Achievement and Using *Ex-situ* Pig Renal Corrosion Casts in Training of the Medical Students and Residents

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Renal parenchyma is served by a complex vascular-ductal system formed by renal artery (RA), renal vein (RV) and the pyelocaliceal system (PCS) continued by ureter. In the training of medical students and residents, the study of the interrelations of the elements of intraparenchymatous branches of the RA, RV tributaries, and PCS, as well as the analysis of renal corrosion casts is superior because it allows simultaneous analysis of the three vascular-ductal systems of the kidney. The present study examines the most favourable order of plastic mass injection for obtain good quality renal corrosion casts. There were used 36 kidneys from 18 domestic pigs, divided into three groups, to whom the vascularductal elements were injected with plastic (Technovit 7143), with different order of injection: the first group - with injection in order: PCS, RV and RA; the second group - with injection in order: PCS, RA and RV; the third group - with injection in order: RA, RV and PCS. Most affected by vascular compression were the renal vein and its intraparenchymatous tributaries. The most favourable order of plastic mass injection for obtain good quality renal corrosion casts by ex-situ injection is: RA, RV and PCS.

Keywords: corrosion casts, pig kidney; pyelocaliceal system; renal artery; renal vein; training

Renal parenchyma is served by a complex vascular-ductal system formed by renal artery (RA), renal vein (RV) and the pyelocaliceal system (PCS) continued by ureter. The main RA with its branches has a segmental distribution, without anastomoses between the arterial branches [1]. In contrast with this aspect, tributaries of intraparenchymal RV have many pericalyceal and peri-pelvic anastomoses. The PCS also has an intra-parenchymal segmental distribution [2]. According to studies by Graves [2-5], accepted at the International Anatomical Congress at Wiesbaden in 1965 and included into Nomina Anatomica [6] and Terminologia Anatomica [7], all descriptions sharing segmental renal parenchyma referring to situations in which the renal vascular-ductal elements (RA, RV and PCS) are unique. Among the anatomical variations of the renal vascular-ductal elements, the most common variations are the variations in number, the most common being the number of RA variations [8-13], followed by variations of the RV [14 - 17] and the rarest - variations of PCS [2, 18]. The diagnostic use of MDCT angiography reveals distinct, quickly and accurately each of the renal vascular-ductal systems (extra- and intraparenchymal) [10, 19, 20].

In the training of medical students and residents, the study of interrelations of the elements of intraparenchymatous branches of the RA, RV tributaries, and PCS, as well as the analysis of renal corrosion casts is superior because it allows simultaneous analysis of the three vascular-ductal systems of the kidney. The present study examines the most favourable order of plastic mass injection for obtaining good quality renal corrosion casts.

Experimental part

In the present study, were used 18 domestic pigs (*Sus scrofa domestica*), with an average mass of 32 kg (30-35 kg), 13 male and 5 female, previously subjects used to perform other experiments in the field of plastic surgery and abdominal surgery, carried out under general anaesthesia. All pigs were treated in accordance with the existing legislation harmonized under Directive 2010/63 / EU and recommendations of the Federation of European Laboratory Science Associations (FELASA). All experiments were approved by the Ethics Committee of the "Victor Babes" University of Medicine and Pharmacy, Timisoara. After the completion of the initial experiments (plastic or abdominal surgery), the pigs were euthanized, using 0.3mL/ kg T61 by intravenous injection. The kidneys with RA, RV and abdominal ureter of the 18 pigs (36 kidneys) were collected at necropsy, and used to study the

