Ultrasonographic and radiographic findings of the kidneys in six dogs and one cat with ethylene glycol intoxication

Echografische en radiografische abnormaliteiten in de nieren van zes honden en een kat met ethyleenglycolintoxicatie

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ABSTRACT

Antifreeze is the most common source of ethylene glycol poisoning in small animals, causing rapid development of acute kidney injury. Ethylene glycol intoxication has been described in the past. However, the evolution of ultrasound devices, and in particular the use of linear probes, allow a more precise evaluation of changes in the echostructure of the kidneys. In this study, the renal ultrasonographic findings were evaluated in six dogs and one cat with ethylene glycol intoxication; particularly, echogenicity changes within the medulla, and the radiographic features of the kidneys in two dogs are described. Severe cortical hyperechogenicity was present in all dogs and was associated with acoustic shadowing in one dog. Different forms of medullary echogenicity were identified with the medullary rim sign being the most common finding. In two dogs, abdominal radiographs showed a diffuse homogeneous increased opacity of both kidneys. However, none of these changes are pathognomonic for ethylene glycol poisoning. In the cat, cortical echogenicity was normal upon admission and evolved into mild hyperechogenicity. The cat did not present medullary rim sign but showed an association of severe hyperechoic outer medulla and moderate medullary band sign.

SAMENVATTING

Antivries is de meest voorkomende bron van ethyleenglycolintoxicatie bij kleine huisdieren, met als gevolg een snelle ontwikkeling van acute nierinsufficiëntie. Ethyleenglycolintoxicatie werd in het verleden reeds meermaals beschreven. De evolutie van ultrasone apparaten, en in het bijzonder het gebruik van lineaire sondes, maakt het echter mogelijk om veranderingen in de echostructuur van de nieren nauwkeuriger te evalueren. In deze studie werden de echografische bevindingen, voornamelijk veranderingen in echogeniciteit van de medulla, geëvalueerd bij zes honden en één kat met ethyleenglycolintoxicatie. Bovendien worden de radiografische veranderingen van de nieren bij twee honden beschreven. Ernstige hyperechogeniciteit van de cortex was te zien bij alle honden en was geassocieerd met een akoestische schaduw bij één hond. Bij twee honden was er tijdens het radiografisch onderzoek van het abdomen een diffuse homogene verhoogde opaciteit te zien van beide nieren. Verschillende types van afwijkende echogeniciteit van de medulla werden aangetoond met als meest voorkomende abnormaliteit een "medullary rim sign". Echter, geen enkele van deze veranderingen is pathognomonisch voor ethyleenglycolintoxicatie. De kat in deze studie werd aangeboden met een normale echogeniciteit van de cortex die naar milde hyperechogeniciteit evolueerde. De kat vertoonde geen "medullary rim sign", maar een combinatie van een ernstig hyperechogene buitenste medulla en een matig "medullary band sign".

INTRODUCTION

Ethylene glycol is an odorless and sweet-tasting, extremely toxic substance. Ingestion of antifreeze is the most common source of exposure in dogs and cats (Davy-Moyle, 2018). The main consequence of this intoxication is the rapid development of acute kidney injury, caused by the direct effects of glycolic acid on the renal tubular epithelium and the deposition of calcium oxalate crystals in the tubular lumen (De Water, 1999). In dogs, the absorption rate of ethylene glycol from the gastrointestinal tract is rapid (thirty minutes to one hour), and the plasma half-life is about 3.5 hours (Hewlett, 1989; Davy-Moyle, 2018). During intoxication with ethylene glycol, the clinical signs are variable, nonspecific and depend on the amount of ingested toxin and the time since its ingestion (Thrall, 1984; Grauer, 1984). The onset of clinical signs is described into three phases following the ingestion of ethylene glycol (Campbell, 2006; Davy-Moyle, 2018). In the first phase, occurring within several hours of ingestion, there are gastrointestinal and neurological clinical signs, such as vomiting, lethargy, paresis, ataxia and seizures. The second phase occurs twelve hours after ingestion and includes cardiopulmonary signs, such as tachypnea and tachycardia (Campbell, 2006; Davy-Moyle, 2018). The final phase of toxicosis becomes apparent by 24 hours with evidence of renal impairment with anuria or oliguria (Campbell, 2006; Davy-Moyle, 2018). Generally, if treatment is not initiated within the first eight hours, the prognosis is poor (Dial, 1994; Connally, 1996; Rollings, 2009).

