Excretory Urography in the Minipig

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Excretory urography was performed on eight healthy minipigs to evaluate radiographic anatomical status and excretory function of the urinary tracts and to get an optimal procedure. The right and left kidneys were located in T13-L4 and T12-L3.5, respectively. The left kidneys were located more cranially than the right. The average lengths and widths of kidneys were 8.50±0.58 (mean±SD) and 4.30±0.39 cm on the ventrodorsal projection and 8.70±0.76 and 4.10±0.40 cm on the lateral projection, respectively. The lengths of kidneys were twice the width. When the lengths of kidneys were compared with lengths of the second lumbar vertebra, the ratios of kidney lengths to L2 lengths were 3.62±0.30 on the ventrodorsal projection and 3.63±1.10 on the lateral projection. The lengths and widths of renal pelvis including major calices were 4.01±0.46 and 2.20±0.41 cm, respectively. The lengths and widths of minor calices were 0.49±0.06 and 0.10±0.01 cm. The lengths and widths of the ureters were 12.25±2.05 and 2.94±0.86 cm. The nephrogram phase was reached in 3–5 minutes, and the pyelogram phase in 5–15 minutes individually after injection of contrast medium. The result of this study shows similar information and procedure of excretory urography for other laboratory animals and leads to the potential use of this method for minipigs.

Key words – Excretory urography, minipig

Introduction

Kidneys of minipigs are considered to be suitable for human organ transplantation as the anatomy of pigs is more similar to that of the human than that of any other commonly used laboratory animals [11]. However, diagnostic assessing and measuring the urinary tracts in minipigs has not been widely studied.

Plain radiographs have yielded insufficient information due to absolutely large amount of ingesta, gas, and feces in the gastrointestinal tracts. Though fasting for 3–4 days could be helpful, but still the exact outline of the urinary tracts cannot be visualized because of remaining gas and feces in the gastrointestinal tracts.

Excretory urography is a simple and useful radiographic contrast study and has been widely used in various animals [3,4]. Although excretory urography is not the most precise measurement for the renal function, it can be used to examine the whole urinary tracts and the relative excretory function of the kidneys, especially in the assessment of the renal pelvis and ureter. Therefore excretory urography remains a simple but essential tool to verify localized upper urinary tract diseases. And there have been no basic data for excretory urography in minipigs.

The object of the study is to evaluate the optimal method of excretory urography and to determine the average data for the urinary anatomy and function of minipigs.

Materials and Methods

Excretory urography was performed on eight healthy minipigs (PWG Genetics Korea, Ltd. PWG micro-pig minipig®). All minipigs were 42 weeks old, weighing 19.7–24.0 kg without gender discrimination. Before experiments, all minipigs were fasted for 3–4 days to reduce the ingesta and feces in the gastrointestinal tracts and to get better radiographic images. Water was supplied ad libitum. Blood test, urinary test, and abdominal ultrasonographs were previously performed and only normal minipigs were included in this experiment.

Anesthesia was induced with tiletamin HCl-zolazepam (Zoletil®, Virvac, Korea) at a dose of 4–5 ml/kg by intramuscular injection. Contrast medium of Iopamidol (Pamiram® 370, Dongkook Pharm Co., Korea) was injected as bolus rapidly through a previously placed intravenous catheter in the ear vein at a dose of 3 ml/kg (1,110 I mg/kg). Reaction to the injection and the duration of reaction were
recorded. Right lateral and ventrodorsal abdominal radiographs were taken prior to injection of contrast medium and at 1, 3, 5, 10, 20, 30, 40, and 60 minutes after injection. For better visualization of the ureter, oblique radiographs were also obtained at 30 and/or 40 minutes.

The time taken for the contrast medium to induce tubular nephrogram, pyelogram, and cystogram was recorded. Renal sizes were measured on both right lateral and ventrodorsal view and compared to the lengths of the second lumbar vertebrae individually. Lengths and widths of the pelvis, calyces and ureters were measured according to the method of Feeney et al. [3-7]. The total lengths of ureter from the pelvis and the trigone of the urinary bladder were measured. All values for lengths and widths were assessed by a measure or a thin tape measure as visualized on the ventrodorsal and lateral views. All data were recorded by the mean and standard deviation values (mean ±SD), respectively. And values were expressed in centimeters. The periodicity of peristalsis of the ureter was also measured through fluoroscopy.

