FUNCTIONAL AND DEVELOPMENTAL MORPHOLOGY | VOLUME 1 NUMBER 3 | 1991 p.p. 51–61

Variability of the V. Cava Caudalis and Its Tributaries in Some Laboratory Animals. I. The Guinea Pig (*Cavia aperea* f. porcellus)

L. MALINOVSKÝ, E. NAVRÁTILOVÁ AND V. D'ANDREA

Department of Anatomy, Faculty of Medicine, Masaryk University, Brno, Czechoslovakia, and Department of Neurology, University "La Sapienza", Rome, Italy

Received for publication May 20, 1990
Accepted March 1, 1991

SUMMARY

The authors studied variability of the v. caudalis and its tributaries in 30 guinea pigs (*Cavia aperea* f. porcellus – 15 males and 15 females) after injecting the relevant venous system with blue-dyed latex.

Since the largest lobe of the quinea pig's liver (the lobus sinister) is situated on the left, the right kidney lies futher cranially than the left one. In males, as a rule, the right v. renalis opens into the v. cava caudalis further cranially than the left one. The number of vv. renales showed no sex-related differences, although in 17 regions (i.e. in 29 %) there was more than one. The increase most often concerned the v. renalis dextra (the ratio in relation to the left vein was 15:2). The tributaries of the vv. renales are the v. spermatica or v. uterina cranialis a v. lumbalis and a v. or vv. suprarenales. There are usually two tributaries, (the commonest of which is the v. spermatica or v. uterina cranialis) on both the right and the left side, though somewhat more frequently on the left (23:19). Blood is drained from the surface or capsule of the kidney relatively often (in 75 % of the cases) by the capsularis, which is the most frequent tributary of the v. spermatica or v. uterina cranialis of the corresponding side.

Vv. suprarenales (1–4) are a constant finding on both sides. In males they open more often into the v. cava caudalis and in both sexes they also open into the v. renalis and v. lumbalis. The v. spermatica dextra opened into the v. renalis dextra in 10 cases and the v. spermatica sinistra into the v. renalis sinistra in 12 cases. The v. uterina cranialis dextra was a tributary of the v. renalis dextra in eight cases and the v. uterina cranialis sinistra joined the v. renalis sinistra in 13 cases. Drainage into the v. renalis can thus be regarded as the norm in both sexes and on both sides. The v. uterina caudalis leads from the corpus and cervix uteri and joins the v. uterina cranialis. It has a regular incidence and caudally it is most often a tributary of the v. iliaca communis. The v. ovarica is a constant tributary of the v. uterina cranialis; it is usually joined by several vv. lumbales or v. v. capsulares.

The vv. lumbales are not organized segmentally. In 80 % of the regions there is more than one. Most frequently they join the v. cava caudalis or even the vv. renales. In females, union with the v. renalis sinistra predominates, both right and left; in males, union with the v. cava caudalis is commoner. The vv. capsulares and vv. suprarenales are tributaries of the vv. lumbales (in 41 % of the regions). A v. iliolumbalis was found in most cases; in about 1/4 of them it was duplicated; it mostly opened into the v. iliaca communis or v. iliaca externa.

Duplication of the v. cava caudalis was found in three cases in males and in one female. Union of the two veins, forming a single v. cava caudalis, occured further cranially in the males than in the female. The aorta abdominalis usually lay to the left of the v. cava caudalis (19 cases – 63.3 %); there was only one case (3.3 %); in which it as found on the right. It lies dorsally to the v. cava caudalis in six cases (20.0 %) and between the two vv. cavae caudales in all four of these cases (13.3 %).

In 22 cases the v. cava caudalis was formed by confluence of the v. iliaca communis dextra and sinistra. In the remaining eight cases the v. sacralis mediana contributed directly to its formation (in the other cases in most frequently united with the v. iliaca communis dextra).

Portocaval anastomoses were observed in eight cases (more frequently in males); they occured between the v. cava caudalis or its tributaries and the veins of the large intestine.

The complicated development of the v. cava caudalis, phylogenetic reminiscences and differences in the canalization of the original venous networks evidently play a role in the richly variable morphology of this vein and its tributaries. A detailed comparison of our findings with relationships in other laboratory animals is at present impossible, as exact data are not available. The authors will therefore concentrate on the study of further laboratory animals.

INTRODUCTION

In our preceding studies (Malinovský and Navrátilová 1990a, b), Malinovský et al. 1991, Navrátilová and Malinovský 1990, 1991, Navrátilová et al. 1991), were investigated the variability of the tributaries of the v. portae in various laboratory animals. The findings were indicative not only of a great variability of the given veins, but also of similarity of their organization in related species. Relationships in the cat were very different from those in rodents and lagomorphs. These findings made us interested in the organization of the v. cava caudalis in laboratory animals. The complicated morphogenetic origin of this vein explains its manifold deviations from "normal" (Barnett et al. 1958); in addition, it could furnish some morphological data on developmental relationships between different laboratory animals.

The development of the guinea pig's venous system (especially the v. cava caudalis) was studied in detail by Zumstein (1897); in a further study (1898), he made a detailed examination of the development of the v. cava caudalis in the mole and the rabbit. The best known study of the embryonal development of the v. cava caudalis is the one by Huntington and McClure (1920) on relationship in the cat, which is basically extended and supplemented by the rich material of Butler et al. (1946). The comparative anatomical results on development of the vena cava are summed up by Barnett at al. (1958).

At present, the only detailed study of the tributaries of the v. cava caudalis is the one by Habermehl (1951–1952), who studied its variability and its tributaries in the cat; his series comprised only 15 animals (7 females and 8 males), however. Since he demonstrated great variability of the tributaries of the v. cava caudalis, it can be concluded that the data in standard manuals and textbooks (Ellenberger and Baum 1921, Nejedlý 1965) and atlases (Greene 1959) apply to only some varieties. Del Campo and Ginther (1972) compared the venous pattern of the uterus and ovaries of the guinea pig, rat, hamster and rabbit. Mention should also be made of the experimental study by Pogorzelski (1957) on the collateral circulation in this region. We therefore decided to extend our research on the region ot the v. portae in some laboratory animals to the region of the v. cava caudalis, starting with the guinea pig – the oldest representative of the rodent order.

MATERIAL AND METHODS

We examined the morphology and tributaries of the v. cava caudalis and their relationship to the aorta abdominalis in 30 adult guinea pigs (*Cavia aperea* f. porcellus) (15 females and 15 males). After anaesthetizing the animals with ether, their abdominal cavity was opened and the v. cava caudalis was injected, via the liver, with blue-dyed latex. The material was placed in 5 % formalin solution and when the latex had hardened it was dissected in the usual way. The ensure exactness, the result were drawn immediately. Owing to the manner of injection, the v. cava caudalis and its tributaries were studied caudally to the diaphragm (in the subhepatic region).

