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Excretory urography can track down morphological changes in the urinary bladder associated with urachal anomalies in calves for early diagnosis

Kazutaka Yamada, DVM, PhD*; Itsuki Morita; Kei Kazama, DVM, PhD; Naoyuki Aihara, DVM, PhD; Kaoru Hori, DVM, PhD; Taro Kondo, DVM, PhD; Kazuhiro Kawai, DVM, PhD; Ken Onda, DVM, PhD

School of Veterinary Medicine, Azabu University, Sagamihara, Japan

*Corresponding author: Dr. Yamada (kyamada@azabu-u.ac.jp)

OBJECTIVE
To investigate radiographic detection by excretory urography of morphological changes in the urinary bladder associated with urachal anomalies in calves.

METHODS
Excretory urography was performed to detect morphological changes in the urinary bladder of 13 calves, of which 6 were nondysuric with swelling of umbilical region and 7 were dysuric without clinical umbilical swelling from November 2022 through April 2024.

RESULTS
The urinary bladder was delineated in all 13 calves after excretory urography. The aspect ratios (length:height), which objectively evaluate the shape of the urinary bladder, ranged from 1.08 to 2.43 (1.90 in average) and 1.34 to 11.89 (4.75 in average) in nondysuric and dysuric calves, respectively. The ratios of calves with nondysuric were significantly lower than those of dysuric ($P < .05$).

CONCLUSIONS
Excretory urography could play an important role in evaluating abnormal morphological changes due to urachus anomalies in the urinary bladder of calves.

CLINICAL RELEVANCE
Among calves with dysuria, urachal anomaly should be included in the differential diagnosis. Excretory urography is proposed as an alternative option for early diagnosis among calves presenting with dysuria to improve livestock productivity.

Keywords: calves, contrast agent, excretory urography, umbilicus, urachal anomaly

The urachus acts as a communication channel between the umbilicus and urinary bladder during fetal development. After the rupture of the umbilical cord during birth, the 2 umbilical arteries retract actively, and the urachus is pulled back passively by these vessels into the abdomen. Smooth-muscle contraction triggers luminal closure, with the umbilical arteries ultimately becoming the lateral ligaments of the urinary bladder.[1] However, inflammation before umbilical closure can cause incomplete closure of the umbilicus, which can lead to omphalitis, omphalophlebitis, umbilical arteritis, pyourachus, urachal diverticula, or persistent urachus. Omphalophlebitis occasionally leads to umbilical vein abscess or liver abscess,[2–4] whereas umbilical arteritis and pyourachus occasionally cause pyocystitis, which may ascend upstream to affect the kidneys, which can lead to poor prognosis.[5] In addition, inflammation of structures caudal to the umbilicus is often accompanied by adhesions of the abdominal wall, digestive tract, or urinary bladder. Adherence of the urachus structure to the bladder can promote contractile dysfunction of the urinary bladder, which results in dysuria.[6] Furthermore, this dysfunction may promote retention of urine in the bladder, which may also lead to cystitis. In the worst scenario, inflammation can spread systemically, causing multiple arthritis,[6] discospondylitis,[7] meningitis,[6]

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and sepsis.[8] Although omphalitis may seem trivial, it should never be underestimated. Thus, this study aimed to investigate a procedure for the detection of morphological changes in the urinary bladder associated with urachal anomalies in calves.

Methods

Calves

This study investigated 13 calves referred to the Large Animal Veterinary Education Center at Azabu University, Sagamihara, Japan, from November 2022 through April 2024, 6 of which were nondysuric with signs of swelling in the umbilical region, and 7 were dysuric as evidenced by intermittent urination, frequent urination with low urine volume, prolonged urination, inability to urinate after raising their tails, or inability to urinate after curving back posture. In this study, calves nondysuric with umbilical swelling were also investigated. During the clinical course, an abdominal ultrasound (MyLabOneVet; Esaote SpA) with 1 to 5 MHz variable convex probe was performed on 8 calves. All of the procedures were conducted in accordance with the clinical guidelines of Azabu University and were approved by the IACUC (230327-2).

Radiography

Plain radiographs and excretory urograms were obtained using an X-ray unit (MRAD-A80S; Canon) and a digital radiography system (AeroDR fine; KONICA MINOLTA). Imaging technique was 100 kV, 100 mA, 0.05 seconds in plain and excretory urography. The obtained images were read using a viewer (OsiriX-N; Newton-Graphics).

Excretory urography was conducted with the calves in a standing position without sedation. Images were obtained before and 5, 10, and 15 minutes after IV administration of a contrast agent (Iopamidol, 370 mgI/mL; Fuji Pharma) via a 16-gauge indwelling catheter in the jugular vein. Calves weighing ≥ 50 kg received 200-mL doses, whereas those weighing < 50 kg received 100-mL doses.

