TITLE: ULTRASONOGRAPHIC IDENTIFICATION OF THE DORSAL ATLANTOAXIAL LIGAMENT IN DOGS

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Ultrasonographic identification of the dorsal atlantoaxial ligament in dogs

ABSTRACT

OBJECTIVE: The purpose of this study was to evaluate if ultrasonography is a feasible tool to identify the dorsal atlantoaxial ligament in dogs.

STUDY DESIGN: Canine cadaveric study.

SAMPLE POPULATION: Canine cervical spines (n=35)

METHODS: Thirty-five canine cadavers with an estimated body weight of 6-35kg were retrieved. Three cervical spines were dissected to demonstrate the dorsal aspect of the atlantoaxial joint and assess the length and thickness of the dorsal atlantoaxial ligament. Thirty cadavers were used for the ultrasonographic evaluation of the dorsal atlantoaxial ligament and a subjective score (0-3) was assigned to each dog depending on the visibility of the dorsal atlantoaxial ligament in both the transverse and the sagittal planes.

RESULTS: The dorsal atlantoaxial ligament was detectable on ultrasound in all cadavers: 27/30 and 28/30 were graded as moderately visible (grade 2) or clearly visible (grade 3) in the sagittal and transverse view respectively. Only 1/30 cadaver specimen of a large breed dog was graded as 1 (indistinct) in both the sagittal and transverse planes. None of the cadavers were graded as 0 (not visible) in any view.

CONCLUSIONS: Ultrasonographic identification of the dorsal atlantoaxial ligament is a feasible technique in normal canine cadavers. Future studies on patients clinically affected from atlantoaxial instability/subluxation need to be done to evaluate the role of this diagnostic tool in a safer diagnosis of this condition.

CLINICAL RELEVANCE: Identification of the dorsal atlantoaxial ligament through ultrasonography could potentially diagnose patients with atlantoaxial instability/subluxation using a non-invasive and safe diagnostic imaging technique.

INTRODUCTION

Atlantoaxial instability is a common condition of the cervical spine which can result in subluxation of the axis in relation to the atlas and subsequent spinal cord compression[1,2,3,]. Atlantoaxial instability/subluxation is a potentially life-threatening condition[4]. Patients with this condition develop clinical signs at a young age, with 52-70% of patients being less than 1 year old[5]. Clinical signs vary from neck pain and mild ataxia in 24.9% of cases to tetraplegia in 6.5% of cases[1].

Atlantoaxial subluxation has been reported in 38 breeds of dogs, being most common in Yorkshire terriers (28%), Toy Poodles (18%) and Chihuahuas (15% of cases)[6]. Congenital atlantoaxial subluxation is most commonly seen in small and toy breed dogs, but can also be seen in medium and large breed dogs[7,8,9,10,11,12]. These animals with atlantoaxial congenital abnormalities will have atlantoaxial subluxation either spontaneously or with minimal trauma[13]. Traumatic atlantoaxial subluxation can occur in any breed of dog[2] with one of the possible causes being traumatic rupture of the atlantoaxial ligaments during a forceful overflexion of the neck[2].

Diagnosis of atlantoaxial subluxation is based on clinical evaluation of the patient, and is confirmed by various imaging techniques (plain radiographs, CT or MRI). One of the simplest methods is identifying an increased space between the dorsal lamina of the atlas and the spinous process of the axis[2,5] on plain radiographs, which indirectly demonstrates the dorsal atlantoaxial ligament. Flexed cervical radiographs can be done in those cases where the increase space cannot be detected on neutral position[5], but this should be done with extreme care as it could lead to further compression of the spinal cord[2] and deterioration in the clinical status of the patient. Although myelography can been used to diagnose atlantoaxial subluxation, this technique is no longer recommended due to the risks associated to myelograms and the accessibility to other diagnostic techniques[1]. Advanced diagnostic techniques such as MRI and CT can provide additional information regarding spinal cord injury[14] and osseous abnormalities[15] in the atlantoaxial joint, being also useful for surgical planning[1]. However these techniques are expensive and have disadvantages such as requiring a long anaesthetic period (MRI) or exposing the patient to an increased radiation dose (CT). In contrast to these techniques, ultrasonography is a fast, safe and relatively inexpensive technique. Ultrasonography has been used to assess the craniocervical junction in animals with Chiari-like malformation and syngomyelia[5, 16, 17] and intracranial arachnoid cysts[18]. Ultrasonography has also been used to evaluate the musculoskeletal anatomy of the dorsal cervical spine[19]. However, information regarding the use of ultrasonography to assess atlantoaxial ligaments is lacking.