RESULTS

The main tributaries of the renal segment of the v. cava caudalis are the vv. renales. Owing to their different origin, we studied the relationships of the v. renalis dextra and v. renalis sinistra separately and with reference to sex-related differences. Compared with human skeletopic, the position of the kidneys in the guinea pig is reversed, i.e. the right kidney lies further cranially than the left kidney, probably because the largest lobe of the liver (the lobus sinister) is situated on the left. This causes the left kidney to shift in a caudal direction and influences the level at which the v. renalis sinistra joins the v. cava caudalis.

The interrelationship of the termination of the two vv. renales is shown in Table 1. In one female we found a v. renalis communis in the form of a short trunk resulting from union of the v. renalis dextra and v. renalis sinistra. Whereas relationships on the right and left side in female were absolutely identical, in males, the v. renalis dextra opened into the v. cava

Table 1. Level of termination of the vv. renales (In some cases there was a plurality of vv. renales).

relation to the opposite vein	dx ♂	dx ♀	sin ♂	sin ♀
cranial	11	6	1	6
at the same level	4	2	6	2
caudal	3	6	9	6

caudalis cranially to the termination of the v. renalis sinistra in the ratio 11:3. The level at which the v. renalis dextra emptied into the v. cava caudalis thus exhibited distinct sex-related differences.

Differences were also found in the number of vv. renales (Table 2). One v. renalis was recorded in 43 renal regions (one case comparises two regions, i.e. the right side and the left), duplication of the v. renalis was seen in 16 regions and in one case three vv. renales were found. No sex-related differences were observed, but there was a distinct difference between the right side and the left (plurality of the v. renalis was commoner on the right side – 15:2).

Table 2. Number of vv. renales on the right and left side and according to sex.

N	dx ♂	dx ♀	sin ♂	sin ♀
1	6	9	13	15
2	8	6	2	–
3	1	–	–	–

As a rule, both vv. renales are characterized by a few venous tributaries. A survey is given in Table 3, which shows that there were no great sex- or side-related differences in the number of tributaries of the vv. renales; two tributaries were the most frequent (in about one third of the renal regions).

The last question studied here was the one of which veins are tributaries of the vv. renales. Table 4 gives a survey according to sex and side. It shows that were no great differences as regards the side. It shows that were no great differences as regards the side. In females the v. renalis sinistra was joined the most frequently by vv. lumbales.

Table 3. Number of tributaries of the vv. renales according to side and sex.

N	dx ♂	dx ♀	sin ♂	sin ♀
0	2	1	1	1
1	3	4	4	3
2	6	7	5	3
3	2	1	3	2
4	2	2	2	6

Table 4. Tributaries of the vv. renales according to side and sex.

vein	dx ♂	dx ♀	sin ♂	sin ♀
v. suprarenalis	4	3	5	3
vv. suprarenales	4	3	4	6
v. lumbalis	7	11	5	12
v. spermatica resp. v. uterina cranialis	10	9	12	11

A v. capsularis draining blood from the kidney surface or capsule was a relativity frequent finding. Its incidence and termination according to sex and side are illustrated in Table 5, which shows that there were no significant differences between the incidence and termination of the vein as regard either sex or side.

Vv. suprarenales occured in both sexes and on both sides in every case. There were 1–4 of the, but most often two (in 34 regions out of 60). The way in which they terminated is shown in Table 6. Most frequently (especially in males, but also in females) they emptied into the v. cava caudalis (males 18:11); on the right they also emptied oftener into the v. cava caudalis (20:9), but on the left oftener into the v. lumbalis (9:3) and less often into the v. renalis (17:14).

Table 5. Incidence and termination of the v. capsularis according to sex and side.

vein	dx ♂	dx ♀	sin ♂	sin ♀
v. uterina cranialis resp. v. spermatica	8	4	5	4
v. lumbalis	3	4	2	1
v. renalis	1	1	1	3
v. ovarica	–	3	–	4

The v. spermatica is a paired vein draining blood from the testis. The testis lies in the abdominal cavity or in the scrotum, which at mating time bulges only very slightly above the root of the penis. The vein begins as a plexus pampiniformis formed of veins arising from the testis and veins leading from the epididymis. It is a relatively thin, long vein, which climbs the dorsal wall of the abdomen to the renal segment of the v. cava caudalis. On the right side, it emptied in 10 cases into the v. renalis dextra; if it was duplicated, it emptied into the vein further caudally. On the left side, it emptied into the v. renalis sinistra in 12 cases. In all remaining cases (5 on the right, 3 on the left) it opened into the v. cava caudalis. Where it bifurcated, it joined the vein of the relevant side. In

Table 6. Manner of termination of the v. renalis or vv. renales in both sexes, according to side.

vein	dx ♂	dx ♀	sin ♂	sin ♀
v. cava caudalis	12	8	6	3
v. renalis	8	6	8	9
v. lumbalis	3	–	3	6

general, we can claim that there were no significant differences between the right and the left side which might have a bearing on the origin of the v. cava caudalis. It is thus actually the norm for the v. spermatica to empty into the corresponding v. renalis. If it oppened into the v. cava caudalis, it always did so caudalis to the v. renalis. In 13 cases the v. spermatica was joined by a v. capsularis and in six cases by a v. lumbalis. The number of tributaries was larger on the right side (12:7).

The v. uterina cranialis arises throught its full extent from the uterine cornua. It runs over their lateral side, where it joins the venous plex. On the right side, it opened in eight cases into the v. renalis dextra and in seven into the v. cava caudalis (in all but one case caudally to the termination of the v. renalis dextra). On the left side, in 13 cases it was a tributary of the v. renalis sinistra and in two it joined the v. cava caudalis or v. cava caudalis sinistra – again below the termination of the v. renalis sinistra. The tributaries of the v. uterina cranialis included the v. ovarica (in every case and one both sides), the v. capsularis (in 5 cases, on both sides) and one or two vv. lumbales (in 4 cases on the right and in 3 on the left). On both sides the v. uterina cranialis had one or two tributaries and there were no differences between the number of tributaries on either side.

The v. uterina caudalis began as a thin vein leading from the corpus and cervix uteri; cranially it joined the v. uterina cranialis and then led caudally over the side of the given parts of the uterus, picking up the v. vaginalis on the way. It occured in every case, on both the right and left side. Apart from the v. vaginalis and a single anastosis with the v. vesicalis, it had no tributaries. Caudally it joined diverse veins in the vicinity, with small differences on the right and left (seeTable 7).