Ultrasonography and radiography are non-invasive techniques used to guide the diagnosis of ethylene glycol poisoning. The two most important studies describing the ultrasonographic findings of the kidneys in dogs and cats with ethylene glycol intoxication date from more than thirty years ago (Adams, 1989; Adams, 1991b). Since then, ultrasound (US) devices have evolved and allow better image quality, especially with the use of linear probes. These more powerful devices allow to assess medullary echogenicity changes more accurately. In recent publications, differences in echogenicity have been described more precisely within different parts of the medulla, such as the medullary rim sign (MRS), the hyperechoic outer medulla (HOM) and the medullary band sign (MBS) (Biller, 1992; Forrest, 1998; Hart, 2013; Ferreira, 2020; Cordella, 2020). The MRS has been observed in previous studies on ethylene glycol intoxication in animals (Adams, 1991a; Biller, 1992), but this is not the case for the two other forms of focal echogenicity changes in the medulla. To the author's knowledge, the radiographic appearance of the kidneys in canine patients with ethylene glycol intoxication has coarsely been described (Adams, 1991b; Babski, 2012).

The aim of this study was to describe the US changes in the kidneys during ethylene glycol poisoning in dogs and cats, focusing on the medulla and to determine the radiographic features of the kidneys during ethylene glycol poisoning in dogs. It was hypothesized that MRS would be the main type of medullary abnormality which may be accompanied by other types of changes, such as HOM and MBS. Furthermore, it was supposed that severe forms of ethylene glycol poisoning may be accompanied by increased kidney opacity on abdominal radiographs due to the deposition of radioopaque calcium oxalate crystals.

MATERIALS AND METHODS

Case selection

This is a retrospective clinical case series in six dogs and one cat. Dogs and cats presented to the intensive care unit of a referral veterinary hospital (SIAMU, VetAgro Sup, Campus Vétérinaire de Lyon, France), between January 2009 and June 2020 with a diagnosis of ethylene glycol intoxication were considered for inclusion in this study. Inclusion criteria were a final diagnosis of ethylene glycol intoxication and the realization of an abdominal US. A final diagnosis of ethylene glycol intoxication was made if the animal fulfilled at least one of the following three criteria: history of ethylene glycol ingestion reported by the owners, confirmation by ethylene glycol dosage in urine and/or plasma, or histopathology by renal biopsy. Animals with other causes of acute renal failure, such as leptospirosis, or with a final diagnosis inconsistent with ethylene glycol poisoning were excluded. All medical records were retrospectively reviewed. The following clinical information was retrieved from the medical records for each case: signalment (age, sex, breed, weight), clinical signs, abdominal US findings, radiographic findings when available, treatment and outcome.

Abdominal ultrasonography

A 4–10 MHz microconvex and a 5–13 MHz linear probes (ProSound Alpha 10, Aloka, Saint Priest, France) were used between January 2009 and September 2015, for the first three cases. An 8-11 MHz microconvex and a 12-18 MHz linear probes (Aplio 500; Toshiba, American Medical Systems, Tustin, Canada) were used between November 2015 and June 2020, for the remaining four cases. All examinations were performed with the patient in dorsal or lateral recumbency. All abdominal organs were evaluated according to in-house standard operating procedures.

Kidney size was considered enlarged if the renal length was superior to 4.5 cm in cats (d'Anjou, 2015), or if the ratio of the maximal renal length to the luminal diameter of the aorta at the level of the kidney was superior to 9.1 in dogs (Mareschal, 2007). The echogenicity of the renal cortex was increased if it was similar to or greater than that of the spleen (Konde, 1984; d'Anjou, 2015) and was graded as: normal,