The dorsal atlantoaxial ligament courses from the dorsal lamina of the atlas to the most cranioventral aspect of the spinous process of the axis, and this thick dorsal atlantoaxial ligament contributes to the stability of the atlantoaxial joint[20]. As this is the exact location where the increase in intervertebral space is seen radiographically in those patients with atlantoaxial subluxation, it has been suggested that the increase in space is allowed by the stretching or the rupture of the dorsal atlantoaxial ligament[2, 20, 21].

The objective of this study was to evaluate if ultrasonography was a feasible tool to identify and evaluate the integrity of the dorsal atlantoaxial ligament. Based on the relative small size of the ligament and its anatomical location we hypothesised that the dorsal atlantoaxial ligament would not be detectable on ultrasonography.

MATERIALS AND METHODS

Ethical approval for the study was obtained from the authors' institution. Thirty five adult canine cadavers of dogs euthanized for reasons unrelated to this study were used. The cadavers had been initially frozen for several days and were allowed to thaw at room temperature prior to our study. Initially 3 cadavers were dissected to demonstrate the dorsal aspect of the cervical spine and assess the length and thickness of the dorsal atlantoaxial ligament (Figure 1), and to subjectively determine if it would be of sufficient size and in an adequate location to be detected by ultrasonography. A further two cadavers were used to correlate the ultrasonographic findings with the anatomy of each specimen. Ultrasound guided injection of ink into the suspected dorsal atlantoaxial ligament was followed by dissection of these 2 cadavers. Thirty adult canine cadavers were then collected and used for the ultrasonographic evaluation of the dorsal atlantoaxial ligament. The cadavers were positioned in lateral recumbency and the dorsal cervical area was clipped at the level of the atlantoaxial joint. The skin was cleaned with spirit and gel was applied.

Ultrasonography was carried out using an 8 MHz microconvex transducer, with the cadavers positioned in right lateral recumbency with a neutral or slightly flexed cervical position. The transducer was placed on the dorsal aspect of the neck caudal to the occipital crest, and the cranial aspect of the spinous process of C2 was identified. The transducer was placed in a transverse plane to identify the spinous process of C2 and then moved cranially to identify the dorsal atlantoaxial ligament as a thin hyperechoic structure with linear striations running in a cranioventral direction from the cranial tip of the spinous process of C2 to the dorsocaudal aspect of the dorsal lamina of C1. Once the ligament had been identified it was also scanned in a straight sagittal plane (Figures 2 and 3). All the ultrasonographic studies were performed by a board-certified specialist in diagnostic imaging. A subjective score (0-3) was assigned to each dog depending on the detectability of the dorsal atlantoaxial ligament and its differentiation from surrounding structures in both the transverse and the sagittal plane. This grading score was similar to the classification used in previous cadaveric studies[22]. Those cadavers in which the dorsal atlantoaxial ligament was clearly identified based on the expected location, fibre orientation and fibre echogenicity were assigned a grade 3, if it was moderately visible they were assigned a grade 2, if the margins of the ligament were indistinct but an hypoechogenic band could be identified in the expected location of the ligament they were assigned a grade 1 and they were assigned a grade 0 when the fibres of the dorsal atlantoaxial ligament were not discernible at ultrasonographic evaluation.

RESULTS

Anatomical dissection of the two cadavers in which coloured ink was injected (ultrasound guided) in the ligament showed the presence of the injected ink in close association with the dorsal atlantoaxial ligament (with some leakage from the ligament suspected), confirming the accuracy of the ultrasonographic findings.