Table 7. Connection of the v. uterina caudalis to surrounding veins according to side.

vein	dx	sin
v. iliaca communis	8	7
v. iliaca externa	1	3
v. iliaca interna	3	1
v. iliolumbalis	2	3
v. cava caudalis sinistra	–	1
v. sacralis mediana	1	–

The v. ovarica occured in every case, as a constant tributary of the v. uterina cranialis. It arose from the inferior pole of the ovary, led in a caudal direction and joined the v. uterina cranialis. Its tributaries are shown, according to the sides, in Table 8. On the right side, its tributaries in one case were two vv. lumbales and two a vv. capsulares, while on the left, also in case, they were a v. capsularis together with three vv. lumbales.

Table 8. Tributaries of the v. ovarica

vein	dx	sin
v. (vv.) lumbalis	5	8
v. (vv.) capsularis	3	3
without tributaries	8	5

The vv. lumbales differed from the usual scheme in that they were not organized segmentally and that, as a rule, the most cranial vein was the thickest. There were no fundamental differences in the number of these veins in relation either to sex or to the side. A survey is given in Table 9.

Table 9. Number of vv. lumbales according to sex and side.

N	dx ♂	dx ♀	sin ♂	sin ♀
1	2	4	3	3
2	4	4	4	7
3	6	6	4	2
4	2	1	2	3
5	1	–	2	–

The cranial vv. lumbales drain blood from the subhepatic region of the dorsal abdominal wall and often from the region of the m. psoas major as well. The middle and caudal vv. lumbales are very thin; they

collect blood from the region of the m. psoas major and the surrounding parts. The non-segmental organization of these veins accounts for diversity of their connection, which are illustrated, according to sex the number of cases and the number of veins, in Table 10. The table shows that union with the v. renalis preponderated in females, but with the v. cava caudalis in males. Differences between the right and the left side were not important.

Table 10. Connections of the vv. lumbales according to sex, side and the number of veins.

vein	dx ♂	dx ♀	sin ♂	sin ♀
v. renalis	7/7	11/11	5/6	13/13
v. cava caudalis	13/22	7/12	14/22	8/11
v. spermatica resp. v. uterina cranialis	4/6	4/5	2/3	3/3
v. iliaca communis	1/1	–	–	–
v. ovarica	–	4/5	–	8/8

Tributaries of the vv. lumbales were found in relatively few cases. Table 11 shows them according to sex, side and the number of cases. Except for the right side in females, there were no significant differences between the sexes, sides and the drainage area.

Table 11. Tributaries of the vv. lumbales according to sex and side.

vein	dx ♂	dx ♀	sin ♂	sin ♀
v. capsularis	3	3	2	3
vv. suprarenales	3	7	3	–

We took vein which, as a rule, entered the v. iliaca communis or v. iliaca externa near the origin of the v. cava caudalis to be the v. iliolumbalis; it was formed by union of a thickish tributary from the lumbar region and a thin tributary from the iliac region, but was not found in all the animals examined. A survey is given in Table 12. The termination of the v. iliolumbalis, according to sex, side and number of cases, is shown in Table 13. As a rule, this vein had no further tributaries from the pelvis, although in three cases in females it was joined by the v. uterina caudalis. Origin of the v. cava caudalis.

In 22 cases the v. cava caudalis originated at the transition of the lumbar to the sacral spine, usually by confluence of the v. iliaca communis dextra and sinistra. Its formation by convergence of the v. iliaca communis sinistra, v. iliaca communis dextra and v. sacralis mediana was observed in six cases. To these we should add two more cases in which the v. cava caudalis was duplicated and in which it was also formed by confluence of the vv. iliacae communes and v. sacralis mediana. In three cases in males the v. cava caudalis was duplicated from its origin at the transition from the v. iliaca communis to cranially to the termination of the vv. renales and vv. suprarenales (Fig. 3). The paired vv. cavae caudales did not unite until they were level with the upper pole of the right kidney. In females, duplication of the v. cava caudalis was found only once in our material, caudally to where the vv. renales and vv. suprarenales united to form a single v. cava caudalis.

In addition to the venous tributaries already de-

Table 12. Incidence of the v. iliolumbalis according to sex and side.

	dx ♂	dx ♀	sin ♂	sin ♀
N	12	14	13	11
duplication	2×	4×	4×	4×

Table 13. Termination of the v. iliolumbalis according to sex, side and the number of cases.

vein	dx ♂	dx ♀	sin ♂	sin ♀
v. iliaca communis	7	6	5	3
v. iliaca externa	5	7	8	8
v. cava caudalis dextra	1	–	–	–
v. iliaca interna	–	1	–	–
v. femoralis	–	–	–	1

Table 14. Tributaries of the v. cava caudalis according to sex and side.

vein	dx ♂	dx ♀	sin ♂	sin ♀
v. renalis	15/1–3	14/1–2	15/1–3	14/1–2
v. renalis communis	–	1	–	–
v. suprarenalis	12/1–3	8/1–2	5/1–2	4/1–2
v. lumbalis	13/1–5	7/1–2	14/1–4	8/1–3
v. iliolumbalis	1/1	–	–	–
v. iliaca communis	12 + 3	14 + 1	12 + 3	14 + 1
v. sacralis mediana	♂ 5/1		♀ 1/1	
v. spermatica	5/1	–	3/1	–
v. uterina cranialis	–	6/1	–	3/1
v. vesicalis	♂ 2/1		♀ –	

scribed, the v. cava caudalis can be joined by the v. sacralis mediana and v. vesicalis. A survey of all the tributaries of the v. cava caudalis (or vv. cavae caudales), according to sex, side and the number of tributaries, is given in Table 14. The relationship of the v. cava caudalis and aorta abdominalis, in both sexes and according to sides, is summed up in Table 15. The bifurcation of the abdominal aorta and the site of origin of the v. cava caudalis were level with each other in 15 cases. The norm can be taken to be when aorta runs to the left of the v. cava caudalis (19 cases). Both these conditions (the same level, the aorta to the left) were fulfilled in only 11 cases (3 males and 8 females).

Table 15. Relationship of the v. cava caudalis and aorta abdominalis according to sex, side and the number of cases.

position of the aorta	♂	♀	Σ
left to the v. cava caudalis	9	10	19
right to the v. cava caudalis	1	–	1
behind the v. cava caudalis	2	4	6
between the vv. cavae	3	1	4

In the given region of the guinea pig v. cava caudalis, we also observed a few portocaval anastomoses; a survey is given in Table 16. In the portal region it is virtually only vv. colicae that are involved.

