

Acid-base and biochemical stabilization and quality of recovery in male cats with urethral obstruction and anesthetized with propofol or a combination of ketamine and diazepam

Gabrielle C. Freitas, Marina G. Monteiro Carvalho Mori da Cunha, Kleber Gomes, João P. Monteiro Carvalho Mori da Cunha, Monique Togni, Ney L. Pippi, Adriano B. Carregaro

Abstract

This study compared acid-base and biochemical changes and quality of recovery in male cats with experimentally induced urethral obstruction and anesthetized with either propofol or a combination of ketamine and diazepam for urethral catheterization. Ten male cats with urethral obstruction were enrolled for urethral catheterization and anesthetized with either ketamine-diazepam (KD) or propofol (P). Lactated Ringer's solution was administered by intravenous (IV) beginning 15 min before and continuing for 48 h after relief of urethral obstruction. Quality of recovery and time to standing were evaluated. The urethral catheter was maintained to measure urinary output. Hematocrit (Hct), total plasma protein (TPP), albumin, total protein (TP), blood urea nitrogen (BUN), creatinine, pH, bicarbonate (HCO_3^-), chloride, base excess, anion gap, sodium, potassium, and partial pressure of carbon dioxide in mixed venous blood (pvcO_2) were measured before urethral obstruction, at start of fluid therapy (0 h), and at subsequent intervals. The quality of recovery and time to standing were respectively 4 and 75 min in the KD group and 5 and 16 min in the P group. The blood urea nitrogen values were increased at 0, 2, and 8 h in both groups. Serum creatinine increased at 0 and 2 h in cats administered KD and at 0, 2, and 8 h in cats receiving P, although the values were above the reference range in both groups until 8 h. Acidosis occurred for up to 2 h in both groups. Acid-base and biochemical stabilization were similar in cats anesthetized with propofol or with ketamine-diazepam. Cats that received propofol recovered much faster, but the ketamine-diazepam combination was shown to be more advantageous when treating uncooperative cats as it can be administered by intramuscular (IM) injection.

Résumé

Cette étude visait à comparer les changements biochimiques et acide-base ainsi que la qualité de la convalescence chez des chats mâles avec une obstruction urétrale induite expérimentalement et anesthésiés avec soit du propofol ou une combinaison de kétamine et diazépam pour une cathétérisation urétrale. Dix chats mâles avec une obstruction urétrale ont été recrutés pour cathétérisation urétrale et anesthésiés avec soit une combinaison kétamine-diazépam (KD) ou du propofol (P). Une solution de lactate de Ringer a été administrée par voie intraveineuse (IV) débutant 15 min avant et continuant 48 h après l'élimination de l'obstruction urétrale. La qualité de la convalescence et le délai avant de se tenir debout ont été évalués. Le cathéter urinaire était laissé en place pour mesurer l'excrétion urinaire. Les valeurs des paramètres suivants ont été mesurées avant l'obstruction urétrale, au début de la fluidothérapie (0 h) et à des intervalles subséquents : hématoците (Hct), protéines plasmatiques totales (TPP), albumine, protéines totales (TP), azotémie (BUN), créatinine, pH, bicarbonate (HCO_3^-), chlorure, excès de base, trou anionique, sodium, potassium, pression partielle de dioxyde de carbone dans le sang veineux (pvcO_2). La qualité de la convalescence et le temps avant de se tenir debout étaient respectivement de 4 et 75 minutes dans le groupe KD et de 5 et 16 minutes dans le groupe P. Les valeurs de BUN étaient augmentées à 0, 2 et 8 h dans les deux groupes. La créatinine sérique augmenta à 0 et 2 h chez les chats recevant KD et à 0, 2 et 8 h chez les chats recevant P, bien que les valeurs étaient supérieures à l'écart de référence dans les deux groupes jusqu'à 8 h. Une acidose s'est produite pendant 2 h dans les deux groupes. L'équilibre acide-base et la stabilisation biochimique étaient similaires chez les chats anesthésiés avec du propofol ou avec KD. Les chats qui ont reçu du propofol ont récupéré beaucoup plus rapidement, mais la combinaison KD s'est avérée plus avantageuse pour traiter des chats non-coopératifs étant donné la possibilité d'administration par voie intra-musculaire.

