries [21]. It is our view that future studies of the human testis should focus on this issue so that the problem may be definitively resolved. The results of the study do not support the notion, put forward elsewhere, of a close similarity between the human and rat testis vascular complex [7, 15], and we would tend to agree with those who have argued against this [28]. This similarity was based on observations with an electron microscope [24], while our study was restricted to optical observations. With regard to the venous intratesticular complex, the present study confirms the observations of other authors [2, 5, 21].

The venous vessels were easily filled with resin injected proximally (i.e. against the normal flow of the blood). This makes it possible to detect the absence of significant valves in the plexus pampiniformis, a conclusion confirmed by the fact that there are no narrows in the veins. Other authors have also pointed out that there are no venous valves in the plexus [11]. However, some have described valves in the lumen of the plexus pampiniformis vessels [14]. There are several hypotheses concerning the physiological role of the winding and straight segments of the intertesticular arteries as well as the arterial conglomerations inside the bovine mediastinum testis [4, 8], but our study did not confirm any of these, being focused on vascular morphology. However, the absence of these structures in the human testis prompts speculation. It is possible that the winding course of the arteries in bulls compensates for the shorter length of the terminal branches of the testicular artery in comparison with that of humans. If this is the case, its main role would be to decrease arterial pressure inside the gonad. It may be suggested that inside the mediastinum testis the arteries form conglomerations, as in bulls, or vascular networks, as in humans, due to the necessity of thermoregulation and metabolite exchange with the venous vessels. However, the absence of a venous network in the bovine mediastinum testis does not support this notion. The study revealed the presence of a minor branch of the testicular artery in bulls. Although not common (4/30), this artery is a significant variation which has not yet been described. Moreover, previous studies have stressed that the testicular artery gives off no branches in its testicular part until terminal division [12, 13, 17, 30]. We can explain this non-conformity by the large number of gonads involved in our study. With an incidence of approximately 10%, studies on a smaller group may not show the variation.

The possible practical conclusion of the study is a recommendation for the best testicular biopsy site for humans and bulls. The lateral surface of the human gonad and the posterior margin of the bovine one seem to carry the lowest risk of serious bleeding. In the case of bulls the testicular artery pulse should be localised before the manoeuvre, which can be achieved by palpation. Because of the possible presence of accessory branches in bulls we are of the opinion that the best site in the bovine testis is therefore in the middle of the posterior margin. According to our study, there are no larger vessels in this area and the vascular density is also relatively low.

## CONCLUSIONS

1. The topography of the blood vessel complex differs significantly in the human and bovine testes with regard to both arterial and venous networks.

2. Testicular artery division is located in both groups on the posterior margin of the gonad, but more inferiorly in bulls than in humans.
3. The arteries of the tunica albuginea networks are winding in bulls and straight in humans.
4. The intratesticular veins in humans run centripetally and centrifugally, while in bulls they run explicitly centrifugally.
5. In contrast to humans, there is no significant venous network of the mediastinum testis in bulls.
6. The pattern of testicular artery division and the vascular complex of the spermatic cord are similar in the two species.
7. For blind biopsy of the testis we recommend the inferior part of the lateral aspect of the gonad in humans and the middle part of the posterior margin of the gonad in bulls, as these areas express the lowest risk of damage to major vessels.

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