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Intravenous Urography in Cats - Comparison of Bolus, Abdominal Compression and Infusion Techniques*

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ABSTRACT

***Background*:** Diagnostic imaging is an integral part of the examination of patients with urinary tract pathologies and many imaging modalities are available. Owing to easy accessibility and low cost, radiography used together with ultrasonography as one of the first-step imaging methods in order to visualize the urinary system. Contrast-enhanced radiographic examination of the upper urinary system "intravenous urography" (IVU) can be performed with bolus injection, abdominal compression (with bolus injection) and infusion techniques. The aim of present study was to evaluate the urograms obtained in cats with urinary system complaints, compare the application of the IVU techniques and urogram quality, and interpret their diagnostic efficacy.

***Materials, Methods & Results*:** A total of 30 cats (of different age, breed, sex and weight) with urinary system complaint brought to Selcuk University Veterinary Faculty and Balikesir University Veterinary Faculty Surgery Clinics were included in the study. The cats were randomly divided into 3 groups with 10 cats in each group. In these groups, IVU was performed with bolus (Group 1), infusion (Group 2) and abdominal compression with bolus injection (Group 3) techniques. Non-ionic monomeric contrast agent iohexol3 (300 mg I/mL, GE Healthcare) at a dose of 800 mg I/kg was administered as an IV bolus injection in the Bolus group; iohexol at a dose of 1200 mg I/kg was diluted in an equal volume of 0.9% NaCl solution and the prepared solution was administered as an IV infusion through the catheter within 10 min in the Infusion group; iohexol at a dose of 800 mg I/kg was administered through the catheter after an elastic compression band was placed around the caudal abdomen to provide compression on the ureters in the bolus injection with abdominal compression group. The contrast agent (iohexol) injection was well tolerated by all cats. None of the cats developed anaphylactoid reactions or anesthesia-related complication. Changes observed in the heart and respiration rates and body temperature during the procedure did not show a statistically significant difference between the groups ($P > 0.05$). The renal and ureteral opacity scores and groups were compared, there was a significant difference was observed ($P < 0.05$). Urograms with "1 point" and "2 points" in kidney opacity scores were in the bolus injection group; urograms with "3 points" and "4 points" showed a statistically significant increase in the infusion and abdominal compression groups ($P < 0.05$). Urograms with "2 points" and "3 points" in ureteral opacity scores did not show a statistically significant difference ($P > 0.05$).

***Discussion*:** Currently, radiological IVU can still be used as a feasible, economical and valuable diagnostic tool with appropriate techniques, contrast agents and dose selection. For this purpose, patient preparation before IVU is very important to increase the interpretation ability of the urograms obtained. Sedation or anesthesia is not required to obtain better urograms. The bolus injection technique would be preferable for evaluating the anatomical position of the kidneys and observing the renal parenchyma. Urograms up to 20 min after the injection in the ventrodorsal (VD) position would be sufficient for proper observation of the nephrography phase. The infusion technique would be preferable for evaluating the collecting system. Urograms up to 20 min following the completion of the infusion in the VD position would be sufficient for proper observation of the pyelography phase and ureters. Urograms should be obtained in the VD and lateral positions for ureteral evaluation. Urograms taken after 5 or 40 min would be sufficient, depending on the ureteral part to be examined.

Keywords: abdominal compression, bolus, cat, infusion, urography.

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INTRODUCTION

Imaging is an integral part of the diagnostic examination of patients with urinary tract pathologies and there are many imaging modalities. Owing to easy accessibility and low cost, radiography used together with ultrasonography as one of the first-step imaging methods in order to visualize the urinary system [4]. Contrast-enhanced urinary system imaging procedure in animals is also called intravenous urography (IVU), intravenous pyelography (IVP) or excretory urography (EU) [4,28]. An IVU can be performed using radiography [1,12,15,27] or computed tomography (CT) [6,23,34].

Indications for IVU include determination of kidney/ureter size, shape and localization that cannot be seen on direct radiographs, observation of possible traumas and urinary system integrity, and determination of kidney localization in the presence of suspected ectopic ureter or a retroperitoneal mass [30]. It can also allow for subjective evaluation of kidney function [12,17,30]. IVU can be divided into four phases, which are observed sequentially but overlap in most cases; arteriography, nephrography, pyelography and cystography.