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Rural Science Center, Federal University of Santa Maria, 97105-900, Santa Maria, RS, Brazil (Freitas, M. and J. Monteiro Carvalho Mori da Cunha, Gomes, Togni, Pippi); Department of Zootechnical Science, University of São Paulo, Av. Duque de Caxias Norte, 225, Pirassununga, 13635-900, SP, Brazil (Carregaro).

Address all correspondence to Dr. Adriano B. Carregaro; telephone: (55) 19-35654092; fax (55) 19-35654114; e-mail: carregaro@usp.br

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Introduction

Urethral obstruction is one of the most common emergencies involving the urinary tract in cats. If untreated, it can rapidly progress to severe acid-base disturbances (1). In addition to azotemia, metabolic acidosis, hyperkalemia, hyperphosphatemia, and hypocalcemia are also observed. Over a prolonged period, urethral obstruction results in fluid depletion, which culminates in hypovolemia and hypoperfusion (2).

Glomerular filtration rate decreases 4 to 5 h after the onset of urethral obstruction due to the increase in intrarenal and intratubular pressure (3). Since kidneys directly and indirectly excrete some anesthetic agents, these drugs must be selected carefully for patients with renal impairment. The renal patient becomes susceptible to pharmacological overdose due to disturbances in plasma protein concentrations, drug ionization, pharmacokinetic effects, and excretion (4). Moreover, anesthetic agents can worsen cardiovascular depression in hyperkalemic cats, which makes it essential to reduce serum levels of potassium before anesthesia and relief of urethral obstruction (5).

In docile or severely depressed animals, physical restraint, possibly combined with topical anesthesia, is an alternative to anesthetic agents. The risks associated with anesthetics, however, must be compared with the possibility of iatrogenic urethral trauma in an uncooperative patient (6). Ketamine is widely used in cats as a chemical restraint and is especially advantageous in aggressive cats as it can be administered by intramuscular (IM) injection. It has been reported that low doses [1 to 2 mg/kg bodyweight (BW)] of ketamine given intravenously (IV) are adequate for the urethral release procedure, with the benefit of maintaining or increasing cardiac performance (6–9). The use of ketamine in cats with urethral obstruction is controversial, however, as most of the drug is excreted unchanged by the kidneys (6,7) and may accumulate in the body if the urethra of the patient is not relieved appropriately. It is therefore recommended that multiple doses of this anesthetic be avoided in cats in which the relief procedure is difficult or if this pathology has recurred. Such animals are predisposed to the occurrence of urethral stenosis, which might complicate the relief procedure (9) and consequently the excretion of the drug.

The available literature indicates that combining ketamine with diazepam relieves urethral obstruction in cats (6,8,9). This combination promotes urethral relaxation (9) and reduces muscle hypertonia and risks of convulsion (10) without changing the glomerular filtration rate (11). As the active metabolites of diazepam can contribute to prolonging depression in uremic animals (5), it is considered detrimental to use it alone in animals with urethral obstruction. Moreover, there were no pressor or cardiovascular stimulating effects detected with the ketamine-diazepam induction (12) and the effects of ketamine are not reversible and should not be used in animals with cardiac disease (9).

General anesthetics, such as propofol and inhalation anesthetics, should also be indicated if general anesthesia is necessary. These anesthetics should be administered cautiously in patients with post-renal azotemia, however, and lower-than-recommended doses should be used for patients with normal renal function (6). Propofol stands out for its smooth and rapid onset of action, short duration,

and lack of systemic accumulation (13). Repeated administrations or continuous infusions of propofol are useful for maintaining short-term anesthesia in cats (14–16). It may become complicated in some cases, such as when the animal is aggressive or hypotensive, as venipuncture is required for its administration.

