



MORPHOMETRICAL EVALUATION OF SOME ANATOMICAL FEATURES IN PIG KIDNEYS: ARE THEY DIFFERENT FROM HUMAN KIDNEYS

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ABSTRACT

In this study we present morphometrical evaluation of some kidney's anatomical characteristics in two different pig breeds reared in Macedonian farms in order to determinate whether the investigated pig kidneys could be suitable as an experimental model in human medicine.

The material was consisted of 156 pig kidneys taken from two adult pig breeds (96 kidneys of *Landrace/Yorkshire crossbreed* and 60 kidneys from breed *Dalland*), slaughtered at age of 5.5 months and weighting of 95 kg of mean. The kidneys were evaluated morphmetrically, considering weight, length, cranial and caudal pole width and cranial and caudal pole thickness. The data was statistically evaluated and compared with previous published findings for human kidneys.

The results for the pig kidney morphometric measurements for *Landrace/Yorkshire crossbreed* were the following: weight 158.95g, length 12.73cm, cranial pole width and thickness: 6.39cm and 3.00cm respectively, caudal pole width and thickness 5.75cm and 2.83cm, respectively. In breed *Dalland*, the renal morphometric measurements showed: weight 182.98g, length 12.61cm, cranial pole width: 6.59cm and cranial pole thickness: 3.15cm, caudal pole width: 5.91cm and caudal pole thickness: 3.04cm. There were positive correlations between several variables considering the renal morphometry. Except for the length, the results of other morphmetrical measurements for *Landrace/Yorkshire crossbreed* were smaller than those obtained for breed *Dalland*.

From anatomical view despite the differences among these two breeds founded in this study, there are many similarities between the pig and human kidney morphometry. Considering that the best anatomical region for kidney implantation in humans depends on kidney's anatomical features (length of blood vessels and urinary loop as well as the number of blood vessels) and renal morphological characteristics (weight, length, width and thickness) we can conclude that the pig kidneys from both investigated breeds in selected category could be suitable as an experimental models for endourological research.

Key words: kidneys, pig, human, comparative anatomy, morphometry

INTRODUCTION

The experimental animals play crucial role for solving many problems in human medicine. In the past, the anatomical structure of the kidneys of different mammals (mouse, rat, dog, cat, sheep, pig, and monkey) was studied in order to understand the

anatomical structure of human kidney (1, 11, 13). Today, it is believed that the pig kidneys could be a suitable model for urological procedures because their anatomy and physiology resemble with human kidneys (16). Therefore, the most morphological studies are aimed discovering the anatomy of the collecting system and vascular architecture of pig kidneys (10, 19-23, 29, 30) in order to enhance the applicative using a pig kidneys in human medicine (8, 24, 30).

Nowadays, the production of transgenic pigs by injection of a human DNA into fertile pig egg

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becomes promising tools that force the science for future deeper investigations regarding the pig kidneys (5-7, 18, 25). Due to the intensive research in this area in the past decade, there have been a number of experiments on primates who received kidneys from transgenic pigs and lived a certain number of days (3, 15, 33). Although there are several strategies for preventing the xerograph rejection of pig kidneys (immunosuppressant's, evacuation of natural antibodies, immunomodulation, genetic manipulation) which are in advanced stage of research (4, 6) the additional detailed anatomical studies for the pig kidneys are indispensable in order to be able to respond to the demands of using pig kidneys in experimental urology (4).

Therefore in this study we present morphometrical evaluation of several kidneys anatomical characteristics at two different pig breeds reared in Macedonian farms with aim to determinate whether the morfometric measurements of investigated pig kidneys resemble with human kidneys and whether they could be a suitable experimental model in human medicine.

MATERIAL AND METHODS

The material was consisted of 156 pig kidneys taken from two adult pig breeds (96 kidneys of *Landrace/Yorkshire* crossbreed and 60 kidneys from breed *Dalland*), slaughtered at age of 5.5 months and weighting of 95 kg of mean. The kidneys were taken randomly during the slaughtering of animals

in slaughterhouses together with the perirenal fat and renal capsule leaving the renal large blood vessels and urinary loop intact. The kidneys with pathological changes (malformations, anomalies, hydronephrosis, renal oedema, abscesses, renal cysts, etc.) were excluded from the study.

After removal of the fat together with renal capsule and pedicle component, the kidneys were evaluated morphometrically considering: weight, longitudinal length (the longest distance between the cranial and caudal kidney pole), cranial and caudal pole width (measured at the point with largest width cranial and caudal from the hilum of the kidney) and cranial and caudal pole thickness (measured at the point with the biggest thickness cranial and caudal from the hilum of the kidney).

