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Case report

Successful resolution of acute postrenal azotemia from iatrogenic bilateral ureteral ligation in a cat managed with peritoneal dialysis

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Abstract

This report describes a neutered 1-year-old female Scottish Fold cat exhibiting oliguria, lethargy, and severe depression following ovariohysterectomy (OVH). Laboratory tests showed severe metabolic acidosis, hyperkalemia, and azotemia. Ultrasonography revealed hydronephrosis, hydroureter on both sides, and stenosis near the urinary bladder. Abdominal exploration revealed that both ureters were ligated. Iatrogenic bilateral ureteral ligation was diagnosed based on the abdominal exploration results. Peritoneal dialysis (PD) was performed immediately upon recovery from anesthesia. After three consecutive days of PD, azotemia and anuria resolved by the sixth day post-operation, and the patient was discharged the following day. After 7 months of follow-up, the patient exhibited no clinical signs or abnormal laboratory parameters indicative of azotemia. This report demonstrates that PD is a safe, effective, and easily performed procedure for resolving postrenal azotemia resulting from iatrogenic bilateral ureteral ligation in cats, which can be initiated once the patient has recovered from surgery. Furthermore, this report also describes the patient management protocol, PD drain placement method, and peritoneal dialysis protocol, all of which can be implemented in clinical practice.

Keywords: Cats, Peritoneal dialysis, Ovariohysterectomy, Ureteral ligation

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INTRODUCTION

The accurate prevalence of unilateral ureteral ligation following OVH in cats remains unknown and is likely underestimated (Aronson and Phillips, 2017). Bilateral ureteral ligation, whether accompanied by transection or not, may manifest as anuria and severe azotemia leading to acute kidney injury (AKI) and potentially life-threatening electrolyte imbalances (Berent, 2011). Surgical repair by releasing the ligature should be performed as soon as possible to restore urine flow and protect the kidneys (Adin, 2011). Treatment options include nephrostomy tube placement (Nwadike et al., 2000), ureteroneocystostomy, placement of a subcutaneous ureteral bypass device (Nwadike et al., 2000; Berent, 2011; Borchert et al., 2018) and ureteral stent. These options have been employed in various cases. Peritoneal dialysis (PD) is an effective tool for managing AKI or post-AKI in cases where hemodialysis or transplantation are not feasible (Dorval and Boysen, 2009). Numerous reports highlight successful PD corresponding in the treatment of conditions such as leptospirosis (Beckel, 2005), drug-induced AKI cases (Guimaraes et al., 2016), Russell's viper envenomation (Poppinit and SungThong, 2021), and urothorax secondary to non-traumatic uroabdomen (Donati et al., 2021). However, the utilization of PD in managing AKI resulting from iatrogenic bilateral ureter ligation in cats has not been previously reported.

To the best of our knowledge, this is the first report demonstrating successful management of AKI arising from iatrogenic bilateral ureter ligation in a cat through the implementation of peritoneal dialysis post-surgery. The present study highlights that PD is a safe and effective method for managing acute postrenal azotemia, which can be initiated once the patient has recovered from the operation.

HISTORY TAKING, CLINICAL FINDINGS, AND DIAGNOSTIC TOOLS

A 1-year-old neutered female Scottish Fold cat was brought to the emergency unit of Kasetsart University Veterinary Teaching Hospital (KUVTH), Bangkhen campus, Bangkok, Thailand with anuria, lethargy, and severe depression on the fifth day after OVH was performed at a private animal hospital. The patient, an indoor cat, had not undergone any pre-surgery laboratory examination at the first private hospital. The initial evaluation by the secondary referral hospital revealed severe hemodynamic collapse. Blood chemistry results indicated severe azotemia. The cat was promptly referred to KUVTH without receiving any treatment.

The patient exhibited clinical signs of depression, lethargy, and anorexia. Physical examinations provided details on signalment and vital signs as shown in Table 1. Hypothermia and hemodynamic collapse were identified as reasons for the delay in blood pressure measurement.