Table 16. Survey of portocaval anastomoses.

types of anastomoses	N	
	♂	♀
v. cava caudalis with the v. colica media	2	–
v. iliaca communis sinistra with the v. colica sinistra	3	2
v. iliaca externa sinistra with the v. colica sinistra	1	–

A v. sacralis mediana was found in 15 cases in males and in 14 cases in females. Its connections are given in Table 17. This shows that the v. sacralis mediana is relatively the most frequently a tributary of the v. iliaca communis dextra, which it generally joins near the confluence of the two vv. iliacae communes.

Table 17. Connection of the v. sacralis mediana according to sex.

connection with	♂	♀	Σ
v. iliaca communis dextra	6 (from this number in 1 case the v. cava caudalis was doubled)	9	15
v. cava caudalis	4 (from this number in 1 case into the doubled v. cava caudalis)	4 (from this number in 1 case into the doubled v. cava caudalis)	8
v. iliaca communis sinistra	4	1	5
v. iliaca interna dextra	1	–	1

DISCUSSION

Special relationships in the organization of the renal veins are to be found in the seal (Barnett et al. 1958), in which, while the perirenal venous network remains intact, blood is drained from either side by, as a rule, three vv. renales. Reis and Esenther (1959) found a single v. renalis on the right side in 89.2 % of human beings (500 cases examined post – mortem). In she cats, Habermehl (1951–1952) found anomalous organization of the v. cava caudalis in two cases out of 15, so that this further descriptions concerned 13 animals. In toms, duplication of the right vv. renales was found in three cases out of eight (38.8 %). In our male guinea pigs, more than one v. renalis dextra was found in nine cases (59.4 %) on the right and in two cases (13.2 %) on the left, i.e. on the right side this appears to be the norm. In she cats, Habermehl (1951–1952) found one v. renalis on either side in four cases and its duplication on the right side in only one (20 %). In female guinea pigs, the v. renalis was duplicated on the right side in six cases out of 15, i.e. in 40 %.

Reis and Esenther (1959) described persistence of a venous ring (renal collar) round the aorta at vv. renales level in 30 of their human cadavers (i.e. 6 %). Royal and Callen (1979) described in man an incidence of a v. renalis sinistra divided into a pre and a retrorenal arm in 1.5–8.7 % of their cases and with a retrorenal course in 1.8–2.4 %. Reed et al. (1982) found the former situation in 4.4 % of their cases and the latter situation in 1.8 %. We observed no such phenomenon in the guinea pig.

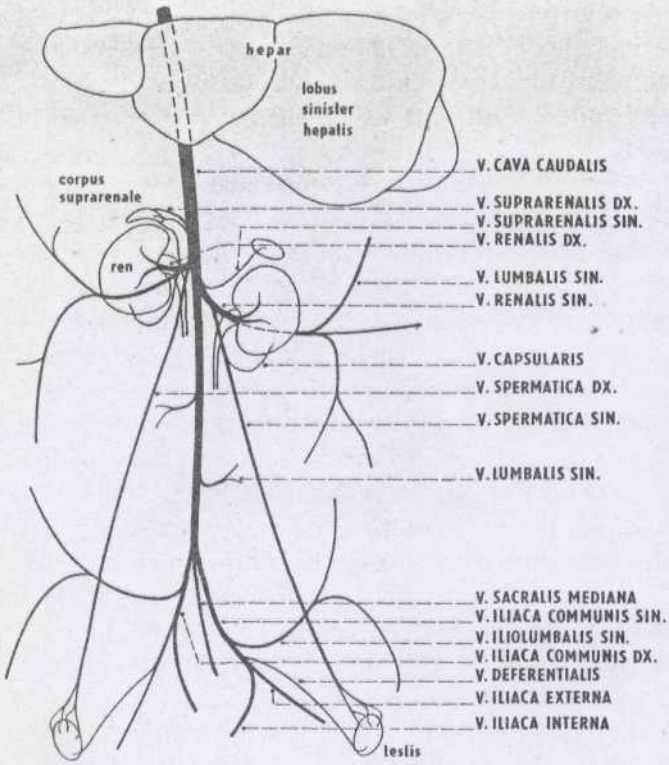

Fig. 1. The v. cava caudalis and its tributaries in a male guinea pig.

As regards the level at which the vv. renales open into the v. cava caudalis, in 12 cases in cats, irrespective of sex, both vv. renales emptied into the v. cava caudalis at the same level in three cases, the v. renalis dextra cranially to the v. renalis sinistra in three cases and caudally to it in six (Habermehl 1951–1952) although in all the animals the v. renalis dextra lay further cranially, in keeping with the topography of the right kidney. In the mole and the rabbit (Zumstein 1898), the v. renalis sinistra opened into the v. cava caudalis caudally to the opening of the v. renalis dextra – evidently in association with the more cranial position of the right kidney. In the dog (Pohle 1920), the v. renalis sinistra likeways always joined the v. cava caudalis further caudally than the right vein. In the quinea pig, there were distinct sex-related and right-left differences in the level at which the vv. renales opened into the cava caudalis. In males, the v. renalis dextra opened cranially to the v. renalis sinistra in 11 cases, level with it in four and caudally to it in only three. The v. renalis sinistra opened cranially to the right vein in only one case, level with it in six and caudally to it in only nine cases. In females, the manner in which the vv. renales opened into the v. cava caudalis was the same on both sides. Out of 14 cases, they opened at the same level in two, while the v. renalis dextra opened cranially and caudally to the v. sinistra in six cases each.

Habermehl (1951–1952) also mentioned the v. capsularis which, according to him, opened either into the v. renalis or v. spermatica or uterina. Our findings in the guinea pig also included emptying of the v. capsularis into the cranial v. lumbalis or v. ovarica.

According to Zumstein, veins from the gonads of the quinea pig (1897) join the v. cava caudalis on the right side and the v. renalis sinistra on the left, together with v. suprarenalis sinistra, while in the mole and the rabbit (1898) they join the v. cava caudalis on both sides. Zumstein (1897) regarded the v. suprenalis dextra in the guinea pig as a tributary of the v. cava caudalis. Huntington and McClure (1920) stated that, in the cat the veins from the gonads opened into v. cava caudalis on the right and into the v. renalis on the left. In toms, the v. spermatica (Habermehl 1951–1952) emptied bilaterally into the v. cava caudalis in only one case; in remaining seven cases the v. spermatica dextra and sinistra joined the corresponding v. renalis. Pohle (1920) in dogs, found that the v. spermatica mostly joined the v. cave caudalis. In male guinea pigs, the v. spermatica opened on the right side into the v. renalis dextra in 10 cases and on the left side into the v. renalis sinistra in 12 cases. In male guinea pigs also, therefore, it is the norm, on the right side, for the v. spermatica to empty into the v. renalis dextra.