All the cadavers were mature adult dogs, but the exact age was unknown. The majority of dogs were crossbreed dogs, while there were 3 German shepherd, 1 Labrador, 1 Rottweiler, 1 Rough Collie and 1 Husky. The estimated weight of the dogs ranged between 6 and 35kg. Dogs were classified as small (estimated body weight <10kg), medium (estimated body weight 10-25 kg) or large (body weight>25kg). In total 19 cadavers were large breed dogs, 10 cadavers were medium size dogs and 1 cadaver was a small breed dog. Table 1 summarizes the results.

Of the 19 large size cadavers 10 were graded as 3 either in the sagittal, in the transverse or in both planes. Eight of the other large breed cadavers were graded as 2 either in the sagittal, in the transverse or in both planes, while 1 cadaver was graded as 1 in both the sagittal and the transverse plane. None of the large size cadavers were graded as 0 in any of the planes.

Of the 10 medium size cadavers 5 were graded as 3 either in the sagittal, in the transverse or in both planes and 5 were graded as 2 in either in the sagittal, in the transverse or in both planes. None of the medium size cadavers were graded as 0 or 1 in any of the planes.

Finally, the only small size cadaver was graded as 3 in both the sagittal and the transverse plane.

DISCUSSION

Results from our study show that ultrasonography is a useful diagnostic tool to identify the dorsal atlantoaxial ligament in normal canine cadavers, and the ligament was detectable in all cadavers.

In our study none of the cadavers were graded as 0 (not visible) in any view and 27/30 and 28/30 were graded as moderately visible (grade 2) or clearly visible (grade 3) in the sagittal and transverse view respectively. Only 1 cadaver specimen of a large breed dog (Husky) was graded as 1 (indistinct) in both the sagittal and transverse plane, while in the other 3 dogs (all large size) in which the identification of the ligament was graded as 1 in one view it was graded as 2 in the other view. Therefore, 29/30 specimens were graded at least 2 in one ultrasonographic view and 16/30 had at least one view graded as 3, with 7/30 being graded 3 in both views, 10/30 being graded 2 in both sagittal and transverse views and 9/30 being graded 2 in one view and 3 in the other view. Interestingly, none of the medium size dogs was graded as 1 in any of the 2 ultrasonographic views, and the only small breed cadaver was graded as 3 in both views. These results suggest that visualization of the ligament might be clearer in smaller breeds. The reason for this finding is not clear from this study, but the authors hypothesise that this could be due to a proportionally smaller muscle mass surrounding the ligament in smaller breeds compared to large breeds, particularly those larger dogs with a bull terrier type conformation. Many of the larger-breed cadavers in this study did have a fairly broad skull conformation, so there may be a degree of bias due to this. An alternative hypothesis would be a proportionally larger dorsal atlantoaxial ligament in smaller breeds allowing proportionally clearer visualisation. As atlantoaxial subluxation is a condition commonly diagnosed in small breed dogs, in which there is typically a congenital origin, further studies will need to determine the feasibility of this technique in small breed dogs. Most of the breeds in this study were medium or large breed dogs, and therefore this study shows that ultrasonography could be a useful diagnostic tool for these breed of dogs, in which the congenital form of atlantoaxial instability/subluxation is less common and are more likely to have the traumatic presentation of atlantoaxial subluxation.

In order to ultrasonographically identify and assess the echogenicity of a ligament it is necessary to maintain the ultrasound beam perpendicular to the ligament[23, 24]. In our study the acoustic window was considered small due to the large size of the spinous process of the axis, and therefore it is possible that the amount of ligament identified did not represent the full extent of the dorsal atlantoaxial ligament. On the other hand, the ultrasonographic evaluation was done with the neck in neutral position or slightly flexed, and it is likely that identification of the dorsal atlantoaxial ligament would have been better if the neck was in a flexed position, as there would be less overlapping of the spinous process of the axis over the atlas. However, the authors decided to do the ultrasonographic evaluation of the dorsal atlantoaxial ligament in neutral or slightly flexed positions as these would be the more clinically relevant positions, avoiding the risk of flexing the neck in clinically affected patients. An 8-10Mhz linear array transducer was briefly used to try to identify the ligament at the beginning of the study, but the clarity of the resulting images of the ligament was poor, with the microconvex array performing noticeably better, and hence this type of transducer was used. The authors suspect that this is due to the conformation of the spinous process of the axis resulting in the ligament being partially masked by the acoustic shadow from the process, and the footprint of the linear array preventing easy angulation to improve image quality due to the surrounding musculature. The fan-shaped image generated by the microconvex array, coupled with the smaller footprint, allowed a clear image of the ligament to be obtained. As the transducer was positioned in a straight sagittal position, further studies will be required to assess if positioning the transducer in a parasagittal position to obtain oblique views of the dorsal atlantoaxial ligament improves its assessment in dogs.