Additional investigation using abdominal ultrasonography was conducted in the dorsal recumbency position through both the ventrodorsal and ventrolateral approaches to further assess the kidneys and both ureters. Ultrasonography revealed the dilation of both renal pelvises along with hydronephrosis. However, stenosis was identified near the urinary bladder, and an inhomogeneous tissue pattern was observed above the urinary bladder in the surgical area, as shown in Figure 1. Based on these findings, iatrogenic bilateral ureteral ligation resulting from the OVH procedure was diagnosed.

Electrocardiography (ECG) results were consistent with atrial standstill accompanied by sinus bradycardia, indicated by the absence of P waves, peaked T wave, and a heart rate slower than normal, as shown in Figure 2. A cephalic venous sample was collected for hematological, biochemical, and blood gas analysis, which revealed severe metabolic acidosis, hyperkalemia, and azotemia.

The abnormal hematological and serum biochemical parameters as well as the blood gas results are presented in Tables 2-4, respectively, based on the reference ranges provided by the IDEXX VetTest Chemistry Analyzer (IDEXX Laboratories, USA).

Table 1 The signalment and vital sign in a cat with anuric acute kidney injury.

Parameter	Result
Body weight	2.7 kg
Body condition score	4/9
Mucous membrane color	Pale pink mucous
Capillary refill time	Prolonged capillary refill time
Hydration status	5% dehydration
Heart and lung sounds	Normal
Heart rate	240 bpm
Respiratory rate	26 times per minute
Temperature	96 °F

kg = kilogram; °F =; Fahrenheit.

Table 2 Results of serum biochemistry analyses in a cat with anuric acute kidney injury before peritoneal dialysis (PD; Day 0), during PD treatment (Day1-3), and after PD (Day 6, 9, 13, 21, 49, and 72).

Day	0	1	2	3	6	9	13	21	49	72	Reference range*
BUN	344	255	212	86	16	12	28	34	27	27	7-27 mg/dL
Creatinine	28.52	18.85	15.65	7.09	1.5	1.09	1.4	1.18	1.52	1.52	0.5-1.8 mg/dL
Phosphorus	20.70	17.8	N/A	9.8	5.9	5.1	2.2	3.6	N/A	N/A	2.5-6.8 mg/dL
Albumin	N/A	3.3	2.5	2.8	2.8	3.1	3	3	3.7	N/A	2.3-4 gm%
Potassium	8.78	N/A	N/A	4.36	4.36	N/A	4.69	N/A	N/A	N/A	3.5-5.8 mEq/L

*Reference ranges of serum parameters analyzed by IDEXX VetTest Chemistry Analyzer, BUN = Blood urea nitrogen; N/A = not applicable.

Table 3 Complete blood count results in a cat with anuric acute kidney injury before peritoneal dialysis (PD; Day 0), during PD therapy (Day1-3), and after PD (Day 6, 9, 13, 21, 49, and 72).

Day	0*	1	3	6	9	13	21	49	72	Reference range*
Hemoglobin	N/A	10.7	N/A	8.4	8.2	7.6	10.4	10.6	11.3	9.8-15.4gm%
Hematocrit	36.1	29.5	29.0	24.2	25.6	23.4	30.5	31.3	32.7	30-45%
RBC	N/A	8.71	N/A	7.0	6.72	6.06	7.98	9.08	10.21	5-10fL
WBC	5.03	8.46	N/A	8.92	6.58	6.75	5.75	3.0	5.3	5.5-19.5 x 103/µL
SEGS	N/A	91.0	N/A	50.0	59.0	55.5	57.0	**	51.0	2.5-12.5 103/µL
LYMPH	N/A	9.0	N/A	33.0	30.0	31.3	28.0	**	40.0	1.5-7 103/µL
RETICS	N/A	0.07	N/A	0.96	0.65	0.13	0.13	**	0.07	0-0.6%
Platelets	130	341	N/A	561	834	769	476	243	414	200-500x 103/µL
Plasma protein	6.9	8.0	6.0	7.0	7.0	7.0	6.6	7.4	7.4	5.8-7.8 gm%

* Laboratory result from secondary referral hospital; RETICS = Reticulocyte; RBC = Red blood cell; WBC = White blood cells; SEGS = Segmented neutrophils; LYMPH = Lymphocytes; N/A = not applicable; ** WBC Abnormal Scattergram.

