Morphological Analysis of Pig Femoro-iliaco-aorto-renal System on Corrosion Casts and MDCT Angiography

Preliminary report for stenting training

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Domestic pigs were frequently used in training centers for residents and students in medicine for the stenting procedures at the level of renal arteries. On 12 domestic pigs (all male) with an average weight of 34 kg (30.0-39.9 kg), were analysed the morphological parameters of femoro-iliaco-aorto-renal arterial system. An analysis of the pelvic segment length (I-II-III) and abdominal (IV), shows almost perfect equality of the lengths of the two segments on the right (76.26 ± 5.30 mm / 76.21 ± 4.51 mm) and a mean difference of 1.25 mm in favour of segment IV (abdominal) (75.53 ± 5.10 mm / 76.78 ± 4.44 mm), a difference that correlate with left renal artery cranial origin. Pelvic diameter portions of femoro-iliac arterial axis increase linear in average by 10% per segment (from 3.99 ± 0.40 mm ± 4.89 in segment I at 4.89±0.33 mm in segment III). Increasing the diameter from the segment III to segment IV is approximately of 30%. The diameter of the proximal part of renal artery (3.46 ± 0.36 mm) on the studied material is smaller than the diameter of the proximal part of the external femoral artery (segment I) (3.99 ± 0.40 mm), making it easy retrograde catheterisation of femoro-iliac-aorto-renal arterial axis. Knowledge of the morphological parameters of femoro-iliaco-aortic arterial axis and their evolution in correlation with the weight of laboratory animals -domestic pigs- favours the achievement in good conditions to arterial catheterization for proximal renal artery stenting.

Keywords: corrosion casts, domestic pigs; femoro-iliaco-aorto-renal axis; morphological parameters; stenting training

Practical training on laboratory animals, computerized models or artificial organs have become a necessity in interventional imagistic and therapeutic procedures [1]. The most common vascular structures subject to various pathological processes (extrinsic compression, stenosis, thrombosis partial or total) are coronary, cerebral and renal arteries. Performance preparing in using catheters and safety and efficiently arterial placement of stents, is achieved when medical residents have become specialists they are able to handle equipment safely and efficiently for stenting, and to have a low rate as complications in patients.

In the last two decades, the domestic pigs were more frequently used in training centers for residents and students in medicine, due to many advantages for use: many similarities with human vascular anatomy, high availability from suppliers, purchase at low price and tolerating the use of pigs in compliance with international law protection animals [1-7]. More recently, morphological and morphometric analyzes are made with high accuracy by MDCT angiography [8-15].

This preliminary study highlights the morphologic parameters of pig femoro-iliaco-aorto-renal arterial system on corrosion casts and MDCT angiography, for preparing the stenting procedures at the level of renal arteries.

Experimental part

In the present study, one used 12 domestic pigs (*Sus scrofa domestica*), with an average weight of 34 kg (30.0-39.9 kg), all male. 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. The 12 pigs were divided into two distinct groups: (i) six pigs for the production of plastic casts of femoro-

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iliaco-aorto-renal arterial system; (ii) six to investigate the infradiafragmatic arterial system with MDCT angiographic scanning.

The pigs from first group were euthanized, using 0.3mL/kg T61 by intravenous injection. The abdominal aorta was canulated and the infradiafragmatic arterial system was injected with Technovit 7143 plastic compound (Heraeus Kulzer GmbH, Wehrheim, Germany) (product based on methacrylate copolymers). The compound was allowed to polymerize for 10 - 15 min. Preparation for morphometric analysis of the femoro-iliac-aorto-renal arterial system consisted of: (i) the evisceration of abdominal-pelvic cavity, (ii) excision of parietal peritoneum, (iii) in bloc excision of the femoro-iliaco-cavo-renal venous system (iv) excision of the femoro-iliaco-aorto-renal arterial wall; (v) the evidence *in situ* of the femoro-iliaco-aorto-renal arterial system injected with Technovit (*in situ* arterial corrosion casts). The *in situ* femoro-iliaco-aorto-renal casts were photographed in same conditions (Nikon D3, Tokyo, Japan, AF-S Nikkor Lens f/1.4G) and analysed (fig.1A).

The pigs from second group were initially premedicated, using a mixture of analgosedative with ketamine (10-20 mg / kg) and midazolam (0.5 mg / kg), administered by deep intramuscular injection in the posterior cervical region muscles; the same path, taking 1 mg of atropine to prevent ketamine-induced hyper salivation. Induction of anaesthesia was achieved by bolus administration of Thiopental (5-7 mg / kg). The animals were intubated endotracheal. Maintenance of anaesthesia was achieved with Halothane. Additional neuromuscular blockers were administered. Artificial ventilation was provided with a mixture of air / O_2 (minimum 50% O_2). Under general anaesthesia, the pigs were examined using a 64-slice multidetector CT scanner (SOMATOM Sensation, Siemens Medical Solutions, Forchheim, Germany). MDCT angiographic data were acquired in the craniocaudal direction. The reconstructed image data sets were transferred to an offline workstation (Syngo MultiModality Workplace) for post-processing. The images were analyzed using a 3D task card, by performing 3D Maximum Intensity Projection (MIP) reconstruction; also inspace task card for 3D Volume Rendering Technique (VRT) reconstructions were used (fig.1B).

