Pig Kidney: Anatomical Relationships Between the Renal Venous Arrangement and the Kidney Collecting System

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Purpose: We present a systematic study of the anatomical relationship between the intrarenal veins and the kidney collecting system in pigs.

Materials and Methods: The intrarenal anatomy (collecting system and veins) was studied in 61, 3-dimensional endocasts of the kidney collecting system together with the intrarenal veins.

Results: There are free anastomoses between the intrarenal veins. The interlobar veins unite to produce large venous trunks, which form the renal vein. In our study we observed 2 trunks (cranial and caudal) in 54 of the 61 cases (88.53%) and 3 trunks (cranial, middle and caudal) in 7 (11.47%). Only the ventral surfaces of the cranial and caudal poles were drained by large veins, while the dorsal surfaces emptied by anastomoses into the ventral interlobar veins. There were large veins in a close relationship to the ventral surface (90.16%) and to the dorsal surface (3.28%) of the ureteropelvic junction. In 33 of the 61 cases (54.10%) there was 1 or 2 small dorsal veins.

Conclusions: Although some results of intrarenal venous arrangement in pigs could not be completely transposed to humans, many similarities of pig and human kidneys support its use as the best animal model for urological procedures.

Key Words: kidney; swine; veins; models, anatomic

Many animals have been used as experimental models for urological procedures but the pig is more often used because its kidney most closely resembles the structural features of the human kidney.[1,2] Pig kidneys are frequently used as a model for search[3] and training[4,5] in nephrolithotomy. Urologists have been looking for a better method to control bleeding during and after endourological procedures.[6] Renal vein injury with massive hemorrhage can be a cause of unsuccessful results of endourological management.[7]

Many studies have been done of pig kidney anatomy, including its morphometric aspects,[1] the collecting system and arterial relationships.[2] Despite the existence of free circulation throughout the venous system the veins are worth attention because a lesion of a large vein results in important back bleeding during and after the operation.[8] Many researchers have studied the intrarenal venous arrangement in humans[9–12] and in pigs[13,14] but no particular attention has been given to the relationship between the intrarenal veins and the collecting system in pigs.

We present a systematic study of the anatomical relationship between the intrarenal veins and the collecting system in 3-dimensional endocasts of the porcine kidney to help urologists in experimental research and urological surgical training when using the pig as an animal model.

MATERIALS AND METHODS

Our material consisted of nonfixed kidneys from adult mixed breed Duroc and Large-White farm pigs that were slaughtered at age 140 days and weighed 60 to 80 kg (mean 72). The institutional animal review committee approved the research protocol.

The intrarenal anatomy (collecting system and veins) was studied in 61 (27 right and 34 left) 3-dimensional endocasts of the collecting system together with the intrarenal veins, which were obtained according to the technique described in previous series.[7,11,12] Briefly, to obtain the endocasts a yellow polyester resin (volume 4 to 8 ml) was injected into the ureter to fill the kidney collecting system and a blue resin (volume 8 to 12 ml) was injected into the main trunk of the renal vein to fill the venous tree. Added to the resin was methyl ethyl peroxide as a catalyst in a proportion of 3% of injected resin. After injection and setting of the resin (24 hours) the perirenal fat was removed and the kidneys were immersed in a bath of concentrated commercial hydrochloric acid for 48 hours until total corrosion of the organic matter was achieved, leaving only the 3-dimensional endocasts of the systems that had been injected. To preserve the same relationships as those that existed in vivo during cast preparation 1 or 2 veins were fixed to the collecting system. Because the polyester resin polymerizes by addition of a catalyst, there is no shrinkage upon setting, enabling accurate analysis of the endocasts.[7,11,12]

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Study received institutional animal review committee approval.

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RESULTS

There are free anastomoses between the intrarenal veins. The most frequent anastomoses were found in the longitudinal axis. These longitudinal arcades occurred in different levels: between interlobular veins (in the cortex), between the arcuate veins (at the base of the pyramids) and between the interlobar veins (close to the renal sinus). There are also transverse anastomoses, which link the ventral and the dorsal veins, at different levels (fig. 1, *A*). Around the minor calices they form a large venous anastomosis, similar to collars (fig. 1, *B*). The interlobar veins unite to produce large venous trunks, which form the renal vein. In our study we observed 2 trunks (cranial and caudal) in 54 of the 61 cases (88.53%) and 3 trunks (cranial, middle and caudal) in 7 (11.47%) (fig. 2).

In all cases venous drainage related to the cranial and caudal caliceal groups originated only from ventral plexuses. Venous dorsal drainage emptied into the ventral plexuses by transverse anastomoses, representing the dorsal aspect of the casts free of large veins (fig. 3, *A*).