Iohexol is the most commonly used contrast agent for positive contrast studies of the entire urinary system [12,13,17,30]. IVU can be performed using different techniques, such as bolus injection with or without abdominal compression [2,5,8,12,15,21,25,30], and infusion of contrast agent [18,21,25]. The aim of present study was to evaluate the urograms obtained in cats with urinary system complaints, compare the application of the IVU techniques and urogram quality, and interpret their diagnostic efficacy.

MATERIALS AND METHODS

Animals

A total of 30 cats (of different age, breed, sex and weight) with urinary tract complaints were admitted to the Surgery Clinics of the Faculty of Veterinary Medicine, Selcuk University and Balikesir University were included in the study: Gender distribution 16 males (3 neutered) and 14 females (3 neutered), weight range 0.9 - 4 kg (2.46 ± 0.87 kg) and age 5 - 60 month (23 ± 17 month). The cats were randomly divided into 3 groups with 10 cats in each group. There were no criteria for grouping. However, the abdominal compression technique was not preferred when traumatized cats had injuries that did not allow compression. In these groups, IVU was performed with bolus injection (Group 1), infusion (Group 2), and bolus injection with abdominal compression (Group 3). The study was conducted with ethical approval from the Center for Experimental Animals of Selcuk University (No. 2021/38). During the study, diagnostic methods were performed in compliance with the ethical rules.

Diet restricted for 24 h before radiographic examinations, but no water restriction. Enemas were given 1 - 2 h before the examination and repeated as needed. An IV catheter was placed in the cephalic vein in all cats for IV fluid, medication, and contrast agent. Medetomidine HCl[1] [Domitor® - 0.08 mg/kg, IM] for sedation and ketamine HCl[2] [Ketasol® - 5-15 mg/kg, IM] were administered for anesthesia. The heart rate (HR), respiratory rate (RR) and body temperature of the cats were determined just before administration of the contrast agent and at 5 min intervals thereafter over a 20 min period. The HR was measured in beats per min using a stethoscope, and RR was measured in breaths per min by visual observation of chest extension. Body temperature was measured rectally with a clinical thermometer in °C.

Bolus injection IVU (Group 1)

Non-ionic monomeric contrast agent Iohexol[3] [Omnipaque® 300 mg I/mL - dose of 800 mg I/kg] was administered as an IV bolus injection at room temperature via a catheter within 10 - 15 s. Radiographs were obtained immediately (0) and 5, 10, 20, and 40 min after contrast agent injection in the lateral and ventrodorsal projections. The completion of the contrast agent injection was accepted as 0 min.

Infusion IVU (Group 2)

Iohexol at a dose of 1200 mg I/kg was diluted in an equal volume of 0.9% NaCl solution. The prepared solution was administered as an IV infusion through the catheter within 10 min using an infusion pump (model eB12, China). Radiographs were obtained immediately (0) and at 5, 10, 20, and 40 min after completion of the infusion of the contrast-containing solution in lateral and ventrodorsal projections.

Bolus injection with abdominal compression IVU (Group 3)

Performed in cats under anesthesia. Before administration of the contrast agent, an elastic com-

pression band was placed around the caudal abdomen to provide compression on the ureters. After application of the compression band, iohexol was administered as IV bolus injection at a dose of 800 mg I/kg through the catheter within 10 - 15 s. The compression band was released 10 min after administration of the contrast agent. Radiographs were obtained immediately (0) and 10, 20, and 40 min after release of the compression band in lateral and ventrodorsal projections.

Scoring urograms

The opacification in the kidneys and ureters in the urograms and their diagnostic abilities were evaluated by scoring. A modified scoring scheme was used for scoring, with ranging from 0 (poor) to 4 (very good) [Table 1].

Statistical analysis

The HR, RR and rectal temperature were assessed by one way repeated measures analysis of variance (ANOVA) between groups. The results of qualitative radiological scores in the urograms of the groups were analyzed for statistical significance between groups using the nonparametric Pearson chi-square test and Fisher's exact test. Statistical analyzes were performed using SPSS Software (v.26, IBM, USA). Data were expressed as mean values ± standard deviation (mean ± SD). The level of significance was set at $P < 0.05$.

Table 1. Modified scoring scheme for renal and ureteral opacities in the urograms.