The variables (width, length, thickness) of the kidneys were measured by same researcher using a caliper with accuracy of 0.1mm while the weight of the kidneys was measured with a digital scale with the precision of 0.01g.

The obtained data were statistically evaluated with statistical software, Statistic 7. For each variable we evaluate the mean, the standard deviation, the coefficient of variation, the Pearson (r) correlation coefficient and Student t-test.

RESULTS

The results of statistical analysis of the renal morphometric measurements are showed in details in Table 1.

Table 1. The results of renal morphometric measurements

	<i>Landrace/Yorkshire</i>							<i>Dalland</i>						
	Valid N	Mean	Median	Min.	Max.	Vari.	Std. Dev.	Valid N	Mean	Median	Min.	Max.	Vari.	Std. Dev.
WEIGHT	96	158,95	158,75	120,50	214,50	444,221	21,0766	60	182,89	177,50	149,50	250,00	519,306	22,7883
LENGHT	96	12,73	12,58	11,16	16,29	0,923	0,9608	60	12,61	12,34	10,80	14,90	0,843	0,9180
CPT	96	3,00	3,02	2,03	3,85	0,151	0,3886	60	3,15	3,20	2,30	3,81	0,097	0,3108
CdPT	96	2,83	2,90	2,04	3,79	0,168	0,4098	60	3,04	3,05	2,42	3,80	0,076	0,2756
CWP	96	6,39	6,40	5,40	7,30	0,168	0,4102	60	6,59	6,63	5,63	7,65	0,194	0,4409
CdWP	96	5,75	5,74	4,86	7,05	0,227	0,4768	60	5,91	5,92	4,49	7,10	0,239	0,4890

CPT – kidney cranial pole thickness, **CdPT** – kidney caudal pole thickness, **CWP** – kidney cranial pole width,

CdWP – kidney caudal pole width

According the results, the kidney morphometric measurements for *Landrace/Yorkshire* crossbreed are: weight 158.95g, length 12.73cm, cranial pole width and thickness: 6.39cm and 3.00cm respectively, caudal pole width and thickness 5.75cm and 2.83cm, respectively. In the *Dalland* breed the kidney morphometric evaluation showed the follow-

ing results: weight 182.98g, length 12.61cm, cranial pole width: 6.59cm and cranial pole thickness: 3.15cm, caudal pole width: 5.91cm and caudal pole thickness: 3.04cm.

The results for the comparative kidney pole morphometry for each breed individually are showed in Table 2.

Table 2. Comparative statistical evaluation of width and thickness between the cranial and the caudal kidney pole

	<i>Landrace/Yorkshire</i>								<i>Dalland</i>							
	Mean	Std.Dv.	N	Diff.	Std.Dv.	t	df	p	Mean	Std.Dv.	N	Diff.	Std.Dv.	t	df	p
CPT	3,00	0,3886							3,15	0,3108						
CdPT	2,83	0,4098	96	0,1698	0,4496	3,7001	95	0,0004	3,04	0,2756	60	0,1122	0,2267	3,8323	59	0,0003
CWP	6,39	0,4102							6,59	0,4409						
CdWP	5,75	0,4768	96	0,6412	0,5824	10,7872	95	0,0000	5,91	0,4890	60	0,6852	0,3896	13,6233	59	0,0000

CPT – kidney cranial pole thickness, **CdPT** - kidney caudal pole thickness, **CWP** - kidney cranial pole width, **CdWP** - kidney caudal pole width

The differences between the kidney pole morphometry, in both investigated breeds, showed that the cranial pole morphometric measurements are significantly higher ($p < 0.05$) compared to those obtained for the kidneys caudal pole.

However, the results from the comparative study of all variables included in the study, between the

both breeds, showed that the kidney morphometric measurements in *Dalland* are statistically higher ($p < 0.05$) when compared to those in *Landrace/Yorkshire* crossbreed. Although the kidney length in *Dalland* is bigger than the longitudinal kidney length in *Landrace/Yorkshire*, this difference is statistically insignificant ($p > 0.05$) (Table 3)

Table 3. The comparative results of kidney morphometric features between the breeds