This study compared the acid-base and biochemical changes and the quality of recovery in male cats with experimentally induced urethral obstruction and anesthetized for urethral catheterization with either propofol or a combination of ketamine and diazepam.

Materials and methods

This study was approved by the Institutional Animal Use and Care Committee (number 31/2008) of Federal University of Santa Maria. Ten adult, neutered male, mixed-breed cats, weighing from 3.5 to 5 kg, were enrolled in a urethral obstruction model (parallel study) (17). All cats were proven to be healthy by clinical and laboratorial evaluation, which included complete blood count, alanine aminotransferase, gamma-glutamyltransferase, blood urea nitrogen (BUN), and creatinine.

After anesthesia with isoflurane in 100% oxygen by use of a facial mask and aseptic preparation of the preputial and peripreputial areas, urethral catheterization was performed with a 3.5 F polypropylene open-end catheter (Sovereign, 3.5 Tom Cat Catheter; Sherwood Medical, St. Louis, Missouri, USA) lubricated with lidocaine gel. The urethral catheter was occluded with the cap of a peripheral venous catheter and fixed in the peripreputial area using a simple interrupted suture with 3-0 monofilament nylon. For each cat, anesthesia to relieve urethral obstruction was performed when 3 out of 4 of the following clinicopathologic criteria were met: venous pH < 7.2; BUN concentration > 200 mg/dL; serum creatinine concentration > 397.8 $\mu\text{mol/L}$; and serum potassium concentration > 6.5 mEq/L.

The animals were randomly allocated into 2 groups: the KD group received a combination of ketamine (Ketalar 100 mg/mL; Parke-Davis, Rio de Janeiro, RJ, Brazil), 10 mg/kg BW and diazepam (Compaz 5 mg/mL; Cristália Produtos Farmacêuticos, Itapira, SP, Brazil), 0.5 mg/kg BW, IM; and the P group received propofol (Propovan 10 mg/mL; Cristália Produtos Farmacêuticos), 5 mg/kg BW, IV, replicating a situation in which anesthesia was necessary for urethral catheterization of the animal. If required, an additional dose of ketamine (5 mg/kg BW) and diazepam (0.25 mg/kg BW) would be administered by IM in the KD group and propofol (2.5 mg/kg BW, IV) in the P group.

For the relief procedure, venipuncture of the cephalic vein was carried out with a 22-g catheter to administer lactated Ringer's solution (Ringer com Lactato de Sódio; Aster Produtos Médicos, Sorocaba, SP, Brazil) by means of a volumetric infusion pump (Infusomat Compact; B. Braun, Niterói, RJ, Brazil) at a rate of 20 mL/kg BW per hour.

Anesthesia was induced by one of the anesthesia protocols 15 min after start of fluid therapy. After anesthesia was established, the urinary bladder was flushed with cold lactated Ringer's solution until the effluent was clear (approximately 15 min). The urethral catheter was then connected to a low-vacuum drainage system to measure urinary output (UO). While under anesthesia, the jugular

Table 1. Results of hematological and biochemical analyses and urinary output (UO) in cats with experimentally induced urethral obstruction and anesthetized with ketamine-diazepam (KD, n = 5) or propofol (P, n = 5)