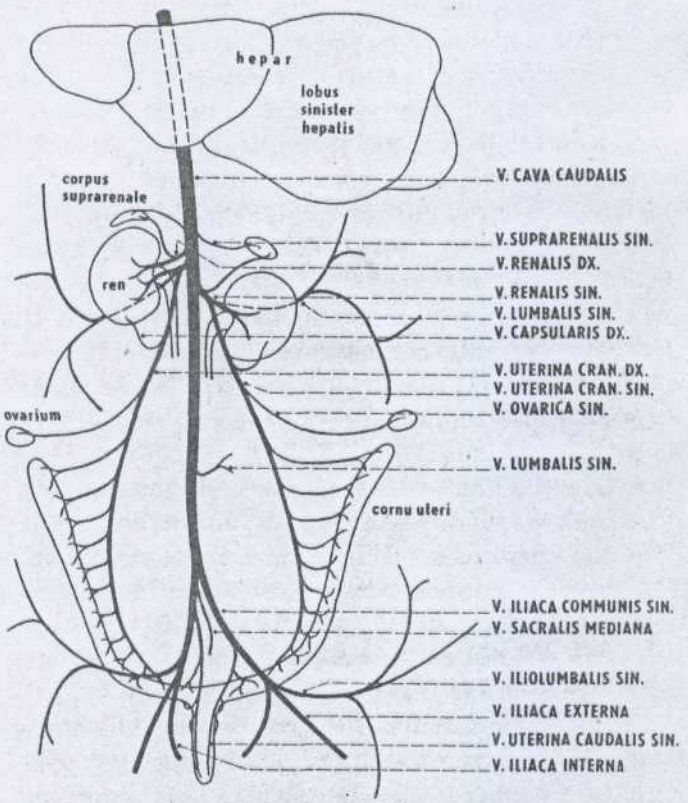

Fig. 2. The v. cava caudalis and its tributaries in a female guinea pig.

In the cat, the v. uterina cranialis (Habermehl 1951–1952, 7 cases in all) opened bilaterally into the v. cava caudalis in four cases, while in three the vv. uterinae craniales (dextra and sinistra) emptied into the corresponding v. renalis. In three bitches (Pohle 1920), the v. uterina cranialis dextra opened twice into the vena cava caudalis and only once into the v. renalis dextra, while the v. uterina cranialis sinistra was always a tributary of the corresponding v. renalis. In the quinea pig, the v. uterina cranialis dextra opened in eight cases into the v. renalis dextra and in seven into the v. cava caudalis. On the left side, the v. uterina cranialis was a tributary of the v. renalis in 13 cases and joined the v. cava caudalis in only two. In the female guinea pig we can thus see distinct differences between the right side and the left, closely resembling relationship in man. As regards the connection of the v. uterina cranialis in the quinea pig, the right side differs markedly from the usual conception in mammals. Michel (1961) described three vv. uterinae – cranialis, media and caudalis – in the golden hamster. No v. uterina media was observed in our guinea pigs.

The data of Del Campo and Ginther (1972), who studied the veins of the ovaries and uterus in eight guinea pigs, six rats, six hamsters and eight rabbits, are at variace with our findings in guinea pigs. In the first three, these authors described the vein draining from the uterus and ovary as the v. uteroovarica. In the rabbit they described a separate v. ovarica and v. uterina. Our findings in the guinea pig do not allow agreement with the definition "v. uteroovarica", since the v. uterina cranialis is a thick vein with several tributaries from the cornu uteri and only one relatively small tributary from the ovary. We therefore regard our description of this vein as the v. uterina cranialis, with the v. ovarica as a tributary, as more appropriate. In the first three species mentioned, the above authors distinguished only one v. uterina, which joined the v. cava caudalis on the right and the v. renalis sinistra on the left and united caudally with the v. iliaca. They thus did not differentiate at all the v. uterina caudalis, which collects blood from the short corpus and cervix uteri and opens as a rule into the v. iliaca communis. The rabbit v. ovarica dextra opens into the v. cava cranialis and the v. ovarica sinistra into the v. iliolumbalis. We did not observe the anastomosis they described between the two vv. uteroovaricae.

In our opinion, some of the reasons for differences in the findings as regards the guinea pig (and also, perhaps, the other species described by del Campo and Ginthar 1972) are the small number of animals examined in each species, imperfect dissection and inadequate knowledge of relevant literature for comparison. The claim of existence of one v. uteroovarica emptying cranially into the v. cava caudalis or v. renalis sinistra and caudally into the v. iliaca is particularly surprising.

According to Zumstein (1897), the vv. lumbales of the guinea pig are small and irregular tributaries of the v. cava caudalis. Habermehl (1951–1952) termed the v. iliolumbalis the v. circumflexa ilium profunda – as he himself stated, in disagreement with other authors. We can evaluate the suitability of this description of the relevant vein only from the author's drawings. Since this vein opens only into the lower segment of the v. cava caudalis and comes from the lumber region, we incline more to the term "v. iliolumbalis". In our opinion, the v. circumflexa ilium profunda ought to run posteroanteriorly (together with the corresponding artery). According to Habermehl (1951–1952), these veins, in tomcats, emptied five times into the v. cava caudalis, twice (both veins) into the v. iliaca communis and once (on the left) into the v. iliaca communis sinistra; in the cats the v. iliolumbalis emptied five times into the v. cava caudalis and twice into the vv. iliacae communes. In quinea pigs (where there were no sex-related differences), 28 of the veins opened into the v. iliaca externa, 21 into the v. iliaca communis and only one into the v. cave caudalis dextra. There