Table 4 Blood gas and electrolytes in a cat with anuric acute kidney injury prior to stabilization before exploratory abdominal surgery.

Time since admission (hr.)	0	5	10	18	23	Reference range*
pH	7.03	7.19	7.20	7.15	7.03	7.31- 7.42
$pvCO_2$	41	29	37	41	68	32-49 mmHg
pvO_2	35	71	54	52	75	24-48 mmHg
SvO_2	38	89	79	74	86	93-100 %
HCO_3	9.3	12.6	14.8	13.8	15.2	20-29 mEq/L
BEecf	-20.0	-17.1	-13.5	-14.6	-12.8	–5 to+ 5 mmol/L
Glucose	376	204	101	98	102	80-120 mmol/L
Lactate	1.6	0.7	0.3	0.4	0.3	0.6-3 mmol/L
Na^+	125	130	134	134	135	144-160 mmol/L
K^+	9.2	9.1	9.6	10.5	9.7	3.5-5.8 mmol/L
Ca^{++}	1.04	1.05	0.98	0.94	1.07	5.0-6.0 mmol/L
tHb	8.7	8.4	8.7	9.9	8.1	12.0-18.0 g/dL

*Reference ranges analyzed by IDEXX VetStat Electrolyte and Blood Gas Analyzer, pH = positive potential of the hydrogen ions; $pvCO_2$ = venous partial pressure of carbon dioxide; PvO_2 = venous partial pressure of oxygen; SvO_2 = mixed venous oxygen saturation; BEecf = base excess in the extracellular fluid compartment. HCO_3 = Bicarbonate; and can influence the metabolic component of acid-base derangements; Na^+ = Sodium; K^+ = Potassium; Ca^{++} = Calcium; tHb = total hemoglobin.

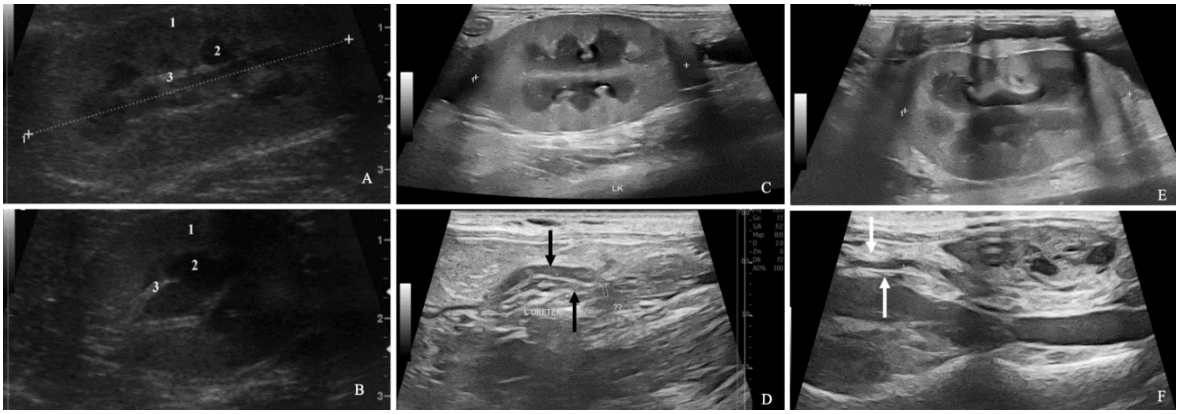

Figure 1 Sagittal (A) and transverse (B) scan of a normal kidney, showing cortex (1), medulla (2) and sinus (3), in a healthy cat, picture from Debruyn, K., 2012; Sagittal ultrasound images of the left kidney and left ureter (C and D), The black arrow indicates the location of the left ureter; right kidney and right ureter (E and F); The white arrow indicates the location of the right ureter in a cat with suspected anuric acute kidney injury (AKI) due to iatrogenic bilateral ureter ligation.