Five specimens were used to assess the feasibility of this technique. Three specimens were used for anatomical dissection to subjectively assess the dimensions and exact location of the dorsal atlantoaxial ligament. Two further specimens had coloured ink injected into the dorsal atlantoaxial ligament under ultrasound guidance followed by anatomical dissection. Although the total number of cadavers used for these assessments was relatively small, the authors considered that the findings in the cadavers were very consistent regarding the subjective dimensions and position of the dorsal atlantoaxial ligament. The location of the coloured ink in the ligament was very accurate in the 2 cadavers used for this purpose, confirming that the ultrasonographic identification of the dorsal atlantoaxial ligament was correct. Even though only 2 cadavers were used for this purpose, the authors considered this number sufficient due the accuracy found in the ultrasound guided ink injection when dissecting both cadavers and the characteristic ultrasonographic images found at the expected anatomical location of the dorsal atlantoaxial ligament.

The authors acknowledge several limitations to this study. First, we did not perform anatomic dissection of the dorsal atlantoaxial ligament of all the cadaveric specimens because the purpose of the study was only to determine whether ultrasound imaging can depict the dorsal atlantoaxial ligament. We therefore acknowledge that although the breeds of the cadavers were not breeds predisposed to atlantoaxial instability/subluxation it is possible that some of the cadavers did actually have abnormalities in the dorsal atlantoaxial ligament. Secondly, the study was performed on previously frozen cadavers and to the authors knowledge there are no studies assessing the influence of the process of freezing/thawing cadavers on the ultrasonographic image of a ligament. Therefore it is possible that this could have affected the ability of the operator to identify the dorsal atlantoaxial ligament. Finally, no attempts were made to perform measurements in the ultrasonographic images and correlate them to anatomic dissections as the purpose of the study was to assess if identification of the dorsal atlantoaxial ligament was possible. The authors performed the study trying to mimic the clinical scenario and only allowing a mild flexion of the neck of the cadavers. In order to measure the full extent of the ligament the dorsal atlantoaxial ligament would have need to be taut by fully flexing the head, which would invalidate the potential benefits of this technique compared with traditional plain radiographs in the diagnosis of atlantoaxial subluxation/instability.

In conclusion, this study demonstrates that ultrasonographic identification of the dorsal atlantoaxial ligament is a feasible technique in normal canine cadavers weighing more than 6 kg. Therefore, identification of the dorsal atlantoaxial ligament through ultrasonography could potentially diagnose patients with atlantoaxial instability/subluxation using a non-invasive and safe diagnostic imaging technique. This technique has the advantage over conventional radiographs that it can be performed with the neck at a neutral or slightly flexed position. Further studies are needed to assess the feasibility to identify the dorsal atlantoaxial ligament in live and numerous small breed dogs and correlate the findings with patients clinically affected by atlantoaxial instability/subluxation.

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DISCLOSURE

The authors declare no conflicts of interest related to this paper.

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FIGURE AND TABLE LEGENDS

Figure 1: Anatomic dissection of the dorsal aspect of the atlantoaxial joint showing the anatomic location of the dorsal atlantoaxial ligament (star)