Parameter	Group	Basal	Time Point							
			0 h	2 h	8 h	12 h	24 h	48 h	72 h	7 d
Hct	KD	38 ± 5.8	37 ± 6.8	33 ± 5.6*	28 ± 9.5*	27 ± 9.3*	25 ± 6.5*	24 ± 6.6*	23 ± 6.0*	27 ± 7.2*
(%)	P	40 ± 4.8	37 ± 6.7*	32 ± 5.6*	27 ± 3.1*	27 ± 5.1*	26 ± 3.0*	26 ± 7.6*	29 ± 5.6*	30 ± 3.5*
TPP	KD	8.1 ± 0.6†	8.4 ± 0.4	7.6 ± 0.9	6.9 ± 1.0*	7.0 ± 0.9*	7.0 ± 0.9*†	8.0 ± 0.7	8.0 ± 1.1	8.2 ± 0.6
(g/dL)	P	9.1 ± 0.7†	8.3 ± 1.3	7.9 ± 0.7*	7.5 ± 0.5*	7.8 ± 0.7*	8.1 ± 0.4†	7.9 ± 0.5*	8.6 ± 0.2	8.6 ± 0.9
Albumin	KD	2.4 ± 0.1†	1.9 ± 0.3	1.9 ± 0.5	1.6 ± 0.4*	1.8 ± 0.6	2.0 ± 0.8	2.2 ± 0.2†	2.0 ± 0.2	2.0 ± 0.2
(g/dL)	P	1.7 ± 0.3†	1.8 ± 0.3	1.6 ± 0.4	1.5 ± 0.3	1.5 ± 0.3	1.6 ± 0.4	1.5 ± 0.4†	1.8 ± 0.4	1.8 ± 0.2
TP	KD	7.7 ± 1.7	7.4 ± 0.8	6.2 ± 1.4	6.3 ± 0.9	7.0 ± 1.2	6.7 ± 1.0	7.7 ± 0.9	8.2 ± 0.6	8.3 ± 0.4
(g/dL)	P	8.4 ± 0.5	7.6 ± 0.6	7.0 ± 1.1*	6.9 ± 1.3*	6.8 ± 0.7*	7.3 ± 1.2	6.9 ± 1.0*	7.6 ± 0.8	8.0 ± 0.5
BUN	KD	55 ± 14	316 ± 40*	267 ± 42*	151 ± 62*	110 ± 58	64 ± 30	57 ± 21	99 ± 76	52 ± 12
(mg/dL)	P	47 ± 19	278 ± 121*	256 ± 112*	143 ± 76*	97 ± 58	45 ± 24	47 ± 14	68 ± 33	58 ± 12
Creatinine	KD	106 ± 8.8	592 ± 168*	389 ± 88.4*†	212 ± 88.4	159 ± 70.7	115 ± 44.2	124 ± 26.5	203 ± 177	106 ± 8.8
(µmol/L)	P	115 ± 26.5	663 ± 115*	521 ± 106*†	274 ± 88.4*	177 ± 61.8	115 ± 17.6	115 ± 17.6	133 ± 26.5	141 ± 26.5
UO	KD	NA	NA	13.5 ± 9.4	13.9 ± 6.3	14.0 ± 6.2	9.1 ± 2.1	4.9 ± 1.1*	NA	NA
(mL/kg/h)	P	NA	NA	14.8 ± 5.2	17.5 ± 2.8	13.4 ± 3.3	11.4 ± 1.2	4.1 ± 1.5*	NA	NA

Data are reported as mean ± standard deviation (SD).

Reference ranges for the variables of interest in cats are as follows: PCV, -32% to 48%; TPP, -6 to 8.6 g/dL; albumin, -2.4 to 3.8 g/dL; TP, -4.4 to 7.8 g/dL; BUN, -15 to 32 mg/dL; creatinine, -88.4 to 176.8 µmol/L; UO, -1 to 2 mL/kg/h.

Hct — hematocrit; TPP — total plasma protein; BUN — blood urea nitrogen; NA — Not available; UO — urinary output.

* Difference between each time and basal time.

† Difference between the groups.

• Difference between the each time of the same group.

was punctured with a 20-g catheter fixed appropriately, which was used to collect venous blood (3 mL) for laboratory tests. A thermal mattress was used to maintain body temperature at 37.8°C to 39.5°C. Fluid therapy was carried out for 48 h post-relief. The infusion rates were gradually reduced, administering 20 mL/kg BW per hour in the first 6 h, 15 mL/kg BW per hour until 12 h, 10 mL/kg BW per hour until 24 h, and 5 mL/kg BW per hour until 48 h of evaluation in accordance with a parallel study (17).

The quality of recovery and time to standing for each cat were evaluated by the same observer. The overall quality of the recovery was scored on the following subjective 5-point scale: 1 = poor — many attempts to stand, falls over repeatedly, marked ataxia; 2 = better — multiple attempts to stand, falls over occasionally, and significant ataxia; 3 = good — lies quietly, several attempts to stand, some ataxia; 4 = very good — lies quietly, few attempts to stand, mild ataxia; 5 = excellent — rolls into sternal recumbency, gets up without falling, minimal ataxia (16).