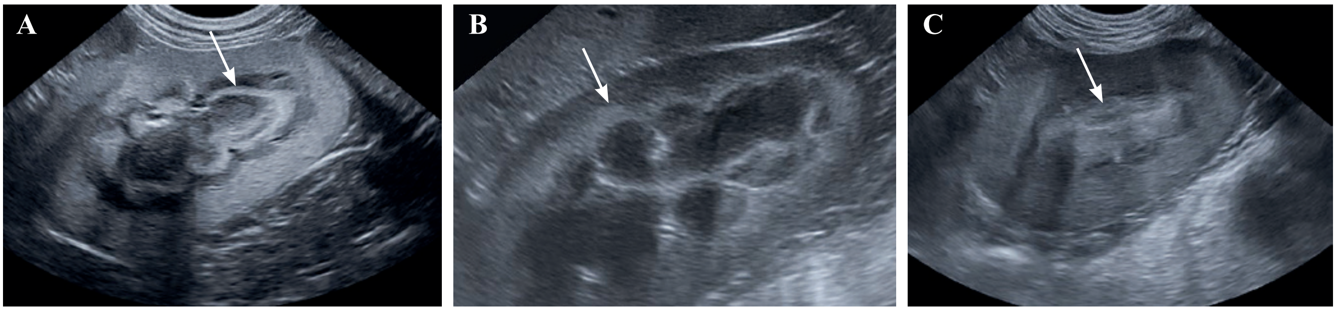

Figure 1. Three longitudinal axis images of the left kidney from three different dogs. A. Medullary rim sign (MRS) is an echogenic line in the region of the outer renal medulla that is parallel to the corticomedullary junction (arrow). B. Hyperechoic outer medulla (HOM) corresponds to the outer medulla which is hyperechoic to the renal cortex and the internal medulla (arrow). C. Medullary band sign (MBS) is seen as a separate hyperechoic band central to the renal cortex occurring within the inner medulla (arrow).

mild, moderate, severe and severe with acoustic shadowing. The thickness of the renal cortex was increased if the cortex was thicker than the medulla in longitudinal plane. The presence of hyperechoic structures in the renal parenchyma was also evaluated. The renal pelvis was considered as dilated when it exceeded 3 mm (d'Anjou, 2011). The amount of retroperitoneal effusion was assessed and subdivided into three categories (mild, moderate, or severe) as previously described (Holloway, 2007). The corticomedullary distinction was subjectively evaluated as normal, reduced or increased.

Changes in the echogenicity of the medulla may be focal or diffuse. Echogenicity of the medulla may be diffusely normal or increased, subjectively graded as mild, moderate or severe. Focal echogenicity changes in the medulla are subdivided into three subcategories: presence of a MRS, HOM or MBS (Figure 1). Each of these were subjectively classified as mild, moderate or severe. A MRS was defined as an echogenic line in the region of the outer renal medulla that is parallel to the corticomedullary junction (Biller, 1992). A HOM was identified when the outer medulla was hyperechoic to the renal cortex and the internal medulla (Hart, 2013). A MBS was defined as a separate hyperechoic band central to the renal cortex occurring within the inner medulla (Forrest, 1998).

Abdominal radiography

Abdominal radiographs were acquired using digital radiography (Trophy N800 HF, Digital Flat Panel, CCR-software Version 801120, STIM, Saint Etienne, France). Right lateral and ventrodorsal views were taken, evaluating the size and changes in kidney opacity. Kidney size was considered normal when the renal length was between 2.5 and 3.5 times the length of L2 in dogs (Finco, 1971), and between 2.4 to 3 times the length of L2 in cats (Barrett, 1972).

All static US and radiographic images were saved and archived in Digital Imaging and Communications in Medicine (DICOM) files. Static images were reviewed in a chronological order using an image analysis workstation (iMac; Apple, Cupertino, Canada) and a commercial software (Horos, Annapolis, Maryland, USA). The data were compiled into a spreadsheet (Excel 2013; Microsoft, Redmond, Washington). All descriptive data were expressed as percentages.