**Results**

There was no reaction to contrast medium injection during and after procedure of excretory urography. Adverse responses to anesthesia were not observed.

Although minipigs were fasted for 3-4 days before experiments, there were some ingesta and gas in the gastrointestinal tracts. Therefore, on survey radiographs before excretory urography, any abdominal organ including the urinary tracts could not be well visualized.

The normal imaging of the kidneys of the minipig could be seen in Fig. 1. The kidneys had smooth margin and homogeneous opacity. The kidneys were dorsoventrally flattened and craniodorsally elongated. The positions of the right and left kidneys were found in T13-L4 and T12-L3, respectively. The left kidneys were located more cranial than the right in six cases, but two cases showed the right kidneys were located more cranially. The distances between the cranial poles of the right and left kidneys were 0.86±0.64 (mean±SD) cm with a range of 0.3-2.2 cm.

The normal measurements of the kidneys were recorded in Table 1. The average lengths and widths of kidneys were 8.50±0.58 and 4.30±0.39 cm on the ventrodorsal projection and 8.70±0.76 and 4.10±0.40 cm on the lateral projection respectively. The lengths of kidneys were about twice the width. And the average length of the second lumbar vertebrae (L2) was 2.35±0.11 cm. The ratios of kidney lengths to L2 lengths were 3.62±0.30 on the ventrodorsal projection and 3.63±1.10 on the lateral projection. There were no statistical differences between ventrodorsal and lateral projection.

The normal radiographic imaging and measurements of the pelvis, calyces and ureters were also made (Fig. 2 and Table 2). The hilus were approximately in the middle of the kidneys. The renal pelvcs were thin, long and cranio-caudally directed toward the poles. The pelvcs were divided into two major calyces and subdivided into minor calyces. The lengths and widths of the renal pelvis including major calyces were 4.01±0.46 and 2.20±0.41 cm.

![Fig. 1. Nephrogram. The kidneys have smooth margin and homogeneous opacity. The kidneys are dorsoventrally flattened and craniodorsally elongated. The lengths of the kidney (long arrow) and the second vertebral body (short arrow) are assessed by a measure both on the ventrodorsal and lateral views. And the ratio of renal length to the second lumbar vertebrae length are recorded respectively.](image-url)
Table 1. Measurements for renal radiographic anatomy in the nephrogram phase

<table>
<thead>
<tr>
<th></th>
<th>Ventrudorsal view</th>
<th>Lateral view</th>
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<tbody>
<tr>
<td></td>
<td>Mean±SD</td>
<td>Range</td>
</tr>
<tr>
<td>Right kidney length</td>
<td>8.10±0.49</td>
<td>7.7~8.5</td>
</tr>
<tr>
<td>Left kidney length</td>
<td>8.56±0.59</td>
<td>7.8~9.5</td>
</tr>
<tr>
<td>Right kidney width</td>
<td>3.97±0.35</td>
<td>3.5~4.5</td>
</tr>
<tr>
<td>Left kidney width</td>
<td>3.35±0.32</td>
<td>3.5~4.7</td>
</tr>
<tr>
<td>Total kidney length</td>
<td>8.50±0.58</td>
<td>7.7~9.5</td>
</tr>
<tr>
<td>Total kidney width</td>
<td>4.30±0.39</td>
<td>3.5~4.7</td>
</tr>
<tr>
<td>L2 length</td>
<td>2.35±0.11</td>
<td>2.2~2.5</td>
</tr>
<tr>
<td>Ratio (length)</td>
<td>3.62±0.30</td>
<td>3.28~4.32</td>
</tr>
<tr>
<td>Ratio (width)</td>
<td>1.83±0.18</td>
<td>1.56~2.05</td>
</tr>
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</table>

*Values are assessed by a measure as visualized on the ventrodorsal and lateral views.
*Values are recorded as the average and standard deviation values.
*Values are expressed in centimeters.
*Ratio (length) means the ratio of renal length to the second lumbar vertebrae length.
*Ratio (width) means the ratio of renal width to the second lumbar vertebrae length.