Group 1 vs. Group 2	Mean Group 1	Mean Group 2	t-value	df	p-level	Valid N Group 1	Valid N Group 2	Std.Dev. Group 1	Std.Dev. Group 2	F-ratio	P variances
WEIGHT	158,95	182,89	-6,6884	154	0,0000	96	60	21,0766	22,7883	1,1690	0,4927
LENGHT	12,73	12,61	0,7205	154	0,4723	96	60	0,9608	0,9180	1,0955	0,7130
CPT	3,00	3,15	-2,5562	154	0,0115	96	60	0,3886	0,3108	1,5631	0,0655
CdPT	2,83	3,04	-3,4930	154	0,0006	96	60	0,4098	0,2756	2,2112	0,0013
CWP	6,39	6,59	-2,9004	154	0,0043	96	60	0,4102	0,4409	1,1553	0,5253
CdWP	5,75	5,91	-1,9889	154	0,0485	96	60	0,4768	0,4890	1,0521	0,8146

CPT – kidney cranial pole thickness , **CdPT** - kidney caudal pole thickness , **CWP** - kidney cranial pole width, **CdWP** - kidney caudal pole width, Group 1 - *Landrace/Yorkshire*, Group 2 - *Dalland*

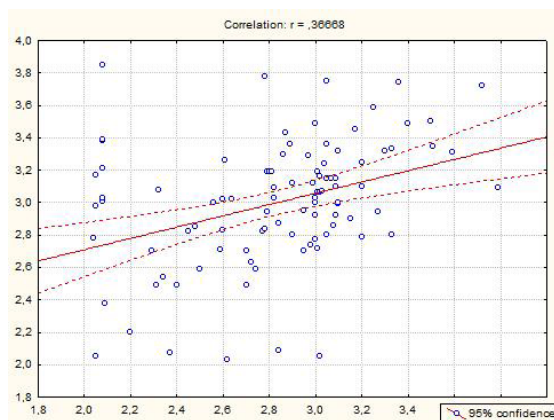
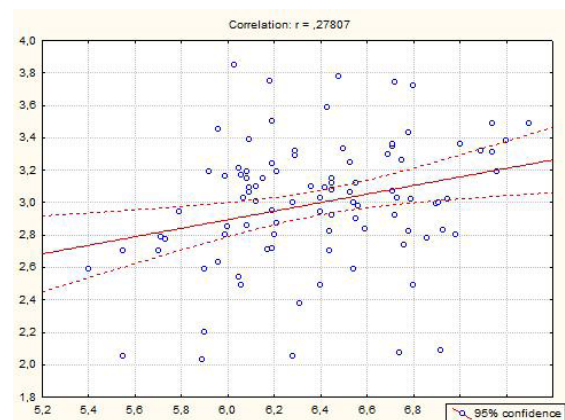
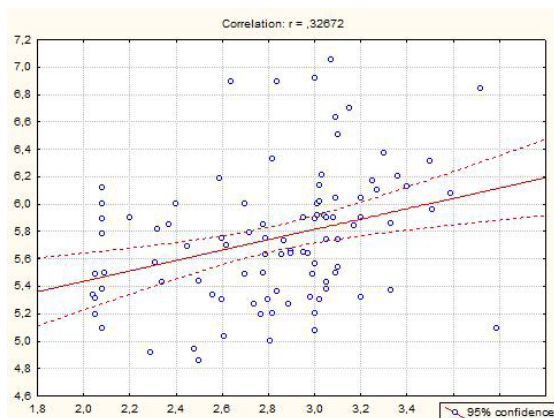
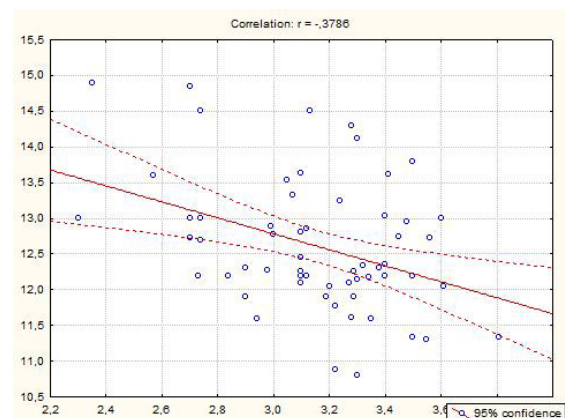
In this study we evaluated the morphological variability of kidney shape and size for each breed separately.