RESULTS

Characteristics of the study population

A summary of patient signalment, US findings, radiographic findings, treatment and outcome is presented in Table 1. Six dogs and one cat were included in this study between January 2009 and June 2020. The average age of the dogs was 2.3 years (range: six months - five years). Four dogs (67 %) were males (three intact and one neutered), two dogs (33 %) were females (one neutered and one intact). The distribution of dog breeds was as follows: 2 Border Collie, 1 Labrador, 1 American Cocker Spaniel, 1 Poodle and 1 crossbreed. All dogs were referred by a primary veterinarian. Three dogs (43%) received intravenous fluids

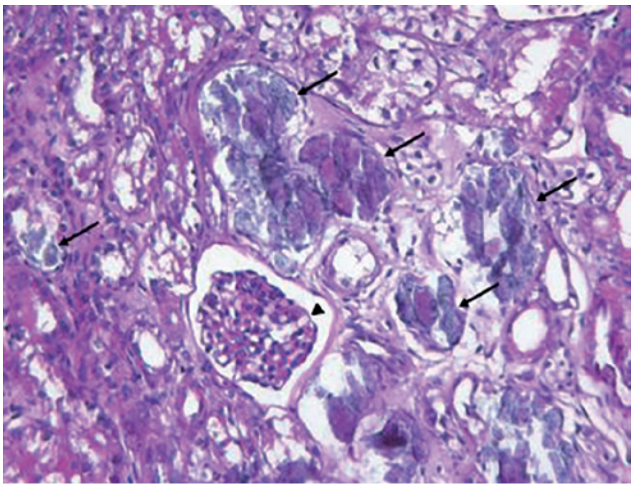

Figure 2. Histopathology of the kidney (HE, x20). The black arrows indicate massive intratubular cortical mineralization and the presence of refractive intratubular crystals. The black arrowhead shows one glomerulus.

before admission at the facility of the authors. The cat was 9.5 months old and was a neutered male. The cat was a Domestic Shorthair and was presented directly to the intensive care unit.

Clinical findings

The duration of clinical signs prior to initial presentation to the intensive care unit ranged from 24 hours to 19 days (median 4.4 days). The clinical signs at admission were characterized by acute vomiting and lethargy in all cases (n=7), anorexia (n= 4), diarrhea (n=2), polydipsia (n=2), anuria (n=3) and seizure (n=1). Physical examination revealed abnormalities in all patients, including dehydration (n=6), tachypnea (n=2), dyspnea (n=2), abdominal pain (n=1), lateral decubitus (n=2), tachycardia (n = 1), hyperthermia (n=1) and hypothermia (n=2).

Diagnosis

Final diagnosis was reached based on the history in four dogs (58 %), ethylene glycol dosage in urine and/or plasma in one dog (14 %) and the cat (14%),

Table 1. Summary of signalment, ultrasonographic findings, radiographic findings, treatment and outcome in six dogs and one cat with ethylene glycol poisoning.

Case No.	Species	Breed	Age (years)	Ultrasonographic findings	Radiographic findings	Treatment	Outcome
1	Dog	Labrador	5	Severe cortical hyperechogenicity Cortical thickening Mild generalized increase in echogenicity of the medulla Mild Medullary Rim Sign (MRS) Moderate Medullary Band Sign (MBS) Reduced corticomedullary border distinction	/	30% ethanol perfusion	Death (cardio respiratory arrest)
2	Dog	American Cocker	0.5	Severe cortical echogenicity associated with acoustic shadowing	Diffuse homogeneous and severe increased opacity of the kidneys	Hemodiafiltration	Alive
3	Dog	Crossbreed	2.5	Mild nephromegaly Severe cortical hyperechogenicity Mild generalized increase in echogenicity of the medulla Mild MRS Moderate Hyperechoic Outer Medulla (HOM) Mild retroperitoneal effusion Reduced corticomedullary border distinction	/	Hemodiafiltration	Alive
4	Dog	Poodle	0.58	Moderate cortical hyperechogenicity Mild MRS Increased corticomedullary border distinction	/	30% ethanol perfusion	Alive
5	Dog	Border Collie	1.5	Severe cortical hyperechogenicity Mild generalized increase in echogenicity of the medulla Moderate MRS Mild MBS Increased corticomedullary border distinction	/	30% ethanol perfusion Hemodiafiltration	Death (euthanasia)
6	Dog	Border Collie	3.5	Severe cortical hyperechogenicity Generalized inhomogeneous increase in echogenicity of the medulla Moderate MRS Increased corticomedullary border distinction	Diffuse homogeneous and mild increased opacity of the kidneys	Nothing	Death (at home)
7	Cat	Domestic Shorthair	0.79	Severe generalized increase in echogenicity of the medulla Severe HOM Moderate MBS Reduced corticomedullary border distinction	/	20% ethanol perfusion	Alive