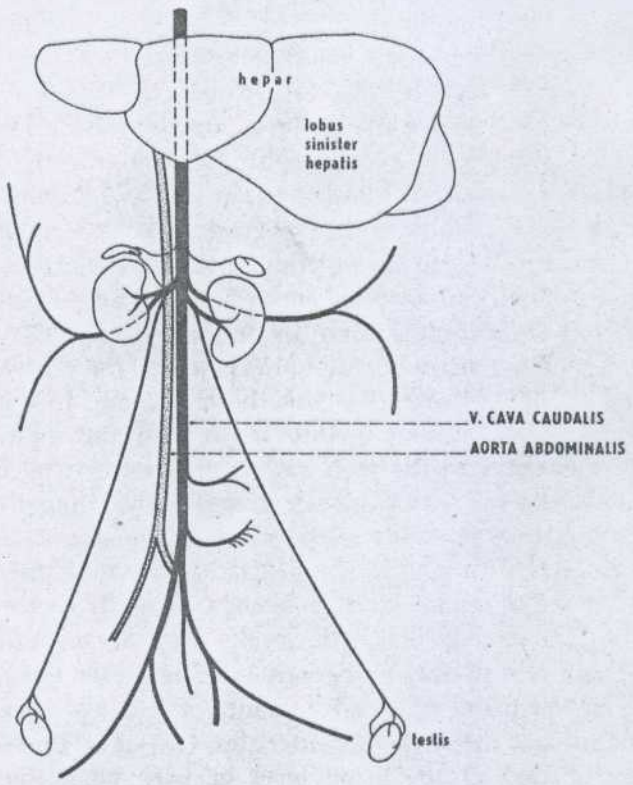

Fig. 3. Duplication of the v. cava caudalis and its tributaries in a male guinea pig.

was thus a significant difference between the cat and the guinea pig.

A large, unified v. cava appears for the first time in lung-fishes (Dipnoi) (Wiedersheim 1906, Ihle et al. 1927, Kämpfe et al. 1980). Gelderen (1933), and particularly Barnett et al. (1988), summed up the comparative morphology of the v. cava caudalis in mammals. Duplication of the v. cava caudalis is common in monotremes and in marsupials. It also occurs in some insectives and in certain primates (the tarsier). Bilaterality of the postrenal segment of the v. cava caudalis has been described in the loris (Nicticebus) and the armadillo and in other edentates. Duplication of the v. cava caudalis is complete in sloths and in the manatee (Trichechus) and is frequent in pinnipeds (seals), cetaceans, some ungulates and elephants.

Schwarze and Badawi (1961) described in billy-goat duplication of the v. cava caudalis with a high point of union above entry of the v. renalis sinistra into the left vein. They concluded that this represented persistence of the vv. supracardinales, united in the middle segment with pars subcardinalis v. cava caudalis. It was thus not a case of persistance of the vv. cardinales posteriores, as some older authors had assumed. The above authors also gave a survey of all previously described cases of duplication of the v. cava caudalis in man and animals (cat, dog).

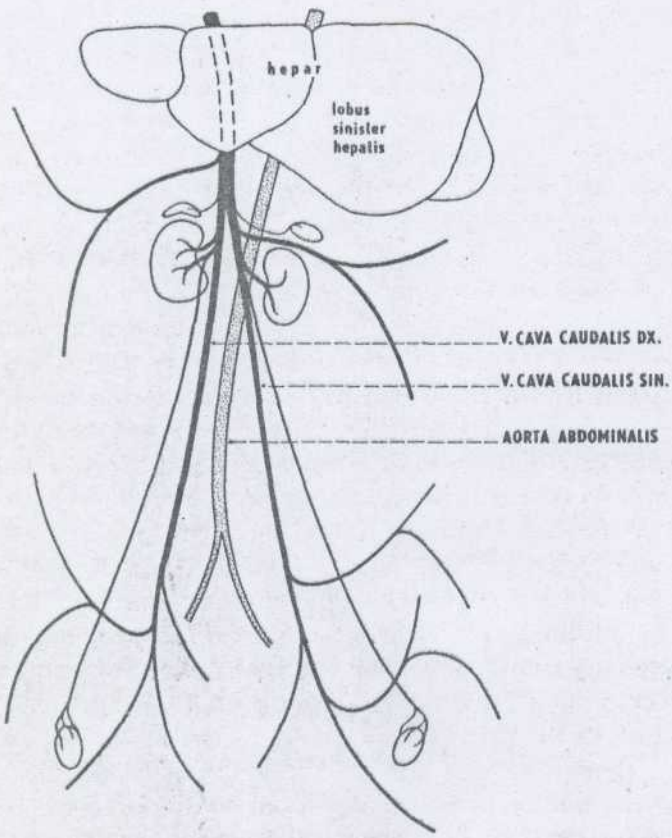

Fig. 4. Anomalous relationship of the v. cava caudalis to the aorta.

Zumstein (1897) examined 20 adult quinea pigs and found a duplicated v. cava caudalis in three (15 %). In our 30 guinea pigs we found duplication of the v. cava caudalis in four (33.3 %), three of which were males and one was a female. From the rich literature on duplication of the v. cava caudalis in man we shall cite only a few authors. According to Košir (1922), a thick vein passed upward, to the left of the aorta abdominalis, up to the level of the 8th thoraric verterbra, and then shifts retroaortally to the right side of the aorta. The author presumes this to be persistence of the v. cardinalis posterior sinistra and dextra, in the absence of a v. cava caudalis. Among 1.055 cadavers examined by Adachi (1937), duplication of the v. cava caudalis was found in 14 (1.3 %, 13 males and only one female). Whether duplication is indeed more frequent in the male sex is a question that still remains to be answered. Adachi further pointed out that varietes of the v. cava caudalis were about three times more frequent in adult Europeans than in adult Japanese. Whereas in man the left v. cava caudalis joins the right vein after receiving the vv. renales sinistrae, as a rule by a wide and almost transverse anastomosis situated ventrally to the aorta (e.g. Nowak 1963), our findings show that, in the quinea pig, both vv. cavae caudales unite at an acute angle in front of the aorta abdominalis, most often suprarenally.

Schmidt (1975) put the frequency of incidence of duplication of the v. cava caudalis in man at 0.5 % and Royal and Callen (1979) at 0.2–3.0 % . Alten (1913) and Neuberger (1913) regarded partial or complete transposition of the v. cava caudalis to the left as the outcome of persistence of the v. cardinalis posterior sinistra. Alten (1913) described in man a case in which the whole of the v. cava caudalis lay to the left of the aorta abdominalis right up to the heart. Royal and Callen (1979) described a shift of the v. cava caudalis to the left of the aorta abdominalis in subrenal region only (frequency of incidence 0.2–0.5 %). In our material (the quinea pig, the v. cava caudalis lay to the left of the aorta abdominalis throughout the whole of the subdiaphragmatic region (see Fig. 4). Among 20 quinea pigs, Zumstein (1897) found one in which the v. cava caudalis ley to the left of the abdominal aorta and in adult rabbits made the same findings likewise in one animal (Zumstein 1898). He took them to cases of the v. cardinalis posterior dextra and persistence of the v. cardinalis posterior sinistra.