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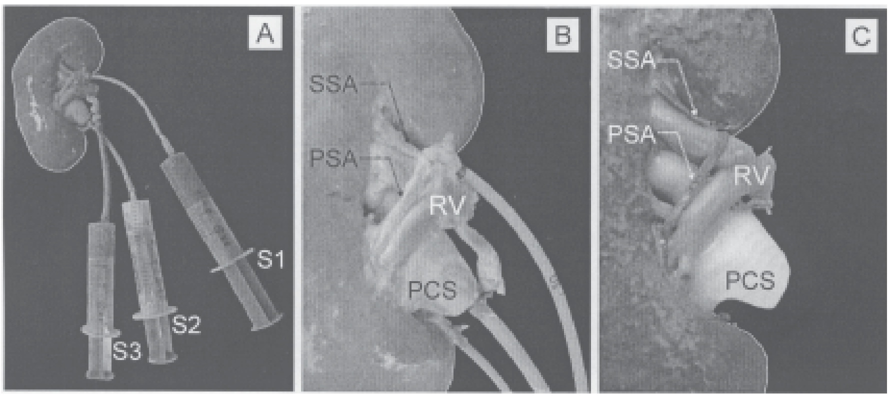

Fig.1. The injecting of plastic mass (Technovit 7143) in the intraparenchymatous vascular-ductal renal elements. A - Connection of the three 20 mL syringe with rubber tubes to the renal vascular-ductal elements. B - Posterior face of the renal synus in the period of plastic mass polymerization. C - Posterior face of the renal synus with partial corrosion of the vascular and ductal structures wall at the level of renal sinus.

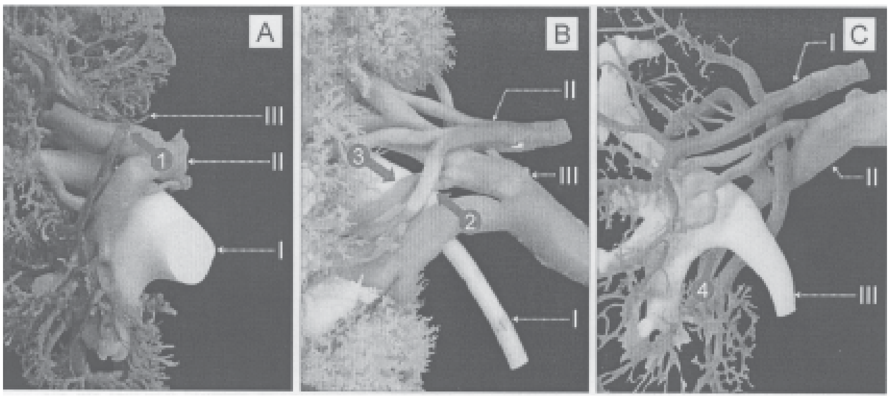

Fig.2. Renal corrosion casts injected for evidence of the pyelocalyceal system, renal artery and renal vein. Posterior view. I - II - III - Order of vascular-ductal injection. A - Corrosion cast of the first group; B - Corrosion casts of the second group; C - Corrosion cast of the third group; 1. Compression of arterial wall of a tributary of the renal vein; 2. Compression of vein wall by a branch of renal artery; 3. Compression of vein wall by the pyelocalyceal system; 4. Compression of pyelocalyceal system of a tributary of renal vein.

intraparenchymal renal vascular-ductal system, focused to determine the order of injection of vascular-ductal systems (RA, RV and PCS) so estranged to obtain a more complete injection of each system.

Preparing for *ex-situ* injecting of porcine kidneys followed a number of six steps:

- anterior mediosagital section of the anterior abdominal wall from xiphoid process of sternum to pubic symphysis and opening the abdominal cavity;
- ligation of mesenteric root and proximal and distal ends of the small intestine, followed by resection of the small bowel mesentery and ablation loops;
- ablation of the posterior parietal peritoneum, highlighting the abdominal aorta, inferior vena cava, the two kidneys and abdominal portions of the two ureters;
- section of the RAs at the level of origin from abdominal aorta, the RVs at watering points at the inferior vena cava and abdominal portion of the ureter at the level of iliac crest;
- kidney ablation followed by vascular-ductal drainage content for 1-2 h;
- cannulation of the proximal part of the RA and distal part of the RV and ureter with a rubber tube, with a comparable diameter to the endoluminal diameter of renal vasculo-ductal elements.