	Score	Findings
Renal Opacity [3]	4	Renal pelvises and calyces are clearly observed.
	3	Renal pelvises and calyces are slightly visible.
	2	Renal pelvises and calyces are not visible, but kidney lines are clearly visible.
	1	Kidney lines are not clearly observed
	0	Kidney lines are not observed
Ureteral Opacity [16]	4	All ureters become sufficiently opaque; full interpretation possible
	3	The ureters become sufficiently opaque; interpretation possible
	2	The ureters become partially opaque; incomplete interpretation
	1	The ureters become insufficiently opaque; interpretation not possible
	0	Ureters are not observed

RESULTS

The diet was restricted 12 - 24 h before the IVU, and in some cases (n = 6), the GIT could not be adequately emptied, although an enema was performed. However, IVU were performed in all cats in this study, including traumatized cats (n = 2). The inability to empty the GIT had a relatively negative effect on radiographic assessment, as radiopaque bodies were observed with superposition on the urinary system.

The contrast agent injections were well tolerated by all cats. No side effects or anaphylactoid reactions were observed in any of the cats. No anesthesia-related complications were observed in the anesthetized cats. Uncomplicated IVU without sedation/anesthesia (n = 3) and with sedation only (n = 5) was performed in the eligible cats after assessment of the general conditions.

Among the recorded vital parameters, changes HR, RR and body temperature per min did not show a statistically significant difference between the groups ($P > 0.05$). However, the HR showed an increase in the bolus and abdominal compression groups in the immediate measurements after contrast agent administration, and this increase continued for up to 10 min in the infusion group. The HR in all groups showed a stable trend at the 15th min. The RR progressed unevenly in the bolus group and remained stable in the abdominal compression group. While body temperature tended to decrease in the bolus and abdominal compression groups, it remained stable in the infusion group (Figure 1).