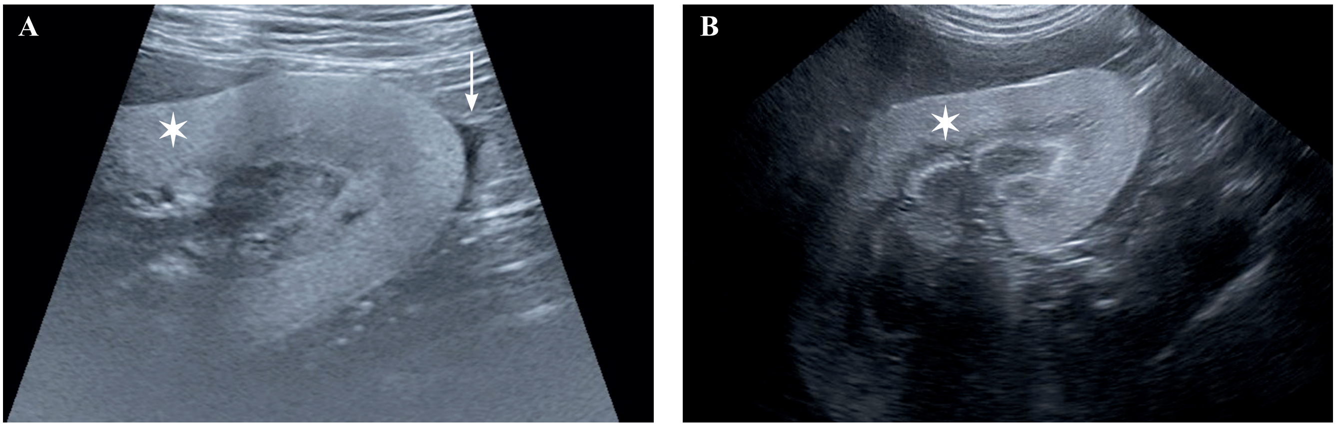

Figure 3. A. Longitudinal axis image of the left kidney with linear probe from dog 3. Note the thin layer of anechoic fluid surrounded the caudal border of the left kidney, corresponding to mild retroperitoneal effusion (arrow). B. Long axis image of the right kidney with microconvex probe from dog 6. Note the severe echogenicity of the cortex of both kidneys (stars).

and kidney biopsies in one dog (14 %). The histologic evaluation was performed by a board-certified veterinary pathologist. The histological sample revealed moderate acute multifocal tubular degeneration and necrosis associated with massive intratubular cortical mineralization and the presence of refringent intratubular crystals (Figure 2). These lesions were consistent with ethylene glycol poisoning.

Kidney US findings

Dogs

The major US findings in the six dogs are summarized in Table 2. Three dogs had an abdominal US performed at the time of admission and the remainder three dogs within 48 hours of admission. Only one dog (16.5 %) presented mild bilateral nephromegaly. Mild retroperitoneal effusion was present in one dog (16.5 %) (Figure 3). Hyperechogenicity of the cortex was present in all dogs (100%), among which 1/6 cases (16.5%) were moderate, 4/6 cases (67 %) were severe (Figure 3), and 1/6 cases (16.5%) were severe with acoustic shadowing (Figure 4). In all cases, this cortical hyperechogenicity was homogeneously diffuse. The remainder of the kidney could not be evaluated in one dog due to severe hyperechogenicity of the cortex with acoustic shadowing. Therefore, the following parameters were only evaluated for five dogs. Only one dog (20%) had thickening of the cortex. Echogenicity of the medulla was mildly and diffusely increased in 3/5 cases (60 %). A MRS was vis-

Table 2. Kidney ultrasonographic findings in six dogs with ethylene glycol poisoning.