In 55 of the 61 cases (90.16%) there was a large ventral tributary of the renal vein only on the ventral surface of the ureteropelvic junction (fig. 2, *A*). In 2 of the 61 cases (3.28%) there were a large ventral tributary of the renal vein and a small dorsal interlobar vein related to the ventral and dorsal aspects of the ureteropelvic junction, respectively. In the remaining 4 cases (6.56%) the ureteropelvic junction was free of large veins.

In 33 of the 61 cases (54.10%) there were 1 or 2 small dorsal veins. In 31 of the 61 cases (50.82%) a single dorsal vein coursed obliquely on the renal pelvis to drain into the cranial tributary of the renal vein in 26 casts (42.62%) or into the caudal tributary in 5 (8.20%) (fig. 3, *A*). In the remaining 2 cases (3.28%) we observed 2 dorsal veins, including 1 draining into the cranial tributary and another emptying into the caudal tributary of the renal vein (fig. 3, *B*). In these cases there was an anastomosis between them. There was a close relationship between these dorsal veins and the junction of the pelvis with the cranial calix in 23 casts (37.75%) (fig. 1, *A*), with the renal pelvis in 11 (18.03%) and with the ureteropelvic junction in 1 (1.64%).

DISCUSSION

As in the human kidney, in the pig kidney there are free anastomoses between the intrarenal veins.[11,12] Therefore, occlusion of venous channels can be performed in the pig kidney without the risk of renal parenchymal loss. On the other hand, incision or lesions of a large vein with no doubt can be a hemorrhagic hazard due to its great size.[8]

The renal vein was formed by 2 large trunks in 88.53% of cases or 3 in 11.47%, which is different from that in humans,

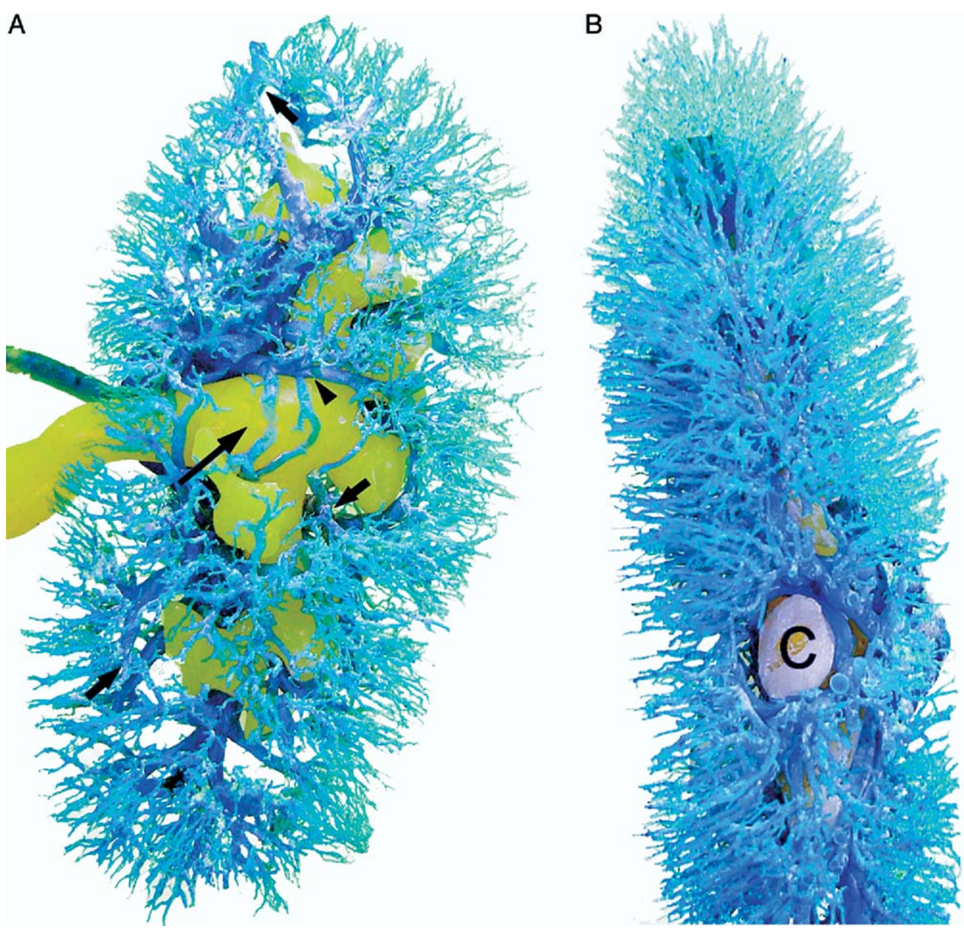

FIG. 1. Endocast shows pelvicaliceal system and renal veins of right kidney. *A*, dorsal view reveals dorsal aspect of renal pelvis free of large veins (long arrow) and transverse anastomoses (short arrows). Note close relationship between dorsal vein and junction of pelvis with cranial calix (arrowhead). *B*, lateral view demonstrates large venous anastomosis, similar to collar, around minor calices (*c*).