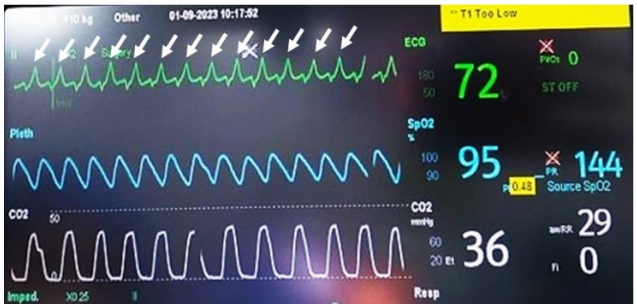

Figure 2 Lead II ECG tracing reveals bradycardia, and atrial standstill. The white arrow highlights a peaked T wave, indicate with a potassium level of 9.6 mmol/L analyzed using the IDEXX VetStat Blood Gas Analyzer.

CASE MANAGEMENT AND TREATMENT PLANNING

Initial stabilization involved the administration of sodium bicarbonate at 1/3 of the calculated dose (body weight × 0.3 × base deficit/0.892) intravenously (IV) over 30 minutes, followed by calculating 2/3 of the sodium bicarbonate volume, mixing with normal saline solution, and setting a rate of 10 ml/hour for IV constant rate infusion. Additional stabilization measures included administering 5% calcium gluconate at 1 ml/kg IV over 30 minutes, with ECG monitoring. Additionally, regular insulin at 0.1 mg/kg IV was administered to enhance potassium uptake. Repeat blood gas analysis and volume calculations for sodium bicarbonate, calcium gluconate, and regular insulin were performed every 5 hours. A urinary catheter was inserted and connected to a closed urine collection system to monitor urinary output. Pain management was initiated with injectable tramadol at 4 mg/kg IV every 8 hours. Infection was controlled with amoxicillin and clavulanic acid at 20 mg/kg IV every 8 hours. The patient was hospitalized and stabilized overnight.

ANESTHESIA PLANNING AND SURGERY

Preoxygenation and ECG monitoring were conducted, revealing a heart rate of 126 bpm with atrial standstill. The anesthesia protocol is detailed in Table 5. During exploratory laparotomy, it was discovered that the hydroureter at the distal portions of both ureters were ligated together with the uterine stump. The area around the stump of the uterus showed necrotic tissue and a blood clot resulting from iatrogenic ureteral ligation during the OVH, as shown in Figure 3. The sutures that were ligating both ureters to the uterine stump were removed. After the sutures were removed, both ureters showed mild dilation without any urine leakage.

Table 5 Anesthetic plan for a cat with anuric acute kidney injury.

Anesthetic Plan	Drug	Dose	Route
Anesthetic induction	Propofol	8 mg/kg	IV
Anesthetic maintenance	Sevoflurance	1.3-1.5%MAC (MAC=2.6)	Inhalation
Pain management	Morphine	0.2 mg/kg	IM
	Fentanyl (loading)	2 mcg/kg	IV
	Fentanyl (CRI)	10 mcg/kg/hr	IV

MAC = minimum alveolar concentration; IV = intravenous; IM = Intramuscular; CRI = constant rate infusion; mcg = microgram; kg = kilogram.