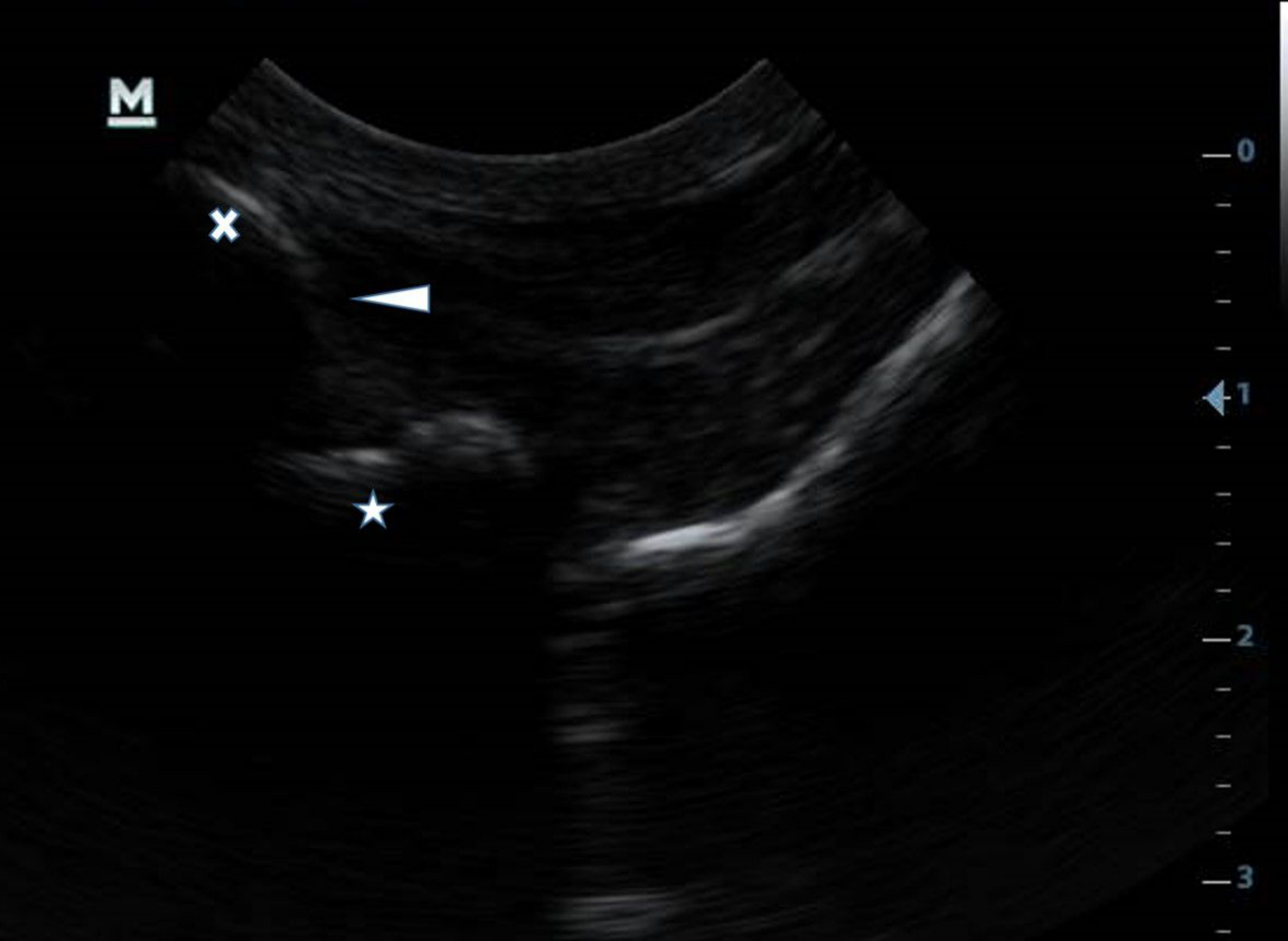
Figure 2: Ultrasonographic sagittal image of the dorsal aspect of the atlantoaxial joint showing the cranial aspect of the spinous process of the axis (x), the dorsal atlantoaxial ligament (arrowhead) and the dorsal arch of the atlas (star)

Figure 3: Ultrasonographic transverse image of the dorsal aspect of the atlantoaxial joint showing the spinous process of the axis (x), the dorsal atlantoaxial ligament (arrowhead) and the dorsal arch of the atlas (star)

Table 1: Assigned grades in the sagittal and transverse ultrasonographic views according to the size of the cadavers.

