An anatomic and contrast enhanced-radiographic investigation of the rabbit kidneys, ureters and urinary bladder

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SUMMARY

Aim: To perform anatomical assessment of the X-ray data of the normal urinary tract of the rabbit in order to give references when interpreting images of the kidney lesions in this species.

Materials: We investigated 9 sexually mature white New Zealand rabbits, aged 12 months, weighed from 3.0 kg to 3.4 kg.

Methods: Excretory urography.

The animals were sedated with (IM) 15 mg/kg Zoletil® 50. The study was done with stationary X-ray apparatus TUR 800 D-1, set with digital apparatus iQ-CR ACE. Left and right and ventrodorsal abdominal radiographies were done subsequently every 5 min after the rapid delivery of a non-ionic contrast agent.

Results: The right kidney was localized between the 13th thoracic vertebrae and second lumbar, and the left from the second to the fourth lumbar vertebrae. The kidneys were visualized as dense soft tissue and show distinct borders compare to the structures.

Conclusion: The urogram corresponded to the nephrographic, pyelographic, ureterographic and cystographic phase of excretion of contrast dye. The excretory urography is a good suitable method for anatomical imaging of the kidneys, ureters and bladder in the rabbit.

Keywords: Imaging anatomy, radiology, rabbit, kidneys.

RéSUMÉ

Etude anatomique et radiologique de contraste des reins, uréters et de la vessie urinaire chez le lapin

But : Exécuter une évaluation anatomique des données radiologiques de l’appareil urinaire du lapin qui puisse servir de référence lors de l’interprétation d’images lésionnelles.

Matériel : Lapins Néo Zélandais Blancs, matures et âgés de 12 mois, pesant 3,0-3,4 kg avaient été étudiés.

Méthodes : Urographie intraveineuse

Les animaux ont été anesthésiés avec (IM) 15 mg/kg Zoletil® 50. L’étude a été faite avec un appareil radiologique stationnaire et un appareil numérique Q-CR ACE. Les radiographies abdominales droite et gauche et ventrodorsales ont été prises chaque 5 min après l’injection en bolus d’un agent de contraste non-ionic. Résultats : Le rein droit a été localisé entre 13ème vertèbre thoracique et second lombaire et le rein gauche : entre deuxième et quatrième vertèbres lombaires. Les reins étaient visualisés comme des structures denses de tissu mou avec des contours distincts. Le parenchyme rénal était atténué lors de la phase néphrographique sur les vues ventrodorsales.

Conclusion : Les urogrammes correspondaient séquentiellement aux phases : néphrogramique, pyélographique, urétérographique et cystographique, phases successives de l’excrétion du produit de contraste. L’urographie intraveineuse est une méthode convenue pour étudier l’anatomie radiographique des reins, des uréters et la vessie chez le lapin.

Mots clés : Anatomie, radiologie, lapin, appareil urinaire.

Introduction

The kidneys of the rabbit have been described by other researchers [3, 4, 8]. The authors showed those organs have a relatively primitive structure. They are unipapillary (unilobar single lobed, unipyramidal) and are localized in the retroperitoneal space. The right kidney is positioned cranially compare to the left one and situated from the 11th-12th intercostal spaces to the second lumbar vertebrae. The cranial pole of the right kidney reaches the liver under the last intercostals space and leaves impression onto its caudate process. The caudal pole of the right kidney reaches the descending part of the duodenum. The left kidney is situated between the 2nd and the 4th lumbar vertebrae and remains ventrocaudal to the right one.

Intravenous urography is the main exploratory radiological technique - allowing morphologic and functional assessment of the urinary organs [2, 7]. While performing intravenous excretory urography in normal human and animal kidneys, renal parenchymal opacification (nephrogram) appears within one minute after injecting a water soluble, radio-opaque contrast product, and pelvic calyceal system (pyelogram) appears within the next two minutes, followed by the ureters within 5-10 minutes.

It has been found the rat kidneys could be investigated by intravenous excretory urography [11]. The organs could be visualized by means of a compression method using prism from a non-contrasted material. Using contrast media is an optimal method. A nephrogram, including a pyelogram has been monitored in rats. The kidney and renal pelvis were visualized 15 to 60 sec after the contrast medium administration. Details of the ureter were visible from 5 to 10 min after the administration. The presence of the contrast medium in the urinary bladder was detected within the next1 to 5 min. Most of the kidney diseases can be diagnosed by using the author action for excretory urography in rats [11].
In the Persian Squirrel intravenous excretory urography has been done by a subcutaneous injection of the contrast material in order to eliminate the difficulties of the venipuncture in these animals [17]. The authors obtained lateral and ventrodorsal radiographs of the abdomen to visualize the normal kidneys. The radiography of the kidneys was done 5 min after the injection of the contrast medium and continued until it was fully eliminated from the entire urinary tract. The authors determined that the kidneys in the squirrel have atypical bean shape and the right kidney was visualized cranially compared to the left in the level of 1st to 3rd lumbar vertebrae. The left kidney was visualized from the 3rd to the 5th lumbar vertebrae. The kidneys were twice as long as the body of the second lumbar vertebrae. They obtained nephrograms, pyelograms and cystograms depending upon the time of the excretion of the contrast medium. The distension of the bladder reached cranially up to the 5th lumbar vertebrae. The kidneys were visualized on both the lateral and ventrodorsal projections while the bladder and the ureters were better seen on the lateral view.