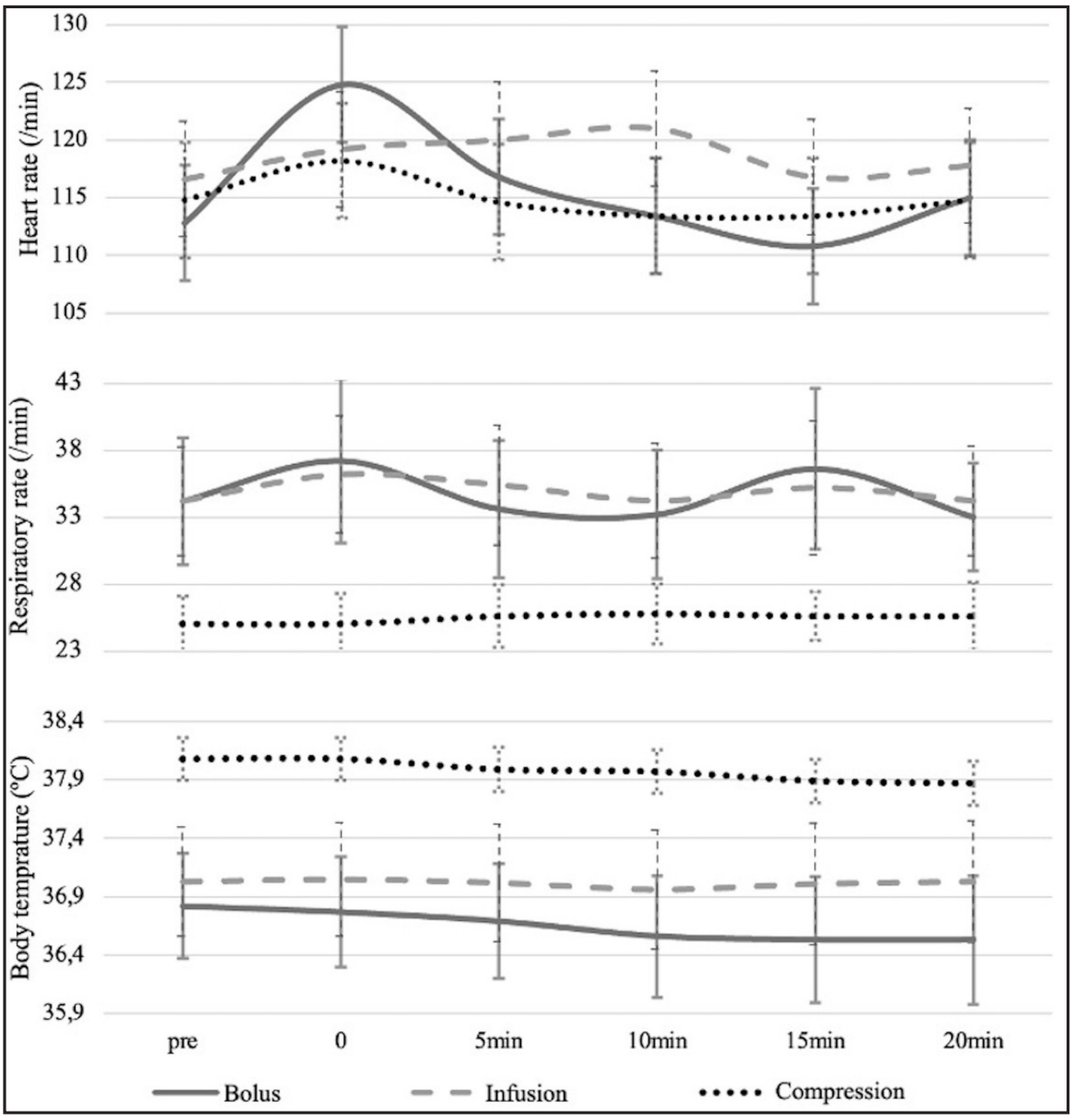

Figure 1. Mean HR, RR and body temperature in cats undergoing urography (mean ± SEM).

The arteriography phase could be observed in the radiographs taken immediately after contrast agent administration (while contrast agent injection continued) in the bolus group. However, it was not observed in the infusion and abdominal compression groups.

The nephrography phase reached interpretable opacity in the radiographs taken immediately and up to the 10th min after contrast agent injection in the bolus group. In the infusion group and the abdominal compression group, it was observed immediately on the radiographs. In the bolus group, the pyelography phase was observed together with the nephrography phase at the 10th min after contrast agent injection. In the radiographs of the infusion group and the abdominal compression group, it was observed immediately together with the nephrography phase. In general, the most appropriate opacification was observed at the 10th min after contrast agent administration. The cystography phase started after 5 - 10 min in all groups and reached the most suitable opacity for interpretation in the 40th min. A urethrography phase was not observed in any of the cases.

A total of 280 urograms were obtained from the groups in which different urography techniques were used. Renal and ureteral opacity scores given by the investigator were compared between groups and a statistically significant difference was found ($P < 0.05$). The distributions of the opacity scores in the groups are shown in Table 2.

Table 2. Distribution of the renal and ureteral opacity scores in groups.

	Score	Group 1	Group 2	Group 3	Total Urogram		Score	Group 1	Group 2	Group 3	Total Urogram
	0	5_{a}	0_{a}	0_{a}	5		0	37_{a}	10_{b}	12_{b}	59
	1	20_{a}	5_{b}	1_{b}	26		1	15_{a}	$26_{a, b}$	31_{b}	72
Renal	2	61_{a}	41_{b}	$46_{a,b}$	148	Ureteral	2	28_{a}	38_{a}	22_{a}	88
	3	8_{a}	36_{b}	19_{b}	63		3	15_{a}	10_{a}	11_{a}	36
	4	6_{a}	18_{b}	14_{b}	38		4	5_{a}	16_{b}	$4_{a, b}$	25
Total		100	100	80	280	Total		100	100	80	280

[a,b]Different subscript letters in each column indicate significant difference at $P < 0.05$ between groups. Group 1: Bolus injection; Group 2: Infusion; Group 3: Abdominal compression.

Urograms for renal opacity with "2 points" in the bolus group showed a significant decrease at the 40th min compared with 0 and 5 min ($P < 0.05$). Urograms with "4 points" in the infusion group showed a significant increase at 40 min compared with 0 min ($P < 0.05$). Apart from this, there was no statistically significant difference between radiographic time points within the groups ($P > 0.05$). There was no statistically significant difference between radiographic positions and scores in any group ($P > 0.05$).

Urograms for ureteral opacity with "0 points" in the bolus group at 0 min compared with the other timing points and urograms with "2 points" at 10 and 20 min showed a statistically significant increase compared with 0 min ($P < 0.05$). Apart from this, there was no statistically significant difference between radiographic time points within the groups ($P > 0.05$). Urograms with "0 points" and "3 points" in the infusion group showed a statistically significant increase in the ventrodorsal position compared with the lateral position ($P < 0.05$).