Venous blood gas and serum electrolyte were analyzed at baseline and at 0, 2, 8, 12, 24, and 48 h after starting the fluid therapy. Hematocrit (Hct), total plasma protein (TPP), albumin, total protein (TP), blood urea nitrogen (BUN), and creatinine were measured at the same time points and also at 72 h and 7 d after starting the fluid therapy. Urine from the low-vacuum drainage system was measured at 2, 4, 8, 12, 24, and 48 h. After relief of urethral obstruction, a syringe was attached to the urethral catheter to collect urine for performing urinalysis.

Cats received meloxicam (Maxicam 0.2%; Ouro Fino Saúde Animal, Cravinhos, SP, Brazil), 0.1 mg/kg BW, IM, q24h starting on the day the occluded urethral catheter was placed and continuing up to 3 d after relief of urethral obstruction. At the end of the study, all cats were donated to households.

All analyses were performed with standard software (GraphPad Prism; GraphPad Software, San Diego, California, USA). A repeated-measures analysis of variance (ANOVA) was used, followed by Dunnett's test to compare each variable except urinary output (UO) at the various time points with the baseline mean value within a group. Urinary output was compared among time points by repeated-measures ANOVA followed by the Tukey test. Values for each variable at each time point were compared between groups by use of the unpaired *t*-test. The quality of recovery was compared by the Mann-Whitney test. A value of $P < 0.05$ was considered significant. Results were expressed as mean \pm standard deviation (SD) except for the quality of recovery, which was expressed as median and interquartile range.

Results

The urethral obstruction model demonstrated an increase in BUN concentration and creatinine levels, metabolic acidosis, and hyperkalemia after a mean period of 42.7 ± 2.8 h in the P group and 39.9 ± 1.3 h in the KD group. All animals presented significant hematuria and proteinuria at the moment of relief of urethral obstruction. An additional dose of propofol (2.5 mg/kg BW, IV) was required in all animals in the P group at the moment of bladder lavage. The time to standing was 16 min (10/20) in P and 75 min (45/90) in KD ($P = 0.004$). No differences were observed in the quality of recovery

between the 2 groups, with the KD group scoring 4 (3/5) and the P group scoring 5 (1/5).

In the KD group, there was a significant drop in Hct from 2 h to 7 d ($P < 0.001$), whereas in P, Hct dropped from 0 h to 7 d ($P < 0.001$) (Table I), with values below the reference range (2) observed after 8 h in both groups. Total plasma protein (TPP) remained decreased at almost all intervals in both groups and, although there were some differences between each group, the concentration profile remained very similar (Table I). In relation to albumin, the groups differed from each other at basal time ($P < 0.001$) and at 48 h ($P = 0.007$), at which time there were higher values in the KD group (Table I). Total protein (TP) values were significantly decreased compared to baseline from 2 to 12 h and at 48 h in the P group ($P = 0.017$) (Table I).

Blood urea nitrogen (BUN) concentration increased significantly compared to baseline from the 0 to 8 h time point in both groups ($P < 0.001$) and was above reference values (2) for up to 12 h (Table I). Serum creatinine concentration values increased significantly in relation to reference values (2) for up to 8 h in both groups (Table I). In the KD group, serum creatinine increased significantly compared to baseline at 0 and 2 h ($P < 0.001$), while in the P group, serum creatinine increased at 0, 2, and 8 h ($P < 0.001$). Moreover, P had significantly higher values at 2 h of evaluation than the KD group ($P = 0.036$). No differences were observed between groups in relation to UO, which decreased significantly in both groups at 48 h in relation to previous intervals ($P < 0.001$) (Table I).