In the subcutaneous method of introducing of the contrast medium, there were nonephrograms visualized, however pyelograms were observed which is due to the particular method of introduction. The pyelogram in the squirrel was visualized from 20 min to 230 min after application of contrast medium, ureterogram—from 60 min to 230 min and cystogram from 25 min to 234 min. The amount of contrast medium in the bladder reached its maximum after the 90 min of application. The bladder was pear shaped [17].

Numerous authors have investigated the kidneys in human, rabbit and dog in connection to the obstructive uropathy [6, 9, 14]. Excretory urography is frequently applied to investigate the urinary organs and provides information about the renal vascular structures, kidney shape and dimension, and renal collector elements. In the context of renal insufficiency, contrast media must be administered in double or threefold of normal dosage to get optimal image. Excretory urography was employed to determine position and shape of kidneys, pelvis renalis, and ureters. Like any other imaging study, intravenous urography should ideally be tailored to answer a specific question. In the literature the length of the left kidney is connected with the length of second lumbar vertebrae.

Radiography of the koala and cat kidneys was studied by some authors [1, 5, 10]. Radiograms of excretory urography were obtained after the administration of contrast agent and at 5, 20, 40, 90 min. Nephrogram, pyelogram, and cystogram phases were obtained. The left kidney was 2.6 folds greater than the second lumbar vertebra.

Contrast study of the kidneys in the rabbit has been done by some investigators [12, 15]. The authors performed intravenous and intrasosseus contrasted excretory urography, using the rabbit as animal model. Urograms obtained by the intravenous and intrasosseus routes were visually evaluated for quality (renal opacification, delineation of the parts of the kidney, ureteral opacification, urinary bladder opacification and filling).

Our aim was to perform an anatomical study of the urinary tract in the rabbit to help for the interpretation its lesions in this species.

Material and Methods

OBJECT

We investigated 9 healthy, sexually mature white New Zealand rabbits, aged 12 months, weighed from 3.0 kg to 3.4 kg. The experimental animals were housed at 25°C, with a 12 h dark/light cycle.

INTRAVENOUS EXCRETORY UROGRAPHY

Before administration of the contrast medium, the animals were fasted for 4 hours. Their intake of water was not restricted [11]. To facilitate handling of the animals when applying the contrast medium and to get good-quality radiographs, the animals were sedated with (IM) 15 mg/kg Zoletil® 50 (tiletamine hydrochloride 125 mg and zolazepam hydrochloride 125 mg in 5 ml of the solution) Virbac, France. The study was done with stationary radiographic machine TUR 800 D-1 (Röntgenbelichtungs automat – 20029), Dresden with digital touch screen apparatus - iQ- CR ACE, which is a CR reader to digitize X-ray imaging. Lateral (right and left) and ventrodorsal radiographs were taken prior and after contrast administration with focus-field distance of 100 cm. Kilovolt peak of 125 kV and Milliampere per seconds of 500 mAs. The radiographs were taken with cassette DICOM 3.0 (24x30 cm; 14´x17´) with size of matrix 2328 x 2928 px, and 18 x 24 cm (14´x17´) with size of the matrix 1728 x 2328 px. Exponential time is 10 mS (50 kV, 5 mAs). The spatial resolution was 10 px/mm, depth of scanning 20 bit/px, and depth after the CPU processing 16 bit/px. The used software was Windows XP SP3. The software utilized for reading and measuring of the X-rays structure was iQ-VIEW Version 2.7.0 BETA INT EN 002R, Copyright© 2006-2011 IMAGE Information Systems Ltd. The animals had initial X-rays. Then the excretory urography was performed in all rabbits. Intravenous injection of contrast medium produced 5, 10, 15 min and so on to 100 min urograms of satisfactory morphologic quality [15, 17].

The lateral and ventrodorsal abdominal radiographies were taken before contrast medium administration, and after the rapid delivery of a non-ionic contrast agent (Omnipaque® 350 – iohexol injection 76%, 350 mg/ml, 3 ml/kg b w, GE Healthcare, Ireland) through the retroauricular vein [13].