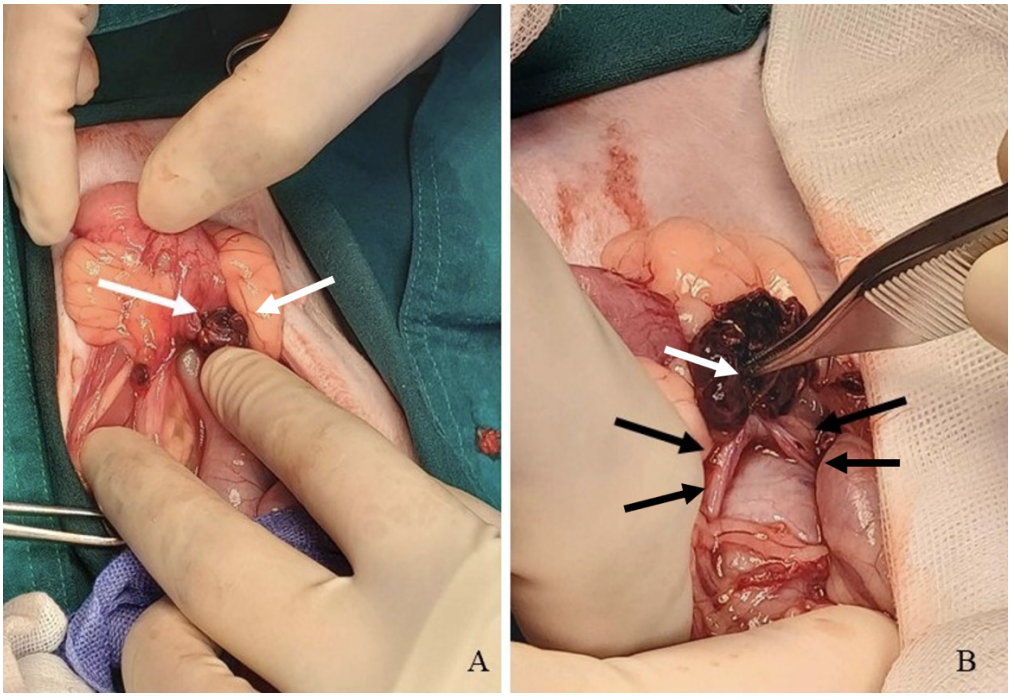

Figure 3 The surgical field displays the ureters ligated with a suture. The white arrow highlights the location of the uterine stump, with a blood clot present over it (A); The distal portions of both ureters were ligated together with the uterine stump. The black arrows indicate the location of both ureters. Additionally, the white arrow denotes the site of the suture-ligated uterine stump and both ureters (B).

PERITONEAL DIALYSIS DRAIN PLACEMENT AND PERITONEAL DIALYSIS PROTOCOL

As part of the PD procedure, an 11 Fr Blake drain (MILA International, Inc., Florence, KY, USA), shown in Figure 4, was inserted into the abdominal cavity using a paramedian approach, positioned at the level of the umbilicus. The trocar penetrated 3 cm to the right side of the midline through the rectus muscle, also positioned at the level of the umbilicus. The Blake drain was secured at the skin exit site using a purse-string suture and a Chinese finger trap suture pattern. The distal suction end of the Blake drain was placed into the caudal abdomen, and a partial omentectomy was performed. An abdominal bandage was applied to prevent migration of the Blake drain tube. The proximal end of the Blake drain was then connected to a Grenade (MILA International, Inc., Florence, KY, USA) to close the system.

Peritoneal dialysis was initiated immediately after recovery. During the first cycle, only 30 ml/kg of commercial dialysate solution containing 1.5% glucose Fresenius® (Fresenius Medical Care, Bangkok, Thailand) was filled into the peritoneum by the automatic peritoneal machine (Renolife®, Renolife, Thailand) and allowed to dwell for 30 minutes. This treatment was repeated for the first 12 hours, with the volume of dialysate infusion increasing from 30 ml/kg to 50 ml/kg in the subsequent two cycles within that timeframe.

Figure 4 11 Fr Blake drain and Grenade, Grenade connected with a Blake drain to close the system (Mila®) (A); Automatic peritoneal machine (Renolife®) (B); Peritoneal dialysis was performed after recovery using an automatic peritoneal machine (Renolife®) (C and D).