The blood gas analysis showed that acidosis (2) was observed for up to 2 h in both groups and pH and bicarbonate (HCO_3^-) concentrations were significantly lower than at baseline ($P < 0.001$) (Table II). The sodium concentration remained low in the KD group only before relief (0 h) ($P = 0.039$) and it remained low for up to 2 h ($P = 0.017$) in the P group. The potassium concentration increased significantly from baseline values at 0 and 2 h in both groups ($P < 0.001$). There were no statistical variations in chloride compared to baseline, although chloride increased in relation to reference values at 2 h and at 24 h in the KD group. Base excess was significantly decreased compared to baseline at 0 h and 2 h in the P group and at 0, 2, and 24 h in the KD group ($P < 0.001$). There were no statistical variations in either anion gap or partial pressure of carbon dioxide in mixed venous blood (pvCO_2) during the evaluated period and observed values were also within or very close to the reference interval for the species (2).

Discussion

Both anesthetic protocols used provided adequate conditions for manipulation during the urethral relief procedure. At the moment of bladder lavage, however, animals in the P group required an additional dose of propofol, probably due to the drug's short period of action. Propofol promotes arterial hypotension in cats as well as respiratory depression and possibly alters heart rate (13). Apnea is also frequently observed after anesthetic induction with propofol (18,19). Although these complications were not observed in this study (data not shown), they can be harmful in animals with severe systemic alterations and can also prolong the hydroelectrolytic stabilization of these animals.

There was no difference in the quality of recovery between the 2 groups. Time to standing was the evaluated parameter that varied

Table II. Results of venous blood gas and electrolyte analyses in cats with experimentally induced urethral obstruction and anesthetized with ketamine-diazepam (KD, n = 5) or propofol (P, n = 5)

Parameter	Group	Basal	Time Point					
			0 h	2 h	8 h	12 h	24 h	48 h
pH	KD	7.30 ± 0.01	7.12 ± 0.04*	7.20 ± 0.09*	7.33 ± 0.08	7.38 ± 0.02	7.37 ± 0.02	7.36 ± 0.04
	P	7.31 ± 0.01	7.16 ± 0.11*	7.24 ± 0.10*	7.34 ± 0.05	7.36 ± 0.04	7.37 ± 0.03	7.36 ± 0.03
HCO ₃ ⁻ (mmol/L)	KD	18.3 ± 1.0	11.4 ± 1.2*	13.7 ± 1.5*	17.3 ± 2.1	18.8 ± 1.7	22.2 ± 2.8*	20.0 ± 2.0
	P	18.1 ± 2.6	11.4 ± 2.7*	13.8 ± 0.7*	16.1 ± 1.5	17.5 ± 2.5	20.0 ± 2.4	18.6 ± 0.7
Na ⁺ (mEq/L)	KD	159 ± 7	151 ± 5*	153 ± 6	158 ± 6	158 ± 6	155 ± 3	156 ± 3
	P	160 ± 2	152 ± 5*	153 ± 6*	155 ± 4	155 ± 8	156 ± 4	157 ± 3
K ⁺ (mEq/L)	KD	4.0 ± 0.5	7.6 ± 1.2*	5.8 ± 1.4*	4.0 ± 0.3	3.8 ± 0.4	3.6 ± 0.3	3.9 ± 0.2
	P	3.7 ± 0.4	6.7 ± 1.0*	5.0 ± 0.9*	3.9 ± 0.3	3.9 ± 0.3	3.4 ± 0.2	3.8 ± 0.4
Cl ⁻ (mmol/L)	KD	119.6 ± 1.7	123.0 ± 6.9	125.5 ± 6.2	121.6 ± 6.0	120.8 ± 6.4	124.0 ± 4.5	122.5 ± 5.3
	P	118.2 ± 3.9	123.3 ± 6.5	120.3 ± 7.0	122.0 ± 4.9	121.5 ± 3.9	119.8 ± 4.7	120.0 ± 1.5
Base Excess	KD	-7.2 ± 0.7	-16.9 ± 1.5*	-13.3 ± 2.8*	-7.7 ± 3.1	-5.6 ± 1.7	-3.6 ± 1.4*	-5.0 ± 2.3
	P	-7.3 ± 2.0	-16.1 ± 4.1*	-12.6 ± 2.3*	-8.7 ± 1.1	-7.8 ± 1.9	-4.6 ± 1.8	-5.9 ± 1.2
p _v CO ₂ (mmHg)	KD	37.2 ± 2.6	35.7 ± 3.9	35.7 ± 4.4	33.9 ± 4.9	32.4 ± 2.9	39.4 ± 5.7	35.9 ± 6.1
	P	36.1 ± 5.9	32.1 ± 5.1	33.5 ± 7.7	30.7 ± 5.6	31.8 ± 6.9	35.7 ± 5.5	33.5 ± 2.3
Anion Gap	KD	24.7 ± 7.6	23.9 ± 11.2	19.3 ± 11.0	23.1 ± 8.9	22.2 ± 10.1	12.4 ± 5.4	17.3 ± 4.5
	P	27.0 ± 3.7	23.8 ± 9.4	26.2 ± 8.2	21.3 ± 6.2	19.9 ± 9.0	19.3 ± 7.0	21.8 ± 3.4