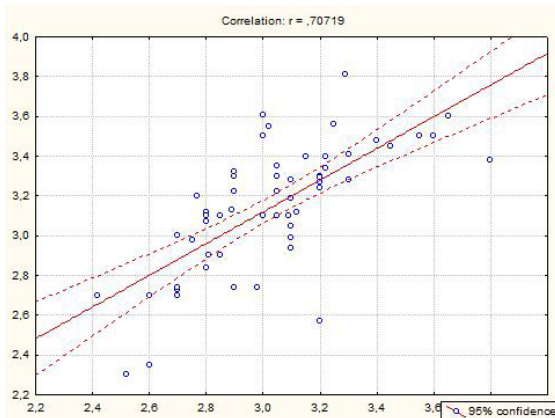
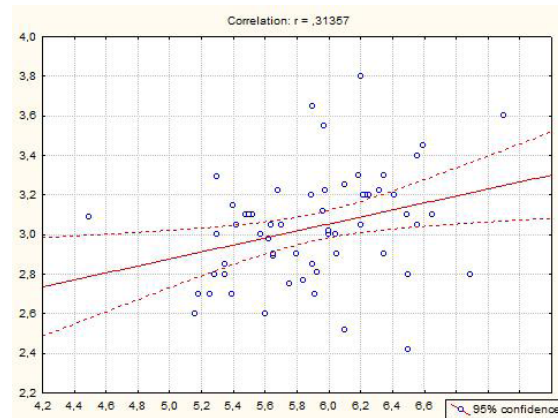
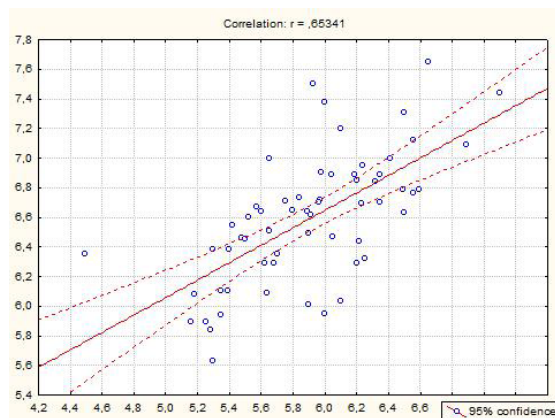
The statistical results are showed in details in Table 4 and Graphs 1-3 for the crossbreed *Landrace/Yorkshire* and Graphs 4-7 for the *Dalland* breed.

Table 4. Correlation coefficients between investigated variables

	<i>Landrace /Yorkshire</i>						<i>Dalland</i>					
	WEIGHT	LENGHT	CPT	CdPT	CWP	CdWP	WEIGHT	LENGHT	CPT	CdPT	CWP	CdWP
WEIGHT	1,00	0,55	0,33	0,38	0,39	0,44	1,00	0,39	0,09	0,41	0,49	0,55
LENGHT	0,55	1,00	-0,08	-0,07	0,01	0,15	0,39	1,00	-0,38	-0,06	0,09	0,09
CPT	0,33	-0,08	1,00	0,37	0,28	0,12	0,09	-0,38	1,00	0,71	-0,01	0,19
CdPT	0,38	-0,07	0,37	1,00	0,12	0,33	0,41	-0,06	0,71	1,00	0,09	0,31
CWP	0,39	0,01	0,28	0,12	1,00	0,14	0,49	0,09	-0,01	0,09	1,00	0,65
CdWP	0,44	0,15	0,12	0,33	0,14	1,00	0,55	0,09	0,19	0,31	0,65	1,00

CPT – kidney cranial pole thickness, CdPT - kidney caudal pole thickness, CWP - kidney cranial pole width, CdWP - kidney caudal pole width

Graph 1. Correlation coefficient of width between cranial and caudal kidney pole thickness (*Landrace/Yorkshire*)**Graph 2.** Correlation coefficient between width and thickness of cranial kidney pole (*Landrace/Yorkshire*)**Graph 3.** Correlation coefficient between width and thickness of caudal kidney pole (*Landrace/Yorkshire*)**Graph 4.** Correlation coefficient between kidney length and cranial kidney pole width (*Dalland*)

Graph 5. Correlation coefficient of thickness between cranial and caudal kidney pole (*Dalland*)**Graph 6.** Correlation coefficient between width and thickness of caudal kidney pole (*Dalland*)**Graph 7.** Correlation coefficient of width between cranial and caudal kidney pole (*Dalland*)

According to the presented statistical data, the morphological variability of kidney shape and size in *Dalland* breed was greater when compared to the *Landrace/Yorkshire* crossbreed.