The body of the second lumbar vertebrae was used as comparative anatomical marker for the length (cranio-caudal size) of the kidneys [1, 5]. When comparing the length of the kidney with the length of the second lumbar vertebrae there was obtained an index, showing the proportion of the measured kidney being longer than the body of the second lumbar vertebrae [17].

The statistical analyses (descriptive statistics) were performed with statistical software StatMost for Windows, version 2.50 [16].

ETHICAL PROTOCOL

The study was approved by the institutional committee of animal care (Approval N° 25, published in Government Gazette,

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The experiments were made in strict compliance with European convention for vertebrate animals’ protection, used for experimental and other scientific purposes (Strasbourg /16th May 1986), European convention for companion animals’ protection (Strasbourg /13th November 1987) and animal protection’s law in Republic of Bulgaria (section IV-Experiments with animals, art. 26, 27 and 28, received on 24th January 2008 and published in Government Gazette, N° 13, 2008).

Results

A radiographic study of the urinary tract of the rabbit in lateral and ventrodorsal projection was performed. It was determined that the right kidney is localized between the caudal end of the 13th thoracic vertebrae and the left kidney between the caudal end of the second lumbar and forth lumbar vertebrae (Fig. 2 and Fig. 3). When observing the lateral nephrograms, it was determined that the left kidney lays caudo-ventrally to the right one (Fig. 2, Fig. 4 and Fig. 6). When studying the kidneys on the lateral projection, the kidney hilus was dorsaland medial when studied on the ventrodorsal projection (Fig. 2 and Fig. 3).

In native radiographic study of the renal organs in the rabbit was determined that the right kidney is being visualized as soft tissue finding with low opacity, from which was seen only the ventrocaudal portion. The point of contact between the right kidney and caudate procesus of the liver was not determined and the medial edge (shown as dorsal) with the kidney hilus were only partially visualized (Fig. 1). Both edges did not have good contour (Fig. 1). The two kidney opacities were considerably distinguishable and recognized from the surrounding soft tissue organs as well as bone structures. The body of the bladder was determined as an oval finding, which was localized in front of the pelvic floor and was with lower opacity. The ureters were not identified (Fig. 1).

In five minutes after administering the contrast medium were done the first nephrograms. The contrast study of the renal organs in lateral and ventrodorsal projections determined that the two kidneys were visualized as dense soft tissue findings. They showed distinct borders vs. the neighbouring structures. The kidneys parenchyma was visualized with distinguishable borders between the parts (cortex and medulla) in ventrodorsal nephrograms and without borders in lateral nephrograms (nephrographic phase). The drainage apparatus (pelvis, beginning of ureter) was not observed (Fig. 2 and Fig. 3). The contact between the right kidney and caudate processus of the liver was visualized as striped finding with relatively low opacity (Fig. 2 and Fig. 3).

In ten minutes after application of the contrast medium we saw the cavity findings of the kidney pelvis with fragments of the abdominal parts of the ureters (pyelographic phase) (Fig. 4 and Fig. 5). In lateral nephrograms was visualized only the pelvis of the left kidney (Fig. 4) and with the ventrodorsal – the two pelvises (Fig. 5).

In fifteen minutes after the application of contrast medium there were tubular findings determined, such as the ureters (ureterographic phase) (Fig. 6 and Fig. 7). In both radiographic projections the ureters were imaged as tubular structures without demarcation line between the walls and lumen. The abdominal and pelvic parts of the ureters have been imaged as well as the bladder partially filled with contrast medium. The left ureter showed better boundaries from the surrounding structures (Fig. 6 and Fig. 7).

In 15 to 20 minutes the entire bladder was filled with contrast medium and acquired pear shape. The body and the neck were well distinguished, as the neck showed lower density (cystographic phase). In lateral and ventrodorsal radiographic projection the bladder distension was determined as the organ was in the caudal portion of the abdomen and reaching cranially the beginning of the sixth lumbar vertebrae. The neck remained in close proximity to the pelvic floor (Fig. 8 and Fig. 9). In the lateral urogram the bladder was imaged as cavity contrast finding, into which the dorsocaudal part (neck) was seen the merger of the two ureters (Fig. 8). In the ventrodorsalurograms the ureteral end was not determined (Fig. 9).
FIGURE 3: Contrast ventrodorsal urogram in rabbit (nephrographic and pyelo-logic phase) (L2 – body of second lumbar vertebrae).

FIGURE 4: Contrast lateral urogram in rabbit (pyelographic phase and ureterographic phase).

FIGURE 5: Contrast ventrodorsal urogram in rabbit (pyelographic phase) (L2 - body of second lumbar vertebrae).

FIGURE 6: Contrast lateral urogram in rabbit (ureterographic phase).

FIGURE 7: Contrast ventrodorsal urogram in rabbit (ureterographic phase) (L2 - body of the second lumbar vertebrae).