Technovit 7143 plastic compound (Germany) (product based on methacrylate copolymers) was prepared for injection by combining a partially polymerized monomer base with a catalyst (Technovit Universal Liquid) (methyl methacrylate and N,N-dimethyl-*p*-toluidine) a ratio of 1:1. A 20 mL syringe Luer-Lock (fig.1A and fig.1B) was used to inject the solution under hand pressure until the entire renal vascular-ductal systems was filled.

The compound was allowed to polymerize for 10 min. To remove the renal parenchyma were submerged in technical hydrochloric acid for 3-5 days. Corrosion with hydrochloric acid was interrupted by daily washing under running water to encourage the disposal of the organic tissues (fig.1C). The renal vascular-ductal casts obtained were rinsed 24 h in running water and finally photographed (Nikon D3, Tokyo, Japan, AF-S Nikkor Lens f/1.4G) and analysed. It was analyzed the interaction between elements renal vascular-ductal injection of plastics (stumbling complete injection of elements according to the order of injection).

S1 - syringe with red plastic mass, S2 - syringe with yellow plastic mass, S3 - syringe with blue plastic mass, PCS - pyelocalyceal system, RV - renal vein, SSA - superior segmental artery (branch of the renal artery), PSA - posterior segmental artery (branch of the renal artery).

The 36 kidneys were divided into three groups (each 12 kidneys in each group) with different order of ductal injection renal vascular-elements: the first group with order (i) PCS, (ii) RV and (iii) RA (fig.2A); the second group with order (i) RV, (ii) PCS, and (iii) RA (fig.2B); the third order with order (i) RA, (ii) RV, and (iii) PCS (fig.2C). Injection of each renal vascular-ductal system (RA, RV and PCS) was performed every 10 minutes, and each rubber tube was clamped (to restrain backflow of plastics).

Results and discussions

In all 36 pieces of pig kidneys corrosion casts was highlighted the PCS, and the vascular elements (RA and branches; RV and affluents.

In the first group (12 pieces of renal corrosion casts): the plastic mass injected completely the pyelocalyceal system; the intraparenchymal venous system is also fully injected, but at 2/12 corrosion casts (16,67% of cases) the pyelocalyceal system exert a slight compression of the venous wall (at the contact level); the segmental renal arteries and their branches are in contact at 7/12 corrosion casts (58.33% of cases) with the venous system elements, resulting in reduction of plastics mass injection flow in the arterial system.

In the second group (12 pieces of renal corrosion casts): the plastic mass injected completely the pyelocalyceal system and the intraparenchymatous arterial system; the venous system, last injected with plastic mass revealed in 3/12 cases (25% of cases) the compression of arterial elements, in 2/12 cases (16.67% of cases) the compression of the pyelocalyceal system, and in 5 cases (41.67% of cases) the concomitant compression of the pyelocalyceal and arterial system.

In the third group (12 pieces of renal corrosion casts): the plastic mass injected completely the arterial system; the venous system revealed in only one cases (8.33% of cases) the compression of the arterial system; completely the pyelocalyceal system reveal the venous compression in only 2/12 cases (16.67% of cases).

Overall analysis of the 36 pieces of corrosion failure shows that the least affected by the order of injection is the PCS (34/36 - 94.44% of cases fully injected), followed by renal artery and its branches (29/36 - 80.56% of cases fully injected) and finally by the renal vein and its tributaries (23/36 - 63.89% of cases fully injected). Only two corrosion casts (2/36 - 5.56% of cases) showed compression of the PCS, all determined by the intaparenchymatous arterial elements. A number of seven pieces of corrosion casts (7/36 - 19.44% of cases) revealed compression of the intraparenchymatous arterial elements, all caused by contact with intraparenchymal tributaries of the renal vein. Most affected by vascular compression were the renal vein and its intraparenchymatous tributaries. A total of 13 pieces of renal corrosion casts (13/36 - 36.11% of cases) revealed signs of vascular and ductal compression. A total of four pieces of corrosion casts (4/36 - 11.11% of cases) revealed compression caused by intraparenchymal arterial elements; four corrosion casts (4/36 - 11.11% of cases) compression caused by PCS elements; five corrosion casts (5/36 - 13.89% of cases) showed concomitant compression caused by RA and PCS elements.