DISCUSSION

The results obtained in this study regarding the kidney weight (*Landrace/Yorkshire*: average 158.95g; *Dalland*: average 182.89g) are different from other published findings that reported higher average weight of pig kidneys that ranges from 200-250g (12, 26), 200-280g (9, 17) and even much lower 98g (29). The difference of our results regarding the kidney weight could be due to the lack of details for the breed, weight and age of pigs that are used in the other studies, as it is shown in this study. How-

ever, our results showed similarities with recently reported average weight of both pig kidneys that is approximately 250-350g (31) as well with the average weight of the human kidneys that usual range between 120-150g(14) and 150-200g(32).

In published literature the average length of the pig kidney is 12.5cm with average width of 6.5cm (26) or 7-12cm length and 5-8cm width (31) which is similar with our results and the data published by Getty R. (12) who reported an average kidney length of 12cm and width that range between 6.0cm and 6.5cm. These authors describe the width of the kidneys in general and do not considerate the morphometrical differences between the cranial and caudal kidney pole that is evident. Recently it has been reported that the kidney with average length of 11.8cm have an average of 5.64cm width of the cranial pole and it is significantly larger compared with the average width of the caudal kidney pole that is 5.35cm(29).

According to our results, although the longitudinal kidney length in *Dalland* was longer compared with the kidney length in *Landrace/Yorkshire*, (12.73cm in *Landrace/Yorkshire* and 12.61cm in *Dalland*) the results were statistically insignificant($p>0.05$). This data are not much different from the average kidney length in adult humans where the kidney length is 12cm (14), 10-12cm (32) and 11.1cm (27).

Regarding the kidney pole morphometry we found that in both investigated breeds the cranial pole morphometry is significantly higher compared to those obtained from kidney's caudal pole. ($p<0.05$) In addition, the kidney morphometric

features compared between the breeds showed that the cranial and caudal pole width in breed *Dalland* (6.59cm and 5.91cm, respectively) are statistically higher ($p<0.05$) when compared to those in *Landrace /Yorkshire* breed (6.39 and 5.75cm, respectively). This finding is in agreement with results recently published for the pig kidneys (29), as well with the findings for human kidneys: 6cm (14) and 5-6cm (32), where the cranial pole morphometry has higher values compared the morphometry in kidneys caudal pole (27).

In this study special consideration was appointed to the kidney pole's thickness. It has been reported an average thickness in pig kidney of 2.76cm and it is for the both renal poles (29). In our study in details we analyze the kidney thickness in each kidney pole and results showed that the cranial pole thickness is significantly greater ($p<0.05$) than the thickness of the caudal pole (in *Landrace/Yorkshire*: 3.00cm > 2.83cm; in *Dalland*: 3.15cm > 3.04cm). The data published for human's (14, 27, 28, 32) resemble with our findings for the pig kidneys.

One of the aims in this study was to evaluate the morphological variability of kidney shape and size for each breed individually.

According to the results, in *Landrace/Yorkshire* crossbreed, there was a positive correlation between kidney weight and the other variables such as: length of the kidney (0.55), thickness of cranial and caudal kidney pole (0.33 and 0.38, respectively) as well with the width of cranial (0.39) and width of caudal kidney pole (0.44). The above correlations were statistically significant ($p<0.05$). Also we found a significant positive correlation between the thickness of cranial and caudal kidney pole (0.37) as well as between the width and the thickness of cranial and caudal kidney pole (0.28 and 0.33, respectively). (Graphs 1, 2 and 3)

Similar results were obtained for the *Dalland* breed. The kidney length was in significant positive correlation with the kidney weight (0.39), the thickness of caudal kidney pole (0.41), and the width of cranial and the caudal kidney pole (0.49 and 0.55, respectively). Also, we found a significant correlation ($p<0.05$) between thickness of cranial and caudal kidney pole (0.71), the width and thickness of caudal kidney pole (0.31) and between the caudal and cranial kidney pole width (0.65) (Graphs 5, 6 and 7). We could not find any similar results in the literature describing the morphological variability

of kidney shape and size so we were unable to compare our results.

However, according to the presented data, the morphological variability of kidney shape and size in *Dalland* breed has greater variability compared to the *Landrace /Yorkshire* crossbreed.

CONCLUSION

At the end, from anatomical view despite the differences among these two breeds appointed in this study, there are many similarities between the pig and human kidney morphometry. Considering that the best anatomical region for kidney implantation in humans depends on kidney's anatomical features (length of blood vessels and urinary loop as well as the number of blood vessels) and renal morphological characteristics (weight, length, width and thickness) (2) we can conclude that the pig kidneys from both investigated breeds and pig category can be suitable in human medicine as an experimental models for endourological research.

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