Parameter	Number observed	Proportion (%)
Enlarged	1/6	16.5
Retroperitoneal effusion	1/6	16.5
Increased cortical echogenicity	6/6	100
Mild	0/6	0
Moderate	1/6	16.5
Severe	4/6	67
Severe with acoustic shadowing	1/6	16.5
Increased medulla echogenicity*		
Diffuse	3/5	60
Medullary Rim Sign	5/5	100
Medullary Band Sign	2/5	40
Hyperechoic Outer Medulla	1/5	20
Thickening of the renal cortex*	1/5	20
Pelvic dilation*	0/5	0
Hyperechoic structure in the parenchyma*	0/5	0
Corticomedullary border distinction modification*	5/5	100
Increased	3/5	60
Reduced	2/5	40

*Not evaluable for the dog with severe cortical echogenicity generating acousting shadowing.

ible in all dogs (100%); this was graded as mild in 3/5 cases (60%) and moderate in 2/5 cases (40%). A MBS was noted in 2/5 cases (40 %), which was classified as mild in one case and moderate in the other case. A moderate HOM was identified in 1/5 dog (20%). Two dogs had association of MRS and MBS. One dog showed association of MRS and HOM. Ultrasound follow-up was performed in one dog on day 3 and day 8 post-admission. The US changes in this dog remained stable over time.

Cat

In the cat, abdominal US was performed at the time of admission. The cat had a normal kidney size and no retroperitoneal effusion. Echogenicity of the cortex was normal at admission and evolved into mild cortical hyperechogenicity four days later. Echogenicity of the medulla was severely and diffusely increased. The cat presented association of severe HOM and moderate MBS. There were no cortical thickening, no pyelectasia and no hyperechoic structures within the parenchyma. There was a reduction of the corticomedullary border distinction.

Kidney radiographic findings

Two dogs had abdominal radiographs at their admission. They revealed a diffuse homogeneous increase in opacity of the kidneys in both cases (100%), which was mild in one case (50%) and severe in the other case (50%) (Figure 5). Radiographic follow-up was available for one dog and radiographic findings remained stable. This was the same dog that had an US follow-up. The cat did not have an abdominal radiograph.

Treatment and outcome

The following treatments were given: 20 to 30% ethanol perfusion in 4/7 patients (58%) and hemodiafiltration in 3/7 patients (42%). One dog had concomitant ethanol perfusion and hemodiafiltration. Three dogs and the cat survived. Three dogs died: one dog was euthanized due to the deterioration of his general condition and one dog died following cardiopulmonary arrest. The owner of the last dog refused treatment and the dog died at home. Necropsy was not performed in any case.

DISCUSSION

In the current study, the most common finding was severe hyperechogenicity of the renal cortex in all dogs, which is in agreement with previous studies (Adams, 1989; Adams, 1991a; Adams, 1991b; Biller, 1992; Mantis, 2000; Holloway, 2007). In one dog, the degree of echogenicity of the cortex was so severe that it was associated with an acoustic shadowing. To the author's knowledge, this severe calcification of the renal parenchyma has never been reported in the literature. In this dog, renal biopsies were performed and revealed the presence of many intratubular refracting calcium crystal deposits, which is in accordance with the imaging findings. The observation of a high amount of calcium oxalate crystals in renal histological sections is considered pathognomonic for ethylene glycol intoxication in dogs (Amoroso, 2017).

Interestingly, the abdominal radiographs available for two dogs revealed a homogeneously and diffusely increased radiopacity of both kidneys. This increase in radiopacity was mild in one dog and severe in the other dog, which was the same with severe cortical hyperechogenicity associated with acoustic shadowing. In a case report by Babski (2012), abdominal radiographs were performed in one dog with ethy-lene glycol poisoning and revealed diffuse decreased serosal detail in the retroperitoneal and peritoneal spaces, due to retroperitoneal and peritoneal effusion. In a study by Adams (1991b), abdominal radiographs were performed in one dog and revealed enlargement of the left kidney and the absence of the right kidney. Apparently, an increased kidney radiopacity secondary