POST-OPERATIVE MANAGEMENT

After exploratory laparotomy, urine output (UOP) during the recovery room period and before peritoneal dialysis (approximately 2 hours) was 26 ml/kg/hour, decreasing to 5.4 ml/kg/hour. at 10 hours after the initiation of peritoneal dialysis. Unfortunately, the cat experienced oliguria and anuria 12 hours after peritoneal dialysis began. A bolus of 1 mg/kg of furosemide (L.B.S. Laboratory Ltd., Thailand) was administered intravenously to induce diuresis simultaneously with peritoneal dialysis. Afterward, urine output was monitored for approximately 12 hours, eventually reaching 8.6 ml/kg/hour, at which point the diuretic medication was discontinued.

Bacterial culture with antibiotic sensitivity testing and cytology of the peritoneal fluid were conducted during abdominal exploration. The bacterial culture results showed no bacterial growth, while fluid cytology revealed a non-septic exudate, as shown in Figure 5. Cefazolin was administered intraperitoneally (IP) as the last cycle of the day through the peritoneal drain (dose: 10 mg/kg with normal saline solution 5 ml) for three consecutive days. The patient was monitored for dialysate leakage, abdominal distension, respiratory rate, and other abnormalities. Since none of the mentioned complications were observed, the dialysate volume was maintained at 50 ml/kg per cycle. After three consecutive days of PD, the cat's clinical signs including sinus bradycardia, atrial standstill, and azotemia showed

improvement. Serum levels of blood urea nitrogen, creatinine, and potassium progressively improved day by day, as show in Figure 6. The Blake drain was removed on the seventh day after the operation, and the cat was discharged from the hospital. After 7 months of follow up, the patient had no clinical signs or abnormal laboratory parameters to indicate azotemia.

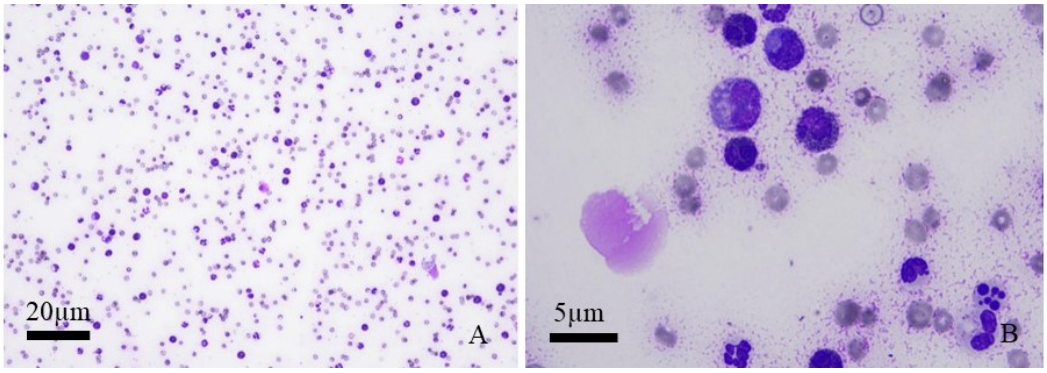

Figure 5 Effusion containing predominantly degenerated neutrophils and macrophages, with a stripped proteinaceous background throughout (A); Cytological diagnosis indicating peritoneal effusion, characterized as a non-septic exudate (B).