Data are reported as mean ± standard deviation (SD).

Reference ranges for the variables of interest in cats are as follows: pH -7.3 to 7.4; bicarbonate (HCO₃⁻) -17.3 to 24.1 mmol/L; sodium (Na⁺) -148 to 157 mEq/L; potassium (K⁺) -3.6 to 4.6 mEq/L; chloride (Cl⁻) -113 to 121 mmol/L; base excess -1 to -7; partial pressure of carbon dioxide in mixed venous blood (p_vCO₂) -33 to 43 mmHg; anion gap -13 to 27.

*Difference between each time and basal time.

the most between the groups. It is known that propofol prolongs anesthetic recovery in cats only when administered by infusion for more than 120 min (16) or when administered on consecutive days (20). Cats metabolize phenolic compounds slowly, however, as these compounds undergo glucuronidation and cats are deficient in hepatic glucuronyl transferase (21). Ketamine is often combined with benzodiazepines for induction and short-term anesthesia in cats (14,22,23), but there have been reports of undesirable behavioral effects, such as excitation, agitation, and vocalization (24). These effects were not observed in the present study, however, which makes the combination of ketamine and diazepam a safe option that is easily administered for clinical management of urethral obstruction in cats. Cats anesthetized with propofol, however, showed a shorter time to standing than cats in the KD group, which can be explained by propofol's shorter period of action.

Metabolic acidosis and hyperkalemia were observed in both groups for up to 2 h after urethral relief and were treated by infusing lactated Ringer's solution at adequate rates. Acidemia has long been recognized as the primary acid-base disturbance associated with urethral obstruction in cats and is a marker for the severity of disease (4). Intense metabolic acidosis ($\text{pH} < 7.2$) causes changes in the respiratory, cardiovascular, and central nervous systems (1). Hyperkalemia is considered to be the most common life-threatening complication in this condition (25), as it reduces the resting potential of cell membranes of the myocardium, which produces a depolarizing blockade effect and decreases electric conduction (26). As a result, muscle weakness and alteration of electric impulse propagation of cardiac cells occur (26).

Both pH and base excess decreased in the 2 groups because of an accumulation of hydrogen (H^+), lactate, and other metabolic acid waste caused by a marked decrease in the glomerular filtration rate (27). Cats in both groups had hyperchloremic metabolic acidosis at 0 and 2 h since there was no change in the anion gap. There was an increase in the serum chloride to balance the low HCO_3^- concentration (28). After relief of urethral obstruction, glomerular filtration returns and acid excretion became normal, normalizing blood pH. As lactated Ringer's solution has bicarbonate precursors, it was observed that this parameter had already stabilized at 8 h.