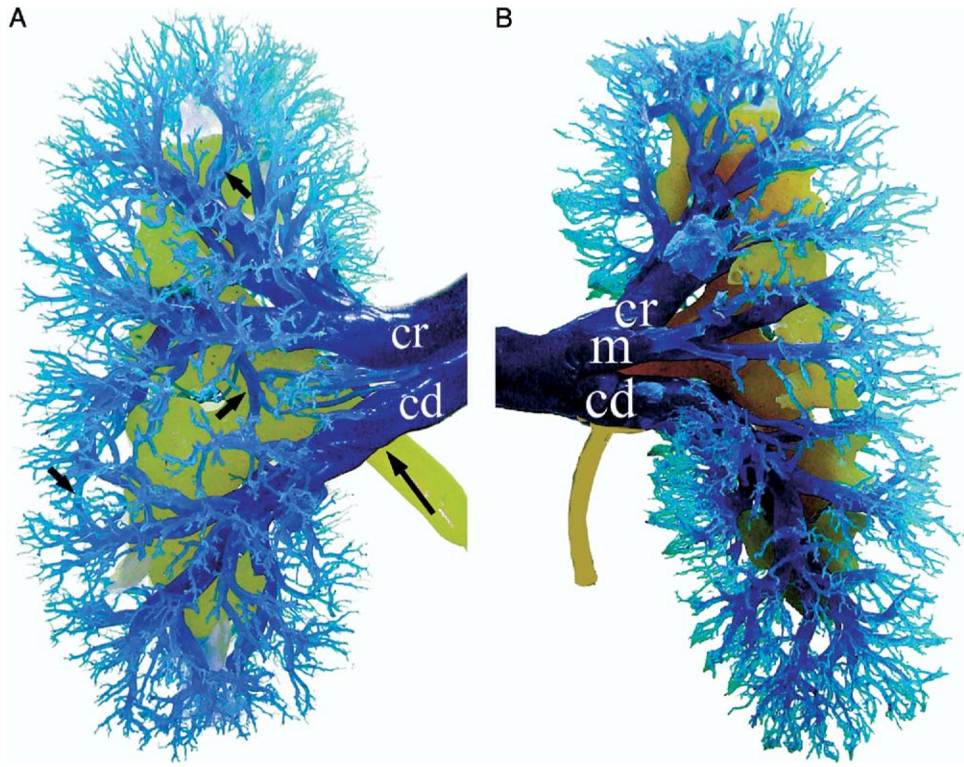

FIG. 2. Ventral view of endocasts of pelvicaliceal system and renal veins. *A*, in right kidney renal vein is formed by 2 large venous trunks, that is cranial (*cr*) and caudal (*cd*). Note relationship between caudal trunk and ventral surface of ureteropelvic junction (long arrow) and numerous longitudinal anastomoses (short arrows). *B*, in left kidney renal vein is formed by 3 large venous trunks, that is cranial, middle (*m*) and caudal.

in whom we found 2 trunks in 28.8% and 3 trunks in 53.8%.[11] Others have noted the branching pattern of the intrarenal venous tree but they did not consider the relationship between the intrarenal veins and the collecting system.[13]

Only the ventral surfaces of the cranial and caudal poles were drained by large veins, while the dorsal surfaces emptied by anastomoses into the ventral interlobar veins (fig. 3, *A*). In humans the superior caliceal group is involved by a dorsal and a ventral venous plexus in 84.6% and the inferior caliceal group in 50%, where large veins originate that course parallel to the anterior and posterior surfaces of the caliceal infundibula.[11] Due to these anatomical differences we realize that dorsal infundibular puncture in pigs does not cause hazard to the veins and, therefore, they do not cause back bleeding.

There were large veins in a close relationship to the ventral and the dorsal surface of the ureteropelvic junction (90.16% and 3.28% of cases, respectively). Therefore, as in humans, deep incision of the ureteropelvic junction, which relieves its obstruction,[15,16] must be done laterally to avoid the risk of dividing a large vein.