DISCUSSION

General anesthesia is not an essential part of the standard protocol for IVU in cats, but IVU may be performed under general anesthesia because of the animal's aggressive attitude toward the examination [7]. Ajadi *et al*. [3] reported that there was no statistical difference between HR, RR and body temperature in anesthetized animals. The absence of a statistically significant difference of vital signs in the presented study was observed in agreement with the literature. However, the increase in heart rate was higher in the bolus group than in the other groups. This may be explained by the low systemic blood pressure caused by contrast agent administration and the cardiovascular depression caused by the anesthetic agents, leading to bradycardia in the infusion and abdominal compression groups, in which anesthesia was applied more. Ajadi *et al*. [3] also reported a progressive decrease in rectal temperature after contrast agent administration, which was associated with the hypotensive effect of the contrast agent. In the presented study, no decrease in the body temperature was observed in the infusion group. This may be explained by the fact that the effect of slow infusion contrast agent administration on body temperature may be less compared with bolus injection, and the hypotensive effect of contrast agent administration can be relatively avoided with the infusion technique.

It has been shown that non-ionic low-osmolarity contrast agents have significant advantages over conventional high-osmolarity contrast agents in terms of both safety and efficacy [2,9,16,33]. However, although the high cost and low incidence of side effects against ionic agents in veterinary medicine have limited the use of non-ionic contrast agents [7], the reported incidence of adverse events may be falsely low or due to the relatively small number of IVU procedures performed in animals. It has been reported that it may also be due to the lack of detection of milder reactions [35]. In the presented study, non-ionic iohexol was used and no side effects were observed. Since most cats are under sedation or anesthesia, mild side effects were thought to be masked or avoided by anesthesia. Financial cost may be more of a concern for imaging modalities than the choice of contrast agent. For this purpose, in the presented study, conventional radiography was used instead of advanced imaging techniques such as CT or magnetic resonance imaging (MRI). It is thought that it can still be used as one of the first-step imaging

techniques in imaging the urinary system in terms of cost and effectiveness.

In the urinary system, CT and MRI provide improved contrast resolution and detail compared with conventional radiography and fluoroscopy. Contrast administration allows better visualization of smaller structures, such as the urethra and ureters [23]. It can be used effectively in the diagnosis of developmental disorders such as ureteral obstruction, ectopic ureter and ureter duplication [11]. Among the advantages of tomographic urography are its relatively good contrast resolution in soft tissue and its ability to characterize small anatomical structures, such as the urethra and ureters [23]. In addition, it is not affected by the GIT content, which may create a superposition with the urinary system [23,34]. Although traditional radiographic IVU was preferred in the presented study, CT imaging is considered a very valuable advanced imaging tool to supplement ultrasonographic and radiographic findings.

The intensity of the nephrographic phase depends on the contrast agent injection rate and total dose [10,14,20]. Pyelographic phase density, on the other hand, depends on the iodine concentration and urine flow rate in the urine, depending on the contrast agent dose and osmosis; an increase in opacity should be observed in the renal pelvis and calyces with the given contrast agent [9,19,20]. The presence of osmosis causes less diuresis of low-osmolar non-ionic iohexol, thereby increasing the iodine concentration more than high-osmolar contrast media. Therefore, lower doses of low-osmolar contrast agents can be used than high-osmolar contrast agents to achieve the same iodine concentration [16]. Agut *et al*. [2] reported that nephrogram qualities did not differ between ionic and non-ionic contrast agents during the first 30 min, but doses of 400 - 800 mg I/kg (iohexol) increased nephrogram qualities up to 45 - 60 min. Consistent with the literature, with iohexol at 800 mg I/kg doses, nephrographic phases could be observed up to the 40 min in the presented study, depending on the technique (following the contrast agent injection). Previous studies in healthy cats and dogs [2,15] showed similar findings to the cats with urinary system complaints in the presented study. This is because of the administration of the recommended dose of 400 mg I/kg iohexol at doses of 800 or 1200 mg I/kg (depending on the technique). It has been suggested that providing the amount of iodine that high-osmolar contrast agents will provide in sick animals with low-osmolar contrast material can be applied more safely. The use of a low-osmolar contrast agent in the pyelography phase can create intense opacity in the calyx, pelvis and ureters, but does not create sufficient fullness. It has been reported that this situation can be relatively prevented by the abdominal compression technique [9,10]. In the presented study, urograms with the best interpretative ability were obtained using the infusion technique. This can be attributed to the fact that animals with urinary system complaints were evaluated in the presented study and that the contrast agent was administered at a lower dose and volume in animals included in the abdominal compression group (800 mg I/kg) than in the infusion group (1200 mg I/kg). Also, the fact that the urinary bladder was relatively full in the infusion group also suggested that it may have decreased the urine flow rate and provided better observation of ureteral opacities in the pyelography phase.