With the use of intensive fluid therapy, it has been reported that blood urea nitrogen (BUN) concentrations stabilize only 48 h after urethral relief (29), although in this study the BUN concentration stabilized at 24 h in both groups. It was observed, however, that creatinine stabilized faster (8 h) in cats in the KD group than in those in the P group (12 h). During induction of anesthesia with propofol, the decrease in arterial pressure in association with decreases in cardiac output and systemic vascular resistance (15) can worsen renal perfusion in cats with urethral obstruction and might prolong creatinine stabilization. Blood urea nitrogen (BUN), creatinine, phosphorus, and other osmotically active solutes accumulate due to impaired renal function. This post-renal azotemia is due to backpressure induced by the obstruction to outflow, which impairs glomerular filtration, tubular function, and renal blood flow (2). The prolonged elevation of BUN concentration reflects the decrease in glomerular filtration rate and tubular dysfunction during the post-obstructive period (4,30). In addition, sodium excretion, which is a good indicator of renal blood flow (31), remained within physi-

ological values (2) after the obstructed urethra was relieved in both groups.

To clinically stabilize the animals, fluid therapy with lactated Ringer's solution 15 min before urethral relief was chosen (32), as well as gradually reducing its infusion rate (1,32). Lactated Ringer's solution has been shown to be more efficient than 0.9% sodium chloride (NaCl) in stabilizing acid-base and electrolytes in cats with urethral obstruction (17). In addition, there is no evidence that lactated Ringer's solution increases potassium serum or impairs its stabilization in cats (17,33). Most patients treated with lactate-containing replacement solutions respond well to the acidosis treatment, probably as a result of expansion of extracellular fluid volume and improved tissue perfusion (34). The incidence of cardiotoxicity in cats with severe urethral obstruction, due to acidosis and hyperkalemia, causes vasoconstriction and negative cardiac inotropism, which can lead to fluid overload when small quantities of fluids are administered (35).

In both groups, urinary output (UO) was significantly increased at all time points evaluated, compared with the reference values for cats (1 to 2 mL/kg BW per h). This was a result of the increase in renal intratubular hydrostatic pressure (35) and post-obstructive diuresis, which is a mechanism for maintaining the electrolytic balance and increasing the excretion of metabolites retained during urethral obstruction (27). It is important to administer fluids and electrolytes to maintain renal function and hydration of the patient (8). Measuring UO is fundamental for monitoring dehydration, which can occur due to post-obstructive diuresis (32,35). Moreover, adjustment of fluid therapy and maintenance of urinary output are fundamental for adequate excretion of anesthetics.

The hallmark of post-obstructive diuresis is increased urine production, which can be caused by a combination of physiological factors (36). After urinary obstruction is resolved, glomerular filtration rate and renal blood flow are reduced (36,37). As a result, in the post-obstruction period, diuresis is secondary to impaired tubular reabsorption of glomerular filtrate (36), which can be caused by BUN osmotic diuresis, expansion of extracellular fluid volume, altered intrarenal physical factors secondary to elevated intrarenal pressure, vasopressin insensitivity, and alterations in other natriuretic factors yet to be defined (36–39).

In both groups, Hct decreased significantly at almost all time points. This was probably caused by hematuria as a result of vessels rupturing subsequent to vesical hyperdistension (35), as well as hemodilution caused by fluid therapy and the cumulative volume of blood collected for assessment. Although TP and TPP remained within physiological parameters (2), the reductions observed in both groups in relation to baseline may have been due to proteinuria, proteic catabolism (30,40), hemodilution, and blood collections.

As cats with urethral obstruction have different acid-base and biochemical disturbances, fluid therapy should be started as soon as possible, that is before anesthesia, to relieve the urethral obstruction. Some cats, however, did not allow the venipuncture required to initialize the fluid therapy even with severe clinical and metabolic disturbances. In these cases, the combination of ketamine and diazepam is quite advantageous because it can be administered intramuscularly.

Based on the results obtained in this study, both propofol and the ketamine-diazepam combination allowed adequate manipulation to initiate the procedure to relieve urethral obstruction. The acid-base and biochemical stabilization were very similar in both groups. While cats that received propofol recovered much faster, the ketamine-diazepam combination was better for use with uncooperative cats as it can be administered through IM injection, which facilitates animal restraint as venipuncture is not required.

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