Table 2. Measurements for renal radiographic anatomy in the pyelogram phase

<table>
<thead>
<tr>
<th></th>
<th>Mean±SD</th>
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<tbody>
<tr>
<td>Pelvic length</td>
<td>4.01±0.46</td>
</tr>
<tr>
<td>Pelvic width</td>
<td>2.20±0.41</td>
</tr>
<tr>
<td>Minor calyx length</td>
<td>0.49±0.06</td>
</tr>
<tr>
<td>Minor calyx width</td>
<td>0.96±0.01</td>
</tr>
<tr>
<td>Ureteral width</td>
<td>2.94±0.86</td>
</tr>
<tr>
<td>Ureteral length</td>
<td>122.50±20.50</td>
</tr>
</tbody>
</table>

*Values are assessed by a tape measure as visualized on the ventrodorsal and lateral views.
*Values are recorded as the average and standard deviation values.
*Values are expressed in centimeters.
*Ureteral length means the length from the pelvis to the trigone of the urinary bladder respectively. The minor calices varied in opacity from less radiopaque and radiopaque same as opacity of the pelvis. Two adjacent minor calices made cup-shaped appearance. There were approximately 8~10 numbers of minor calices individually. The lengths and widths of minor calices were 0.49±0.06 and 0.10±0.01 cm. Ureters left the kidney mediodorsally and then passed caudally in a sharp caudal curve (Fig. 3). The lengths and widths of the ureters were 12.25±2.05 and 2.94±0.86 cm, respectively. The average periodicity of ureteral peristalsis was approximately once per minute through fluoroscopy.

The onset time of nephrogram phases was seen on an average of 3.14±0.10 minutes with a range of 3~5 minutes after injection of contrast medium. It reached a maximum opacity within 5 minutes in 4 minipigs, and within 10 minutes in 4 minipigs with maximum. The onset time of the pyelographic phases was 7.50±1.77 minutes with a range of 5~15 minutes after injection of contrast medium. The time taken for contrast medium to be seen within the bladder varied between 5~30 minutes.

**Discussion**

The survey abdominal radiography show insufficient information because minipig has characteristic coiling arrangement of intestinal structures in the most abdominal cavity [9], therefore there are large amounts of ingesta, gas, and feces of the gastrointestinal tracts. The first important procedure in performing a good excretory urography is to prepare the patient adequately. To clear the gastrointestinal tracts, fasting for 3~4 days before the study was performed in all minipigs, but, there were still small amounts of gaseous and fecal contents in the gastrointestinal tracts. Relatively small fat in the retroperitoneal space seems to be another factor of no visualization of urinary tracts, compared to other animals such as dogs and cats. Therefore excretory urography can be a simple and important method for manifesting urinary tracts of minipigs.

Minipigs could show all phases of the excretory urography described in the dog [3], and this enabled systematic anatomic measurements and excretory functional evaluation of urinary tracts. Excretory urography is divided into the nephrographic and pyelographic phases and each phase should be evaluated and compared to normal findings and variations separately.
Fig. 2. Pyelogram. Minor calices are well identified (A and B). After 10 minutes, renal pelves including major calices are found (C and D).

Fig. 3. Ureters. Ureters leave the kidney mediadorsally and then passed caudally in a sharp caudal curve. Ureters show slow peristalsis.

The normal radiographic anatomy of urinary tracts of minipigs in the nephrogram are similar to conventional pigs and human, but different to dogs and cats. The kidneys of minipigs are dorsally flattened and craniodorsally elongated. The kidneys of dogs are somewhat elongated resembling a bean, whereas those of cats are more rounded [2,6]. The positions of the right and left kidneys were also different from dogs and cats. In minipigs, mostly the left kidneys are located cranial to the right kidneys. In both dogs and cats, the right kidneys are located cranially. The lengths of kidneys of minipigs were twice than the widths. The ratios between the lengths and
widths of kidneys in dogs and cats is low. The ratios of kidney lengths to L2 lengths were 3.62±0.30 on the ventrodorsal projection and 3.63±1.10 on the lateral projection in minipigs. In dogs and cats, the most accepted renal lengths are 2.5 to 3.5 times [8] and 2.4 to 3.0 times the length of L2 vertebral body respectively [1].