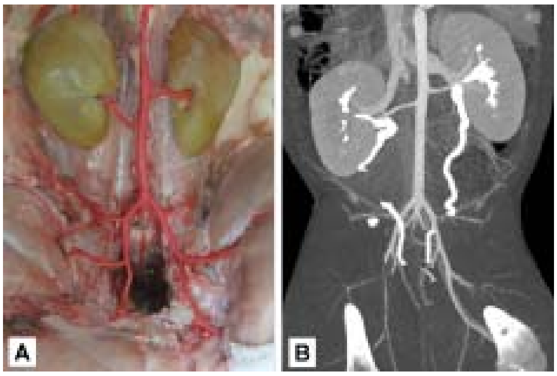

Fig.1. Pig femoro-iliaco-aorto-renal system on corrosion casts [A] and MDCT angiography [B]. Anterior view. [Color figure can be viewed in the online issue, which is available at www.revmaterialeplastice.ro]

On the corrosion casts conducted on pigs of the first group, and the MDCT angiographic images made on pigs on the second group, were evaluated the morphological parameters femoro-iliaco-aortic axis [length and diameter] from the level of the femoral circumflex artery origin at the origin of renal artery.

Results and discussions

According with Dondelinger et al. [1] and Bushi et al. [16], the pig aorto-iliaco-femoral system has several features, different from the human species: (i) from the aortic bifurcation arises the internal iliac arteries and middle sacral artery; (ii) the external iliac arteries originate from the abdominal aorta proximal to aortic bifurcation; (iii) the origin of iliac circumflex artery from external iliac artery, splits the path of this artery into a proximal portion and a distal portion; (iv) the limit between the external iliac artery and femoral artery, is represented by the origin of the internal femoral artery (deep); (v) the origin of femoral circumflex artery divides the external femoral artery path in a proximal portion and a distal portion.

Given this spatial distribution of the arterial femoro-iliac-aortic axis [from the origin of femoral circumflex artery, to the renal artery origin] shows a total of four parts: (i) the proximal part of the external femoral artery; (ii) the distal part of the external iliac artery; (iii) the proximal part of the external iliac artery; (iv) the distal part of the abdominal aorta (from aortic bifurcation to the origin of the renal artery) (fig.2).

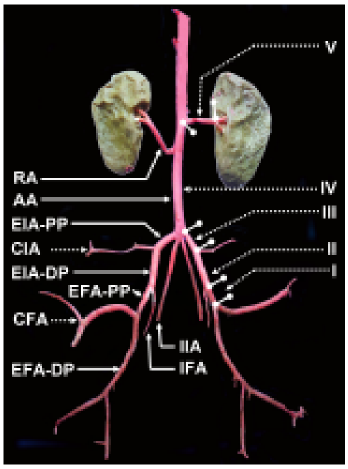

Fig.2. Branching pattern of pig femoro-iliaco-aorto-renal system on corrosion cast. Anterior view.. RA - Renal artery; AA - Abdominal aorta; EIA-PP - External iliac artery - proximal part; CIA - Circumflex iliac artery; EIA-DP - External iliac artery - distal part; EFA-PP - External iliac artery - proximal part; CFA - Circumflex femoral artery; EFA-DP - External femoral artery - distal pat; IIA - Internal iliac artery; IFA - Internal femoral artery; I - The proximal part of the external femoral artery; II - The distal part of the external iliac artery; III - The proximal part of the external iliac artery; IV - The distal part of the abdominal aorta (abdominal segment); V - The proximal part of renal artery. . [Color figure can be viewed in the online issue, which is available at www.revmaterialeplastice.ro]

For each of these parts of the arterial length (table 1 and table 2), and endoluminal diameter was measured (in the distal portion of each part) (table 3). It was also calculated the length of the femoro-iliaco-aortic axis (from the femoral circumflex artery origin, to the origin of the renal artery) and the renal artery diameter (in the proximal part) and the arterial length, from the abdominal aortic wall to the origin of the first branches.

Usually the left kidney is located toward cranial to the right [1] (off contact with emergent liver). In the same way, the left renal artery origin is situated at the same level or more cranial to the right.