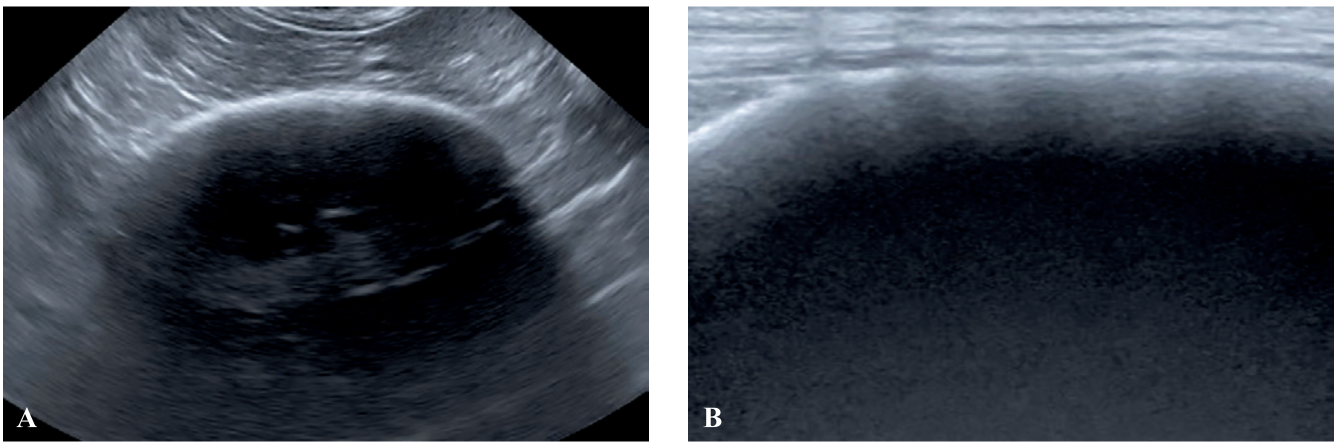

Figure 4. Longitudinal axis image of the left kidney with A. microconvex probe and B. linear probe from dog 2. Note the severe cortical echogenicity with acoustic shadowing, preventing the evaluation of other renal structures, such as the parenchyma, medulla or pyelic cavity.

to ethylene glycol intoxication in dogs has not been previously described. These radiographic changes are most likely due to the deposition of calcium oxalate crystals (Grauer, 1984; Rollings, 2009). In dogs, renal mineralization associated with acute kidney injury has been previously described by means of histopathology with vitamin D intoxication (Morrow, 2002), grapes or raisins intoxication (Morrow, 2005), the polyuric recovery phase of rhabdomyolysis-induced acute kidney injury (De Torrente, 1976; Meneghini, 1993), milk–alkali syndrome (Orwoll, 1982) and ethylene glycol poisoning (Adams, 1989; Adams, 1991b).

The only dog that had an imaging follow-up on day 3 and 8 post-admission showed no change in cortical echogenicity over time, which is in accordance with the literature. Moreover, in an older experimental study by Adams (1989), a US follow-up was available for eight to ten hours following ethylene glycol ingestion and the cortical echogenicity remained stable over time from four hours after ingestion. However, in another previous study, US follow-up was performed four days post-hospitalization and revealed a progression in the intensity of renal cortical and medullary echogenicity of both kidneys (Adams, 1991b).

In the cat however, whilst echogenicity of the cortex was normal at admission, there was an increase in cortical echogenicity on follow-up four days later, similarly found in the literature (Adams, 1991a; Adams, 1991b). The authors suggest that the kinetics of the US changes observed in the feline species may be different from those in the canine species. Thus, the absence of hyperechogenicity of the cortex in cats does not allow to exclude ethylene glycol intoxication.

In the dogs, diffuse and mild medullary hyperechogenicity was present in more than half of the cases. This is in agreement with an old study where, during experimental ethylene glycol intoxication, all dogs showed an increase in medullary echogenicity within five hours (Adams, 1989).

In this study, the MRS was the most common focal medullary change present in all dogs but was absent in the cat. The MRS has already been described in ethylene glycol intoxication and corresponds histologically to intratubular calcium oxalate crystals and mineralization of the renal tubular epithelium (Biller, 1992). MRS can also be seen as a normal variant or with a large variety of pathological renal lesions like nephrocalcinosis, hypercalcemic nephropathy, chronic interstitial nephritis, lymphoma, portosystemic shunt, acute tubular necrosis, leptospirosis or pyogranulomatous vasculitis due to FIP feline infectious peritonitis (Barr, 1987; Yeager, 1989; Biller, 1992; Mantis, 2000; Ferreira, 2020).