The development of the v. cava caudalis is complicated and views in the literature are not altogether unanimous. Basic information is supplied by Zumstein

(1897 – quinea pig; 1898 – mole, rabbit), Huntington and McClure (1907 – cat; 1920 – also cat and still a standard work), Reagan (1927 – rat), Gelderen (1933 – various vertebrates), Grünwald (1938 – man), Butler et al. (1946 – cat), Stanek (1952 – man), Barnett et al. (1958 – various mammals), Schwarze and Badawi (1961 – billy-goat), Schmidt (1975 – man) and Klika et al. (1985 – man).

According to Zumstein (1897), morphogenesis of the guinea pig v. cava caudalis takes place betwen the 19th and 25th day of embryogenesis, when its structure is complete. Zumstein concluded that the postrenal segment the vein was formed from the v. cardinalis posterior dextra, which was joined from the left by an anastomotic segment from the v. cardinalis posterior sinistra. The cranial and caudal part of the v. cardinalis posterior sinistra then disappeared, while a transverse anastomotic segment is connected by the v. suprarenalis sinistra, v. renalis sinistra and v. spermatica sinistra. If the postrenal part on the left did not disappear, a duplicate v. cava caudalis was formed. However, the postrenal segment of the v. cardinalis posterior may persist even when an anastomosis between the two vv. cardinalis posteriores is formed. In the mole Zumstein (1898) studied the development of the vein in embryos measuring from 3 mm up to 30 mm, when definitive relationships were formed. In the rabbit he studied embryos from a lenght of 7.5 mm up to 30 mm. He found that the pronephros of the mole were much larger than those of the guinea pig.

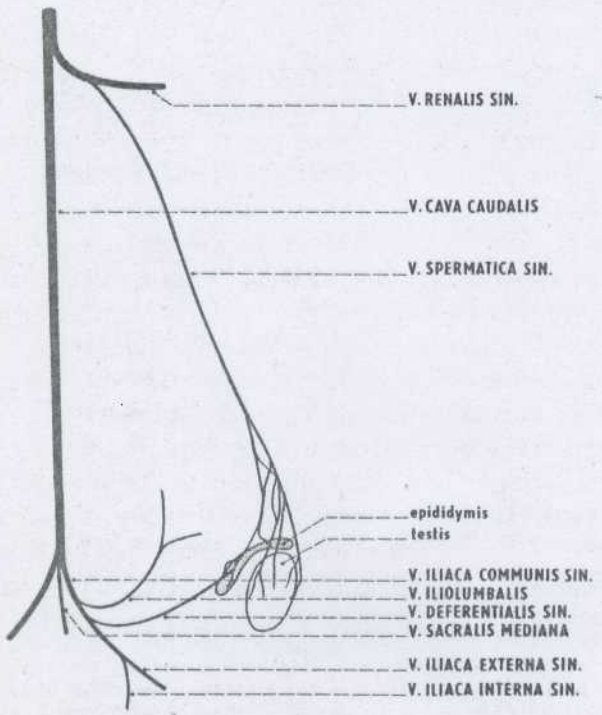

Fig. 5. Drainage of venous blood from the guinea pig testis.

According to Butler (1927), the role of the vv. cardinales caudales, vv. subcardinales and vv. supracardinales in formation of the v. cava caudalis varies and depends on the size and functional fitness of the pronephrones. In some species the pronephrons are active for a relatively long time, while in others (rabbit, rat) they soon cease to be active.

The origin of the vv. spermaticae (or vv. uterinae craniales) is also described in different ways. According to Zumstein (1897, 1898), in adition to the v. cardinalis posterior, a vein draining blood from the pronephrons (evidently the v. subcardinalis of later authors), which then gives rise to the v. spermatica, is formed in the guinea pig, mole and rabbit. Huntington and McClure (1920), in the cat, described these veins as originating from the v. cardinalis posterior (the cranial segment) and the v. subcardinalis (the caudal segment alongside the gonads). In man, Grünwald (1938) and Stanek (1952) stated that they arose from the v. subcardinalis. According to Schwarze and Badawi (1961), this difference is due to the time of disapearance of the vv. cardinales posteriores. In man they disappear early on, so that blood is drained from the pronephrons by the v.v. subcardinalis, which then give rise to the efferent veins of the gonads. In the cat, the vv. cardinales posteriores play an important role in the drainage of blood from the pronephrons. The vv. subcardinales soon disappear and so the veins from the gonads originate from the vv. cardinales posteriores. Habermehl (1951–1952) attributed the marked variability of the venous tributaries of the v. cava caudalis to formation of the efferent organ veins from a venous network in which only some of the channels are preserved.

It can be seen from the above survey that several factors participate in the rich variability with which the v. cava caudalis and its tributaries are organized: the complicated development of the v. cava caudalis and its deviations in the form of phylogenetic reminiscences (the best interpretation is to be found in the scheme of Huntington and McClure 1920, cited above), the size and functional fitness of the pronephros, which determine the time of disappearance of the vv. cardinales posteriores, the original plexiform organ venous trunks and their different canalizations and splitting of the original venous primordia (e.g. in the case of the vv. renales).

Since the tributaries of the v. cava caudalis have been studied in greater detail only in the cat (Habermehl 1951–1952; Pohle, 1920, evidently only a few dogs) and since interest has hitherto centred mainly on

the v. cava caudalis and its variants, it is at present impossible to asses and evaluate in detail our, description of the variability of the tributaries of the v. cava caudalis, either developmentally or from the taxonomic aspect. We shall therefore have to study the tributaries of this vein in suitable series of other laboratory animals belonging to different orders and different species.

REFERENCES

Adachi, B. (1937) Statistik der Varianten der V. cava caudalis bei Japanern. Anat. Anz., 85: 215–223.

Alten, H. (1913) Über linksseitige Lage der Vena cava inferior. Anat. Anz., 43: 337–348.

Barnett, C. H., Harrison, R. J. and Tomlison J. D. W. (1958) Variations in the venous system of mammals. Biol. Rev. 33: 442–487.

Butler, E. G. (1927) The relative role played by the embryonic veins in the development of the mammalian vena cava posterior. Am. J. Anat., 37: 267–354.

Butler, E. G., McElroy, W. D. and Punkert, W. O. (1946) On the relative frequency of variant types of the vena cava posterior in the cat. Anat. Rec., 94: 93–104.