During nephrogram, the kidneys had smooth margin and homogeneous opacity. However, early stage of both vascular and tubular nephrograms immediately after injection of contrast medium showed inhomogeneous opacity. This seemed to be due to time difference between cortex and medulla. The nephrographic initial opacification and following fading sequences are important to evaluate renal function [6]. A good initial opacification followed by progressively decreasing opacity is seen in a normally functioning kidney [6]. In this study, minipigs also showed similar appearance of the opacified sequences. However, the time of onset and maximum opacification and the period of maintaining the nephrogram was variable with a wide range. The normal nephrogram of dogs should be most radiopaque within 7 to 30 seconds after bolus injection of contrast medium [6], but it was not visible at this time in minipigs though the radiographs were taken during the injection of contrast medium serially. Generally the results of nephrogram were more slow with wide ranges because the excretion of urinary tracts in minipigs may be slow. This is the limitations of excretory urography and further studies, for example the method using computed tomography, have to be needed for accurate excretion time.

The pyelogram was more radiopaque than the nephrogram like other animals [2,6]. The renal pelves of minipigs were thin and craniocaudally long including major calices. In dogs and cats, renal pelves were thin, short, and triangle-like appearance. This difference is from the original anatomy, for example the differences between calices and diverticula. In minipigs, the lengths and widths of renal pelvis including major calices were 4.01±0.46 and 2.20±0.41 cm, respectively. There were approximately 8–10 numbers of minor calices individually. The lengths and widths of minor calices were 0.49±0.06 and 0.10±0.01 cm. In dogs, the renal pelvis and pelvic recesses (or diverticula) do not exceed 0.1 or 0.2 cm in diameter [7].

The ureters are not identified on plain radiographs. In pyelogram, the ureters of minipigs left the kidney medially dorsally and then passed caudally in a sharp caudal curve. The diameters of the ureters were 2.94±0.86 cm and similar or slightly wider than those of dogs and cats. Canine ureters are generally 2.5 mm [5] or does not exceed 2 or 3 mm in diameter [7]. Periodicity of ureteral peristalsis in minipigs was slow compared to other animals. The ureters of dogs and cats mostly show the segmentation like disconnected shape secondary to more rapid ureteral peristalsis. In normal dogs the pyelogram follows nephrographic opacification by approximately 1–2 minutes [4]. The pyelographic phase of minipigs might be considered slow because the images were not present within 3 minutes after injection of contrast medium.

Contrary to relatively accurate radiographic anatomy of urinary tracts, the evaluations for function of urinary tracts in excretory urography seemed to be somewhat various with a wide range and have somewhat limitations. However, excretory urography can still be used safe, simple and meaningful method in the minipig to assess and grossly interpret renal anatomy and general information of excretive function.

Acknowledgement

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References

초록: 미니웨지에서 배설성요로조영술의 적용

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미니웨지에서 정상 방사선 해부학과 배설성 기능을 평가하기 위해 배설성요로조영술을 실시하였다. 오른쪽 신장과 왼쪽 신장은 각각 T13-L4, T12-L3.5에 위치하였으며, 왼쪽 신장이 오른쪽 신장보다 두드레 존재하였다. 신장의 길이와 너비는 복부상에서 각각 8.50±0.58 (mean±SD), 4.30±0.39 cm 이었다. 외측상에서 각각 8.70±0.76, 4.10±0.40 cm 이었다. 신장의 길이는 너비의 약 두 배였다. 두 번째 요추 동통의 길이와 신장의 길이를 비교하였을 때, 복부상에서는 각각 3.62±0.30, 외측상에서는 3.63±1.10로 측정되었다. 신주의 길이와 너비는 각각 4.01±0.46, 2.20±0.41 cm 이었다. 콩팥만의 길이와 너비는 각각 0.49±0.06, 0.10±0.01 cm 이었다. 요관의 길이와 너비는 각각 12.25±2.05, 2.94±0.86 cm 이었다. 콩팥조영사진은 3-5분에 관찰되었고, 신우조영사진은 5-15분에 관찰되었다. 배설성요로조영술은 미니웨지 비뇨기계의 정상 방사선학적 해부와 배설성 기능에 대해 전반적으로 평가할 수 있는 간단한 방법이다.