FIGURE 8: Contrast lateral urogram in rabbit (urethra phase and cystographic phase).
Radiomorphometric data (iQ-VIEW Version 2.7.0 BETA INT EN 002R, Copyright© 2006-2011 IMAGE Information Systems Ltd.) showed that the left kidney was longer (cranio-caudal measure) and wider than the right. The kidney hilus of the left kidney had greater diameter (cranio-caudal measure). The diameter of the right ureter during the study was greater as a whole to the left one (Table I). The height (dorsoventral size) of the filled bladder showed the greatest values, followed by the length (cranio-caudal measure) and width (lateral measure) (Table I). When comparing the cranio-caudal measure with the length of the second lumbar vertebrae we determined that the right kidney is 2.32 times longer from the body of the vertebrae and the left – 2.59 times.

**Discussion**

The results from the investigation with intravenous excretory urography showed that the right kidney is localized craniodorsally to the left, with borders of the caudal end of the 13th thoracic vertebrae to caudal end of the second lumbar vertebrae. As a whole, the data confirms the results from the conventional anatomical studies for the kidneys in the rabbit [3, 4, 8]. In comparison with the results of the mentioned authors, we use the body of the corresponding thoracic vertebrae and not the intercostals as marker for the cranial border of the right kidney due to the fact that the vertebra is more quiescent element in inspiration and expiration movements. Similarly to the above authors we also showed contact of the cranial pole of the right kidney with caudate lobe of the liver.

Similar to [11], who studied radiographically the kidneys of the rat, dog, koala and the cat we have done the intravenous excretory urography in the rabbit. Unlike [11] we achieved good contrast visualization of the kidneys without applying abdominal compression. Obtaining the urograms in intervals after introduction of the contrast medium corresponds to the

<table>
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<th>N</th>
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<th>Mean</th>
<th>Standard error</th>
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TABLE I: Radiographic parameters (mm) of the normal kidneys, ureters and urinary bladder of New Zealand white rabbit.
The bladder in the rabbit has pear shape. The distension of the organ reaches cranially the beginning of the sixth lumbar vertebrae.

The contrast nephrogram is established in five minutes after inject of contrast medium, contrast pyelogram – in fifteen minutes and cystogram - in twenty minutes after application.

Radiographically, ureters in the rabbit are visualized only after positive contrasting.

The kidneys in the rabbit are visualized in lateral, as well as in ventrodorsal radiographic projection.

References


Conclusion

The results showed that intravenous excretory urography is good method of anatomical imaging of the kidneys, ureters and the bladder in the rabbit.

The left kidney is longer and wider compare to the right (in ventrodorsal and lateral projections).

The left kidney is 2.59 times longer from the body of the second lumbar vertebrae and the right- 2.32 times (in ventrodorsal projection).

The right ureter is greater as a whole compare to the left (without consider the phase of filling and emptying the urinary bladder.

settings from number of authors [1, 5, 6, 10, 11, 17]. The urograms correspond to nephographic, pyelographic, ureterographic and cystographic phase of excretion of the contrast medium [11, 17]. In our study those phases were observed every 5 minutes.

Our settings were borrowed from the study of [17]. Despite their results we applied the contrast medium. Like [17] we obtained lateral and ventrodorsal urograms as radiographic scan was also in intervals. In the rabbit as determined in the squirrel and koalas [1, 5, 10, 17] the right kidney is 2.32 times longer than the body of the second lumbar vertebrae (in ventrodorsal projection). In the rabbit, compare to the squirrel, and koalas [1, 5, 10, 17] the right kidney is 2.32 times longer from the body of the second lumbar vertebrae, and the left – 2.59 times (in ventrodorsal projection).

On the opposite to the results from the examination of [17], we saw the ureters and bladder inlateral and ventrodorsal projection. The pyelogram in our study was seen within 10 min after application of the contrast medium while in the squirrel [17] obtained pyelogram on the twentieth minute. The anatomical radiographic borders of distension of the bladder in the rabbit were determined in sync with the [17] in the area. The bladder in the rabbit was filled with contrast medium in 20 min after the injection. The reason is the intravenous route. In the rabbit the filled bladder was pear-shaped similar to the squirrel [17].

The normal kidneys in the rabbit were seen in lateral and ventrodorsal projection.

On the opposite to the study from some investigators [2, 7] regarding radiographic specifications of the renal organ in humans and the animals, we obtained nephrograms, pyelograms and ureterograms for longer periods after application of contrast medium. We believe the result is because of the anaesthesia of the experimental animals.

Similarly to [6, 9, 12, 14, 15] we claim that the rabbit is a good biological animal model for radiographic study of the normal kidney structures, their anomalies and obstructive lesions.