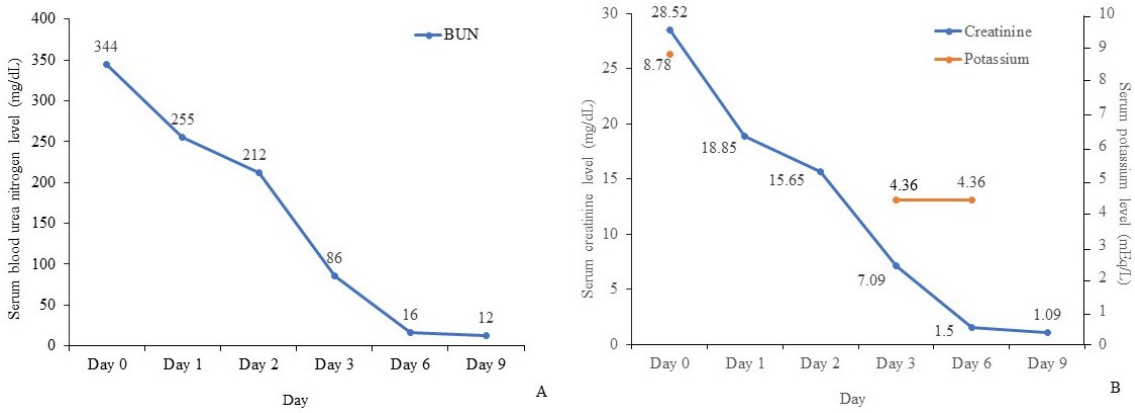

Figure 6 Cat's serum blood urea nitrogen levels monitored during hospital stay (A); Cat's serum creatinine and potassium monitored during hospital stay (B), showing a return to the normal range. Peritoneal dialysis occurred from days 1 to 3.

DISCUSSION

This case report outlines the occurrence of acute kidney injury resulting from iatrogenic bilateral ureteral ligation in a cat, successfully managed through exploratory laparotomy followed by peritoneal dialysis. Ureteral injuries stemming from OVH procedures in cats and dogs can result in significant clinical complications (Plater and Lipscomb, 2020). Factors such as limited visibility or exposure, surgical inexperience, variations in reproductive tract anatomy, and small incisions or hemorrhages during surgery may contribute to accidental ureteral injury (Adin, 2011; Fransson, 2018).

Recommendations to prevent ureteral injury during OVH include having a thorough knowledge of abdominal anatomy, emptying the bladder before surgery, extending the surgical incision, excising the falciform fat, improving visibility during surgery, seeking assistance if difficulties arise, and considering closure without

completing the OVH if uncertainty or correct anatomy identification is an issue (Hamaide, 2016).

In a previous retrospective case series of Plater and Lipscomb (2020) involving cats and dogs with ureteral injuries resulting from complications during OVH, it was found that a key indicator of ureteric injury is poor recovery in the animal or the manifestation of signs related to azotemia after OVH. Anuria is a likely outcome in animals with bilateral ureteral injuries. However, excellent outcomes are possible with appropriate surgical treatment. Although this case report also exhibited clinical signs with a median onset (on the fifth day), excellent outcomes were still achieved through exploratory laparotomy followed by PD.

The indication for peritoneal dialysis in dogs and cats is anuric AKI that is refractory to fluid therapy, particularly in cases where hemodialysis or renal transplantation are unavailable. Additionally, peritoneal dialysis may be warranted in non-anuric patients with severe acute uremia, where the BUN level exceeds 100 mg/dL or the creatinine level exceeds 10 mg/dL, or when electrolyte and acid-base disturbances cannot be managed effectively with medical therapy (Cowgill, 1995).

The swift management of AKI in cats through peritoneal dialysis likely accounts for the high success rate. This finding is more promising than historical reports on peritoneal dialysis in veterinary literature based on the study of Dorval and Boysen (2009). Hence, peritoneal dialysis remains a crucial treatment modality, potentially enhancing the survival prospects of small-sized and lightweight animals suffering from kidney failure in veterinary medicine (Bersenas, 2011; Barretti et al., 2016).

Although removing the sutures from the ligated ureters might treat the cause of azotemia, in this case factors such as the timing of treatment, the patient's blood profile, and the condition of both ureters after suture removal may affect treatment result. Waiting for renal recovery alone may result in an unpredictable recovery period of the kidneys and can put the patient at risk, such as uremic encephalopathy or arrhythmia. In this case, we therefore selected post-operative PD to enhance the excretion of nitrogenous waste and harmful electrolytes.

Procedures for peritoneal tube placement through the abdomen require well-defined guidelines to ensure the long-term functional performance of peritoneal dialysis tubing (Dupre and Coudek, 2013), These procedures can be broadly categorized into three main approaches: laparoscopic (Blitzkow et al., 2022), percutaneous (Takada and Loewen, 2021), and open surgery (Sakurada, 2019). The author also recommends open surgery, particularly in cases requiring exploration laparotomy corresponding to the study of Crabtree et al. (2019).