TABLE 1

	Assigned grade							
	Clearly visible (3)		Moderately visible (2)		Indistinct (1)		Not visible (0)	
	Sagittal	Transverse	Sagittal	Transverse	Sagittal	Transverse	Sagittal	Transverse
Large breed (n=19)	8	6	8	11	3	2	0	0
Medium breed (n=10)	4	3	6	7	0	0	0	0
Small breed (n=1)	1	1	0	0	0	0	0	0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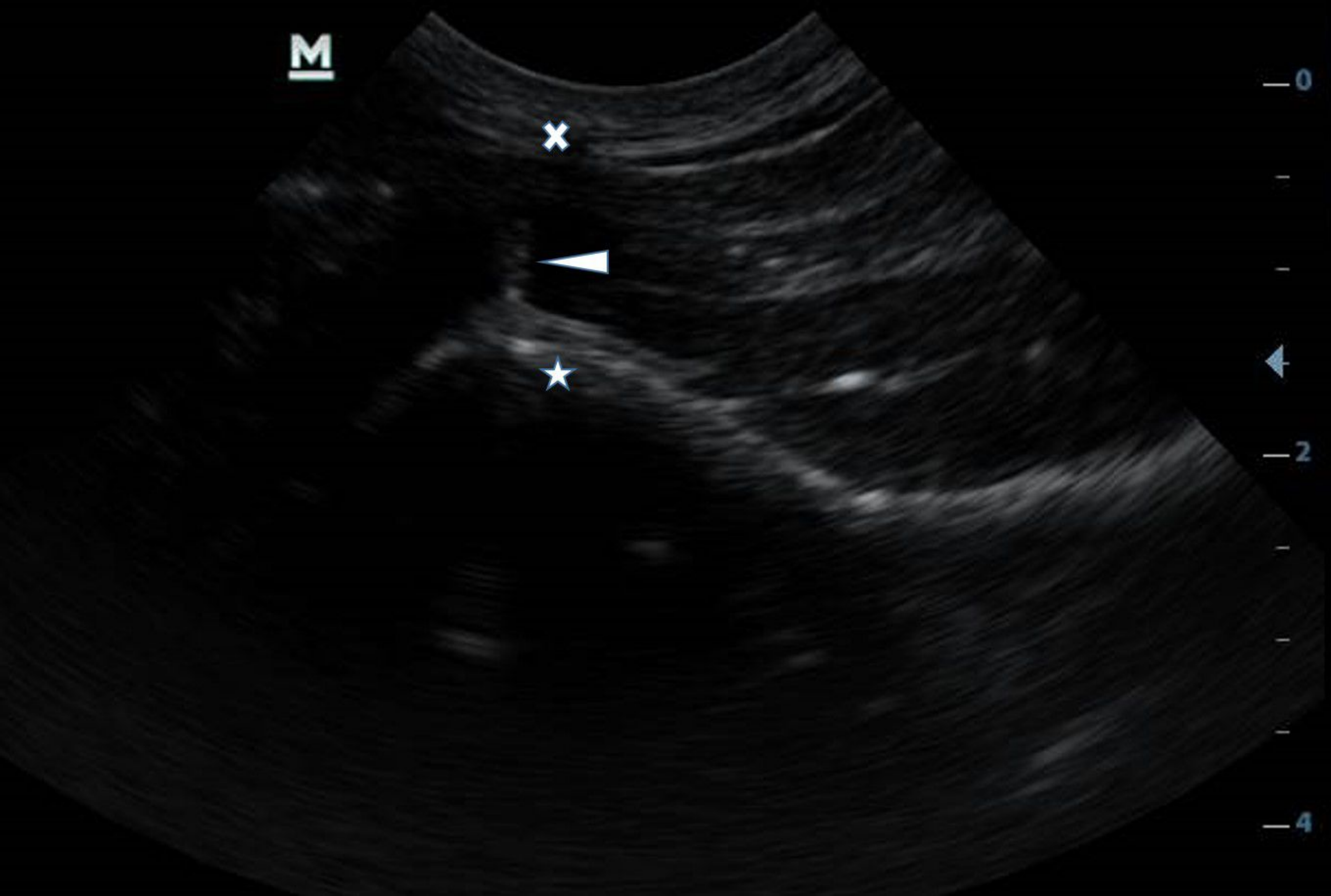
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