Various techniques have been described for regions that need to be observed [21,25,30]. The IVU with bolus injection provided better urograms than other techniques for the renal parenchyma in the presented study. However, this was insufficient to evaluate the collection system. Although there was no significant difference between the techniques for observing the ureters, the ureters were best seen on urograms obtained using the infusion technique. The IVU with infusion provided better urograms than the other techniques for visualizing the collecting system in the presented study. However, it is the weakest technique for observing the kidney parenchyma. The IVU with abdominal compression provided better urograms than bolus injection for visualizing the collecting system in the presented study. In order to interpret the ureters, it was possible to provide urograms that were better than the bolus injection technique but of similar quality to the infusion technique.

Proper radiographic positions required to obtain urograms depend on the findings of the study [1,15,27]. It has been reported that ventrodorsal (VD) positions are more beneficial than lateral positions, and some studies have used only VD positions [2,16]. In the presented study, urograms were taken in the VD and lateral positions. It has been seen that both positions have their own advantages and disadvantages. Contrary to the literature data [2,16], urograms

in which all ureters could be observed were obtained in the lateral position in the presented study. Similar to the literature, although no statistically significant difference was observed in the presented study, the renal pelvis and calyces were superposed in the lateral urograms, making interpretation difficult. Therefore, urograms obtained in the VD position were very effective for the evaluation of kidney structures. It was thought that urograms should be obtained in the VD and lateral positions and the urinary system should be evaluated as a whole.

This study had some limitations. The selected animal population has been healthy in some previous studies [24,31] or has specific uniform pathologies [22,29,32]. In the presented study, cats with complaints related to their urinary system were evaluated. This may have caused the findings obtained by IVU techniques to be affected by different pathologies in the population. It also made it difficult to evaluate the contrast agent dose, effects, and side effects. Population size is very important, especially in evaluations made by observers. Therefore, an increase in the study population will have a more positive effect on the statistical data to be obtained. In addition, in the presented study, the quality of findings was evaluated in animals with different pathologies in clinical conditions with IVU, which is a routine clinical examination and diagnostic method. Another limitation factor is the lack of use of advanced imaging techniques such as CT. Today, CT and MRI, which can provide more effective findings for the evaluation of the urinary system in human medicine, have become standard procedures [26]. Conventional radiography, which is a first-line diagnostic method, was used in this study because of its high accessibility, low cost, and common use in veterinary medicine. Diagnostic findings obtained at accessible and affordable costs were evaluated. Thus, it was thought that the sick animal could receive the appropriate treatment by supporting the animal owners for a more costly process, such as medical or surgical treatment. However, despite its accessibility, physician experience is very important in the evaluation of the urinary system with an IVU. For this reason, urograms should be evaluated by experienced physicians.

Currently, radiological IVU can still be used as a feasible, economical and valuable diagnostic tool with appropriate techniques, contrast agents and dose selection. For this purpose, patient preparation before IVU is very important to increase the interpretation ability of the urograms obtained. Sedation or anesthesia is not required to obtain better urograms. The bolus injection technique would be preferable for evaluating the anatomical position of the kidneys and observing the renal parenchyma. Urograms up to 20 min after the injection in the VD position would be sufficient for proper observation of the nephrography phase. The infusion technique would be preferable for evaluating the collecting system. Urograms up to 20 min following the completion of the infusion in the VD position would be sufficient for proper observation of the pyelography phase and ureters. Urograms should be obtained in the VD and lateral positions for ureteral evaluation. Urograms taken after 5 or 40 min would be sufficient, depending on the ureteral part to be examined. Physical, laboratory, ultrasonographic and radiographic examinations, as well as advanced imaging CT and MRI examinations should be evaluated together for urinary system diseases. In addition, the fact that the animal does not need to be positioned continuously on the CT will increase the consistency of the urograms obtained. However, it also reduces the radiation exposure to physicians or technicians.

CONCLUSION

In conclusion, each IVU technique has several advantages. It is difficult to discuss the superiority of a single technique in any circumstance. For this reason, to obtain maximum findings from urograms, the most appropriate technique and timing should be selected for the region to be evaluated. The obtained urograms and findings should be evaluated along with other clinical and laboratory findings. In order to evaluate urography and contrast agent effects in detail, further studies with advanced imaging techniques such as CT and MRI are needed in larger patient populations with a uniform pathological distribution.

MANUFACTURERS

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