Complications related to peritoneal dialysis catheters include catheter obstruction, which can impede the outflow of dialysate, requiring intervention (Stringel et al., 2008; Ross and Labato, 2013; Crabtree et al., 2019). In this instance, the author performed an omentectomy (surgical removal of the omentum) to prevent omental entrapment, a condition delineated by Ross and Labato (2013), which could result in dialysate retention and subsequent complications.

Based on Dorval and Boysen (2009), PD employing the Blake drain alongside an intermittent closed suction system may contribute to reducing abdominal dialysate retention and enhance the effectiveness of PD by enabling more thorough dialysate exchanges. In a previous study conducted by Pereira et al. (2022), it was observed that the Blake drain showed fewer occurrences of dialysate retention in the abdomen and fewer instances of flow obstructions compared to the Tenckhoff catheter. The author opted for the Blake drain due to its effective and common usage in surgical practice for abdominal drainage.

The concentration of dextrose in the dialysate solutions ranged from 1.5% to 4.25%. In this case given the patient's normal hydration status, a 1.5% dialysate solution was recommended. However, for patients experiencing fluid overload or high serum osmolality, it is advisable to consider using a 2.5% or 4.25% dialysate solution, as suggested in the clinical review of Bersenas (2011).

Peritonitis is a significant infectious complication in PD patients (Tosukhowong et al., 2001). Intraperitoneal (IP) administration is preferred as it ensures maximal antibiotic concentrations in the peritoneum and the cells lining the peritoneal cavity (Varghese et al., 2012). However, well-defined guidelines for recommending IP antibiotics in veterinary medicine are lacking compared to human medicine. Based on the updated guidelines from the International Society for Peritoneal Dialysis (ISPD) in by Li et al. (2022), aminoglycosides are recommended for the treatment of gram-negative peritonitis, while cephalosporins are suggested for gram-positive peritonitis in PD patients. In this case, broad-spectrum antibiotics such as amoxicillin-clavulanate are administered intravenously to manage infections while awaiting the results of peritoneal culture. Additionally, intraperitoneal administration of cephalosporins is considered. However, it is noteworthy that both antibiotics belong to the beta-lactam class, a fact overlooked by the author. The author recommends that readers consider both the class of antibiotic and the route of administration. For instance, in this case, it may be advisable to switch to aminoglycosides, as per a previous case report of Poppinit (2021). It is noted that an intermittent dosage of gentamicin was administered intraperitoneally during the last dialysis cycle each day for managing AKI in a dog bitten by a Russell's viper, aiming to minimize systemic absorption and potential nephron toxicity.

Although suture removal from the ligated ureters might treat the cause of azotemia, in this case, considering the time before treatment, patient blood profile, and appearance of both ureters after suture removal, it is better to perform renal replacement therapy during the recovery period which is unpredictable and waiting for renal to recovery alone can put the patient at risk of uremic encephalopathy or arrhythmia. In this case, we chose postoperative peritoneal dialysis to enhance the excretion of nitrogenous waste and harmful electrolytes.

CONCLUSIONS

Iatrogenic bilateral ureteral ligation is serious complication that can occur after OVH that causes postrenal azotemia. This report has shown that PD is a method that can be performed with an unstable patient to enhance resolve azotemia and metabolic or electrolyte abnormalities caused by AKI. Additionally, PD is less expensive than hemodialysis and requires no special equipment for PD tube placement. The author encourages readers to consider PD as another method to improve management post-renal azotemia caused by iatrogenic ureter ligation after OVH and the present report also provides information for veterinarians on PD protocol management.

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AUTHOR CONTRIBUTIONS

The cat patient in this case was initially brought to P.B. for exploratory laparotomy. N.D. and N.K. assumed roles as anesthesiologists. N.D. presented the option of PD to the cat owner. T.R. conducted peritoneal dialysis, patient care, and monitoring. Subsequently, N.D. conceptualized the idea of documenting the

procedure protocol and composing the manuscript until its completion. C.T. and N.N. edited the manuscript.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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