A MBS was the second most common change in echogenicity of the medulla and was present in two dogs and in the cat. This hyperechoic band has previously been seen in dogs with leptospirosis and represented histologically hemorrhage, congestion, edema and necrosis (Forrest, 1998). It seems to be the first time that a MBS is described with ethylene glycol intoxication. However, it is possible that this band was present in previous literature articles but has only been described as an increase in echogenicity of the medulla. This hyperechoic band in the inner medulla should not be considered specific for leptospirosis in dogs anymore. According to the authors, there seems to be some confusion in the use of the term ‘medullary band sign’. Indeed, in a recent study describing the presence of a MRS in cats and their association with renal disease, the term MBS was used and represented a thick MRS (Cordella, 2020). However, according to a study by Forrest (1998), the MBS represents a hyperechoic band in the center of the medulla.

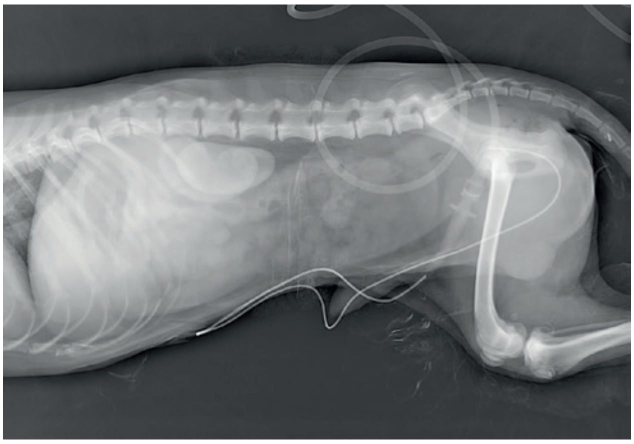

Figure 5. Right lateral abdominal radiographs from dog 2. Note the diffuse homogeneous and severe increased opacity of the kidneys of mineral type. Also note the urinary catheter superimposed on the radiograph.

The HOM was present in only one dog and the cat. In dogs without renal dysfunction, the HOM can be seen as a non-pathologic finding (Hart, 2013). It is histologically normal and seems to correspond more to a band relative to the cortex, rather than a zone of increased medullary echogenicity (Hart, 2013). Differences in the vascular anatomy between the cortex and the HOM should be considered as a priority (Hart, 2013). The main hypothesis is the presence of vascular bundles which would be responsible for the differences in acoustic impedance, at the origin of the HOM (Pallone, 1998). More studies about histologic changes in animals with this US finding will be necessary, in particular in animals with renal pathology. In a previous study on healthy dogs with HOM, it has been shown that small breeds and young dogs are overrepresented (Hart, 2013). In the present study, the only dog with HOM was a 47-kg crossbreed of 2.5 years. Maybe, it was an incidental finding but histological analyses would have been helpful. Unfortunately, no histopathological analysis could be carried out in this dog. Furthermore, this HOM was present bilaterally, like it has been previously described (Hart, 2013). A severe HOM was present in the cat and has previously been described as an increased echogenicity in the outer medulla in cats with ethylene glycol toxicity (Griffin, 2020). In cats, similar changes in echogenicity of the kidneys are possible with ingestion of the Easter Lily plant (Griffin, 2020).

It was interesting to see the association of several changes in medullary echogenicity. Two dogs presented association of MRS and MBS. These two dogs died and did not have renal biopsy. One dog had association of MRS and HOM. This dog survived; unfortunately, renal biopsy was not performed neither. Histological sections would have made it possible to distinguish whether these lesions were incidental or pathological findings. The cat presented association of MBS and HOM and survived.

The 'halo sign' has been previously described in ethylene glycol intoxication and is defined as a marked increase in cortical and medullary echogenicity with hypoechoic areas in the corticomedullary and central medullary regions (Adams, 1989). This thin hypoechoic zone seems to be the normal appearing medulla between the cortex and the MRS (Wood, 1990).

There are several limitations due to the retrospective nature and small sample size of the present study. The main reason for the small number of cases is the rare occurrence of ethylene glycol intoxication in dogs and cats. Additionally, it would have been ideal to have repeated abdominal US on all patients in the study to document the evolution of abnormalities previously identified. An US follow-up was only available for one dog and the cat.

In conclusion, none of the US changes cited in this study are pathognomonic for ethylene glycol poisoning, but the combination of US and radiographic abnormalities is suggestive. However, the presence of a marked hyperechogenicity of the entire renal cortex generating acoustic shadow on US and a generalized increase in the opacity of the kidneys on radiography should lead to primarily evoke this medical condition.

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