Renal artery stenosis usually refers to a disease of the large extra-renal arterial vessels and most frequently is caused for approximately 90% of cases by atherosclerotic obstructions [17], and also by or fibromuscular dysplasia [18]. Renal ostial and first third of the renal artery trunk

Arterial segment	Right segments of femoro-iliaco-aorto-renal arterial axis (n=12)	Length in mm (mean ± SD)
I	The proximal part of the external femoral artery	21.14 ± 2.26
II	The distal part of the external iliac artery	32.00 ± 2.95
III	The proximal part of the external iliac artery	23.11 ± 1.48
IV	The distal part of the abdominal aorta (abdominal segment)	76.21 ± 4.51
I + II + III	Proximal femoro-iliac arterial axis (pelvic segment)	76.26 ± 5.30
I + II + III + IV	Femoro-iliac aortic arterial axis	152.42 ± 5.95
V	The proximal part of renal artery	20.40 ± 3.35

Table 1
LENGTH OF RIGHT SEGMENTS OF FEMORO-ILIACO-AORTO-RENAL ARTERIAL AXIS ON THE STUDIED MATERIAL.
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Arterial segment	Left segments of femoro-iliaco-aorto-renal arterial axis (n=12)	Length in mm (mean ± SD)
I	The proximal part of the external femoral artery	20.60 ± 2.12
II	The distal part of the external iliac artery	32.31 ± 2.98
III	The proximal part of the external iliac artery	22.69 ± 0.99
IV	The distal part of the abdominal aorta (abdominal segment)	76.78 ± 4.44
I + II + III	Proximal femoro-iliac arterial axis (pelvic segment)	75.53 ± 5.10
I + II + III + IV	Femoro-iliac aortic arterial axis	152.38 ± 5.95
V	The proximal part of renal artery	20.85 ± 4.72

Table 2
LENGTH OF LEFT SEGMENTS OF FEMORO-ILIACO-AORTO-RENAL ARTERIAL AXIS ON THE STUDIED MATERIAL

Arterial segment	Segments of femoro-iliaco-aorto-renal arterial axis	Diameter in mm (mean ± SD)
I	The proximal part of the external femoral artery (n=24)	3.99±0.40
II	The distal part of the external iliac artery (n=24)	4.40±0.36
III	The proximal part of the external iliac artery (n=24)	4.89±0.33
IV	The distal part of the abdominal aorta (abdominal segment) (n=12)	6.13±0.27
V	The proximal part of renal artery (n=24)	3.46±0.36

Table 3
DIAMETERS IN DISTAL PART OF EACH SEGMENTS OF FEMORO-ILIACO-AORTO-RENAL ARTERIAL AXIS ON THE STUDIED MATERIAL

stenting is the most common endovascular intervention for treatment of atherosclerotic renal artery stenosis [19].

Catheterization of the renal artery for stenting is performed by the usual retrograde way, from the femoral artery, and more rarely from anterograde way, by thoracic aorta [19]. In the pig catheterisation, arterial easiest approach to this method is the distal femoral artery. Knowledge of diameters and arterial lengths values is essential for achieving an effective training for renal artery stenting.

On the studied material, the differences in length and diameter of the first 3 segments of arterial femoro-iliac arterial axis are insignificant in the right and left. The more cranial location of the right renal artery origin has been found in all 12 cases examined, the difference of renal artery origin (left/right ranging from 3 - 11 mm - mean 5.7 mm). Overall, the segment IV of femoro-iliac-artery renal aorto-left axis has a length of 76.78 ± 4.44 mm, compared to the right side that has an average of 76.21 ± 4.51 mm. An analysis of the pelvic segment length (I -II - III) and abdominal (IV), shows almost perfect equality of the lengths of the two segments on the right (76.26 ± 5.30 mm / 76.21 ± 4.51 mm) and a mean difference of 1.25 mm in favour of segment IV (abdominal) (75.53 ± 5.10 mm / 76.78 ± 4.44 mm), a difference that correlate with left renal artery cranial origin. Pelvic diameter portions of femoro-iliac arterial axis increase linear in average by 10% per segment (from 3.99 ± 0.40 mm in segment I at 4.89±0.33 mm in segment III). Increasing the diameter from the segment III to segment IV is approximately of 30%. The diameter of the proximal part of renal artery (3.46 ± 0.36 mm) on the studied material is smaller than the diameter of the proximal part of the external femoral artery (segment I) (3.99 ± 0.40 mm), making it easy retrograde catheterisation of femoro-iliac-aorto-renal arterial axis.

In compliance with Bushi et al. [16] the arterial diameter increases in mean with 0.3 mm in each 10 kg weight. Using this scale it can be appreciated the diameter of arterial femoro-iliac-aortic axis segments, in order to select catheters in accordance with morphological parameters of animal experience.

Conclusions

Knowledge of the morphological parameters of femoro-iliaco-aortic arterial axis and their evolution in correlation with the weight of laboratory animals [domestic pigs] favours the achievement in good conditions to arterial catheterization for proximal renal artery stenting. Using porcine model in training for renal stenting is the easiest model for training medical students and medical residents.

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