The injection with Technovit 7143 plastic compound (product based on methacrylate copolymers) was followed by immediate clamping of each vascular-ductal element to stop the plastic mass reflux. The rapid polymerization of the methacrylate prevents the decrease of the volume of injected plastic mass, and retraction of the obtained corrosion cast. This disadvantage has been reported in case of using the AGO II injection paste (nitrocellulose paste) previously used in the Laboratory of Anatomy of the "Victor Babes" University of Medicine and Pharmacy Timisoara [21, 22]. The slowly polymerization of the nitrocellulose paste (24 hours), and the significant retraction of the plastic mass volume by diffusion in the tissues of the solvent, distorts the initial interrelations between the intraparenchymatous renal vascular-ductal elements (fig. 3).

If in the tracheo-bronchial injection [23] or of the liver vascular-ductal system [21] immersion of the organs in a container filled with water during injection and polymerization of plastic mass prevents the deformation of the organs and the intraparenchymatous interrelations of vascular and ductal elements.

Complicated embryological development of the kidney and renal vascular elements [24] explain this high frequency (20-30% of cases) of the additional renal arteries. During the transition phase from mesonephros to metanephros, if more than one mesonephric arteries persist, it gets additional renal artery [25]. According to early report [11, 20, 25], the additional renal arteries must be considered persistent mesonephric arteries. The additional renal arteries usually originate from the abdominal aorta, being placed above and below the main renal artery [10, 11], but in rare cases can have ectopic origin at celiac or supraceliac level [26], or at common iliac level [27].

In order to achieve quality renal corrosion casts by *ex-situ* injection, harvesting the kidneys pieces must be done by highlighting the entire height of the abdominal aorta to highlight all the present renal arteries, and harvest them closer to aortic or iliac origin. Reduced diameter of additional renal arteries can make it difficult to canulation and inject with plastic mass. Frequency of multiple renal veins is much lower than the additional renal arteries. Usually their calibre does not imply problems for cannulation and injection. For pyelocalyceal system, only the presence of a ureteral or pyelocalyceal calculus involves a poor injection of plastic mass in the pyelocalyceal system. These situations are extremely rare.

Highlighting the anatomical vascular and nerve formations can be realised: topographic by anatomical dissection [28], in surgical procedures [29], by plastinated cross-sections [30- 32], but only on limited segments and usually in the sectional plan, and by MDCT angiography [10, 11, 33, 34], but most often only for one of the vascular system (arterial or venous). Study on corrosion casts, allows highlighting concomitant several vascular and ductal systems and allows three-dimensional analysis of these structures [17, 23].

When using renal corrosion casts for training medical students and residents, should be considered the normal intraparenchymatous interrelations of the vascular and ductal elements. For primary orientation of renal corrosion casts (orientation to anterior and posterior) must bear in mind that at the level of the renal sinus the vascular elements (RA and RV) are located in the anterior plan, and the pyelocalyceal system in the posterior plan [35, 36]. Principles of organization and distribution of intraparenchymatous vascular-ductal elements in swine are similar to the humans. Analysis of the intraparenchymatous distribution of vascular and ductal elements on renal corrosion casts provides clear tridimensional images, much better than those achieved by radiological images. The development of achieving and use of swine renal corrosion casts in training of medical students and residents can successfully compensate for the lack of human renal pieces and corrosion casts.

Conclusions

Our study reveals that the least affected by the order of injection is the PCS (94.44%, followed by RA and its branches (80.56%) and finally by the RV and its tributaries (63.89%). Most affected by vascular compression were the renal vein and its intraparenchymatous tributaries. The most favourable order of plastic mass injection for obtain inggood quality renal corrosion casts by *ex-situ* injection is: RA, RV and PCS. The organization and distribution of intraparenchymal renal vascular-ductal in swine, is similar to that of the human species. The achieving and study of pig renal corrosion casts can contribute substantially in training of medical students and medical residents.

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Manuscript received: 22.09.2014