In humans a posterior (retropelvic) vein has been noted in a close relationship to the upper infundibulum or to the middle posterior surface of the renal pelvis (48.1% and 21.1% of cases, respectively).[11] We also observed a dorsal vein in the pig kidney. It was also related to the junction of the pelvis with the cranial calix in 37.75% of cases and to the renal pelvis in 18.03%. However, in swine the dorsal veins are smaller than those of the human kidney. Therefore, direct puncture of the dorsal surface of the renal pelvis in pigs would not result in important vascular complications, as in humans.[17] For that reason the technique and results of experimental puncture of the renal pelvis (dorsal surface) in pigs cannot be completely transposed to humans, which must be strongly considered by those involved in urological surgical training. On the other hand, the results of the transparenchymal caliceal approach may be similar to those in humans due to its similar venous arrangement around the neck of the calix and the countless anastomoses between the interlobular and arcuate veins. The numerous transverse anastomoses, which encircle the neck of the caliceal infundibulum, resembling collars, are similar to those in humans (fig. 1, *B*). This is a reason why percutaneous puncture should always aim for the fornix of the calix and never the infundibulum.[8]

Previous studies of the anatomical aspects of the porcine kidney demonstrated that the pig is an excellent model for urological procedures due to several similarities with the human kidney.[1,2,18] Although these studies revealed that the renal size and collecting system in pigs are similar to those of humans,[1] they also indicated some important differences in other aspects, such as the dorsal (posterior) artery[2] and the proportional area of the arterial segments.[18] The venous arrangement on the dorsal surface of the renal pelvis is quite different in pigs, in which there are no large veins, as in humans. This information could also indicate some limitations to using the pig kidney to investigate procedures in this region. In conclusion, although some results of the intrarenal venous arrangement in pigs could not be completely transposed to humans, many similarities of pig

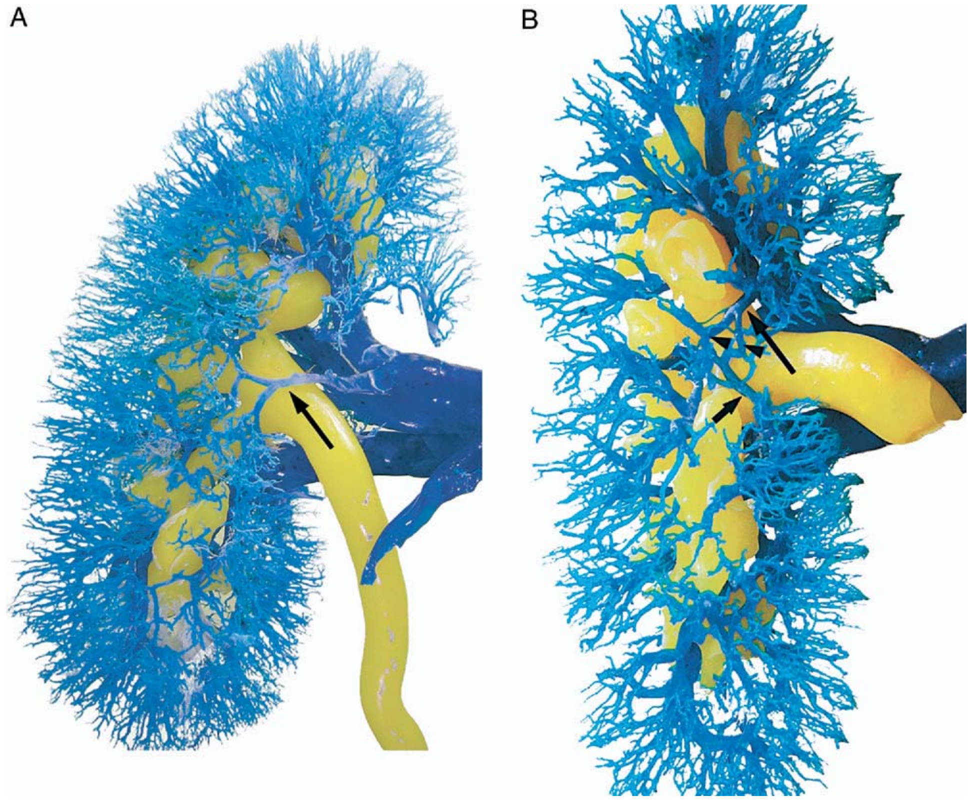

FIG. 3. Dorsal view of endocast of pelvicaliceal system and renal veins of left kidneys. *A*, 1 small dorsal vein courses obliquely on renal pelvis dorsal surface (arrow). *B*, note 2 small dorsal veins, including 1 draining into cranial tributary (long arrow) and other emptying into caudal tributary of renal vein (short arrow). Note anastomoses between them (arrowheads).

and human kidneys support its use as the best animal model for urological procedures.

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