Del Campo, Ch. and Ginther, O. J. (1972) Vascular anatomy of the uterus and ovaries and the unilateral luteolytic effect of the uterus in guinea pigs, rats, hamsters and rabbits. Am. J. Vet. Res. 33: 2561–2578.

Ellenberger, W. and Baum, H. (1921) Handbuch der vergleichenden Anatomie der Haustiere. Berlin: A. Hirschwald.

Gelderen, Ch. van (1933) Venensystem, mit einem Anhang über den Dotter- und Plazentarkreislauf. In: Handbuch der vergleichenden Anatomie der Wirbeltiere. Bd, VI. Bolk, L. L. et al. (eds.) Berlin: Urban und Schwarzenberg, pp. 685–744.

Greene, E. Ch. (1959) Anatomy of the Rat. New York: Hafner Publishing co.

Grundwald, P. (1938) Die Entwicklung der V. cava caudalis beim Menschen. Z. mikrosk-anat. Forsch., 43: 275–330.

Habermehl, K. H. (1951–1952) Das Verhalten der Vena cava caudalis (postrenaler Abschnitt) und ihres visceralen Zuflussgebietes bei der Katze (*Felis domesticus* L.). Anat. Anz., 98: 295–308.

Hochstetter, F. (1887) Über die Bildung der hinteren Hohlvene bei den Saugetieren. Anat. Anz., 2: 517–520.

Huntington, G. S. and McClure, C. F. W. (1907) Development of the postcava and tributaries in the domestic cat. Proc. Ass. Amer. Anat., Anat. Rec., 3: 29–30.

Huntington, G. S. and McClure, C. F. W. (1920] The development of the veine of the domestic cat (*Felis domestica*) with special reference (1) to the share taken by the supracardial veins in the development of the postcava and azygos veins, to the interpretation of the variant conditions of the postcava and its tributaries as found in the adult. Anat. Rec., 20: 1–30.

Ihle, J. E. W., Kampen, P. N. van, Nierstrasz, H. F. and Verluys, J. (1927) Vergleichende Anatomie der Wirbeltiere. Berlin: J. Springer.

Kampfe, L., Kittel, R. and Klapperstuck, J. (1980) Leitfaden der Anatomie der Wirbeltiere. Jena: G. Fischer.

Klika, E., Vacek, Z., Dvořák, M. and Kappeler, K. (1985) Embryologie. Praha: Avicenum/Osveta. (In Czech.)

Košir V. (1922) Persistierende Kardinalvenen und fehlende V. cava inferior. Anat. Anz., 55: 365–368.

Lauber, H. (1901) Ein Fall von teilweiser Persistenz der hinteren Kardinalvene beim Menschen. Anat. Anz., 19: 590–596.

Malinovský, L, and Navrátilová, E. (1990 a) The vena portae of the domestic cat and variability of its tributaries. Folia Morphol. (Prague), 38: 273–277.

Malinovský, L. and Navrátilová, E. (1990 b) Origin of the v. portae and variability of its tributaries in laboratory animals. III. The laboratory rat (*Rattus norvegicus* v. alba). Folia Morphol. (Prague), 38: 366–375.

Malinovský, L., Navrátilová, E. and D'Andrea, v. (1991) The origin of the v. portae and variability of its tributaries in laboratory animals. V. The golden (Syrian) hamster (*Mesocricetus auratus*) Functional and Developmental Morphology, 2: 27–36.

Michel, G. (1961) Die Venen der Bauch – und Beckenhöhle, einschliesslich der Pfortader, und der Beckengliedmasse des syr. Goldhamsters (*Mesocricetus auratus W.*). Anat. Anz., 110: 7–17.

Navrátilová, E. and Malinovský, L. (1990) Origin of the v. portae and variability of its tributaries in laboratory animals. II. The guinea pig (*Cavia aperea f.* porcellus). Folia Morphol. (Prague), 38: 301–311.

Navrátilová, E. and Malinovský, L. (1991). The origin of the v. portae and variability of its tributaries in laboratory animals. IV. The domestic rabbit (*Oryctolagus cuniculus f.* domestica). Functional and Developmental Morphology, in press.

Navrátilová, E., Malinovský, L. and D'Andrea, V. (1991) The origin of the v. portae and variability of its tributaries in laboratory animals. VI. The laboratory mouse (*Mus musculus* var. alba). Functional and Developmental Morphology, in press.

Nejedlý, K. (1965) Biologie a soustavná anatomie laboratorních zvířat. Praha: SPN. (In Czech.)

Neuberger, H. (1913) Ein Fall von vollkommener Persistenz der linken Vena cardinalis posterior bei fehlender Vena cava inferior. Anat. Anz., 43: 65–80.

Nowak, M. (1963) A rare variation of the tributaries of the inferior vena cava in man. Folia morphol. (Warsz.) 22: 144–152.

Pohle, CD. (1920) Das Venensystem des Hundes. Diss. Dresden. (Cit. from Habermehl 1951–1952).

Pogorzelski, J. K. (1957) Experimental study on the collateral circulation in the lower cardinal vein system in albino rat. (In Polish.) Folia morphol. (Warsz.) 8: 201–209.

Reagen, F. P. (1927) The development of the postrenal vena cava in the rat. Anat. Rec. 38: 58.

Reed, M. D., Friedman, A. C. and Nealey, P. (1982) Anomalies of the left renal vein. Analysis of 433 CT scans. J. Comput. Assist. Tomogr., 6: 1124–1126.

Reis, R. H. and Esenther, G. (1959) Variations in the pattern of renal vessels and their relation to the type of posterior vena cava in man. Am. J. Anat., 104: 295–328.

Royal, S. A. and Callen, P. W. (1979) CT evaluation of anomalies of the inferior vena cava and left renal vein. Am. J. Roentgenol., 132: 759–763.

Schmidt, G. P. (1975) Über eine besondere Form der doppelseitigen V. cava inferior. Anat. Anz., 137: 200–206.

Schwarze, R. and Badawi, R. (1961) Eine doppelte V. cava caudalis bei einem Ziegenbock. Anat. Anz., 110: 52–62.

Stanek, I. (1952) Embryológia človeka. Bratislava: Slovenská akademie vied a umení. (In Slovak.)

Wiedersheim, R. (1906) Vergleichende Anatomie der Wirbeltiere. Jena: G. Fischer.

Zumstein, I. (1897) Zur Entwicklung des Venensystems bei dem Meershweinchen. Anat. Hefte, Wiesbaden, 8: 165–190.

Zumstein, I. (1898) Über die Entwicklung der Vena cava inferior bei dem Maulwurfe und bei dem Kaninchen. Anat. Hefte, Wiesbaden, 10: 307–344.