Maximum longitudinal length and maximum transverse length perpendicular to the longitudinal lines on the contrasted urinary bladder were measured using a viewer to objectively evaluate the shape of the urinary bladder. Subsequently, the aspect ratios were calculated by dividing the longitudinal length by the transvers length. The aspect ratio became high when the adhesive urinary bladder was pulled and tension was applied, whereas the shape was close to circular with a low aspect ratio when no tension is applied **(Supplementary Figure S1)**.

Statistical analysis

Statistical analysis was performed using Excel with add-in software that allowed running a *t* test (Microsoft Corp). Aspect ratios for calves with and without dysuria, as well as those before and after surgery, were compared using the unpaired and paired Student *t* test, respectively, with a P value of $< .05$ indicating significance.

Results

All 13 calves included herein weighed between 32 and 157 kg. Moreover, the urinary bladder was delineated in all 13 calves, none of which exhibited deterioration of their general condition after excretory urography. Calves' description, ultrasonographic finding, excretory urography findings, and the aspect ratios of the urinary bladder are summarized in **Supplementary Table S1**.

Two calves in which excretory urography were particularly useful are described in the following paragraphs.

Case 1 suffered from growth insufficiency and had a shortened mandibular. This calf had a history of omphalitis but showed no dysuria at admission. No abnormality was detected in ultrasound examination. Though the urinary bladder was not depicted in plain radiographs, excretory urography

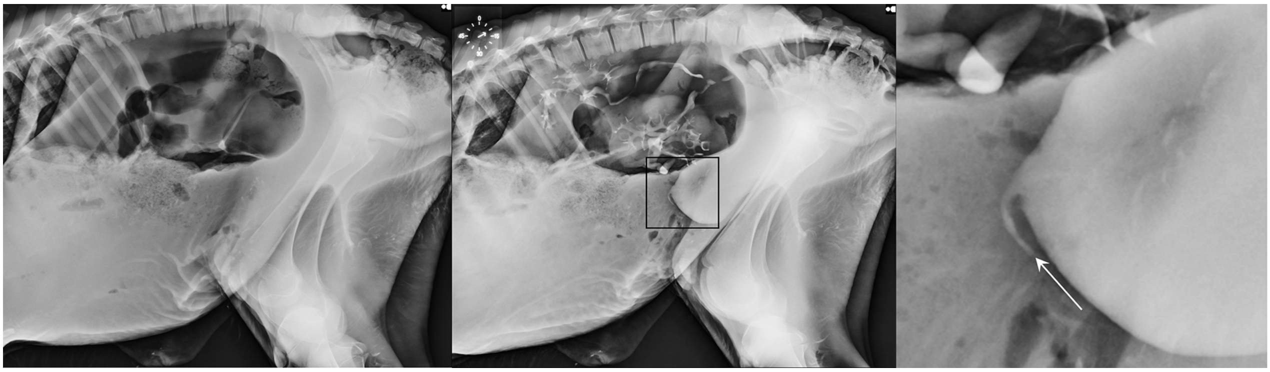

Figure 1—Plain radiograph (left), excretory urogram (center), and magnified image (right) of calf 1 with umbilical swelling, growth insufficiency, and shortened mandibular without dysuria performed 10 minutes after contrast agent injection. Left and right kidneys, ureters, urinary bladder, and urachal diverticulum (arrow) were depicted in the urogram. The size of the kidneys and ureters were normal. Data collection of excretory urography was performed from November 2022 through April 2024.

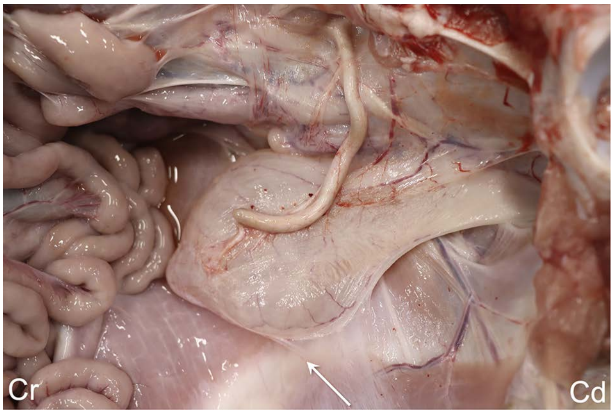

Figure 2—During the gross pathological study of calf 1, a urachal diverticulum (arrow) was identified on the ventral aspect of the urinary bladder. Necropsy was performed from the right side of the body. The images shown are those for the inverted cranial (Cr) and caudal (Cd) for easy comparison with the radiographs.

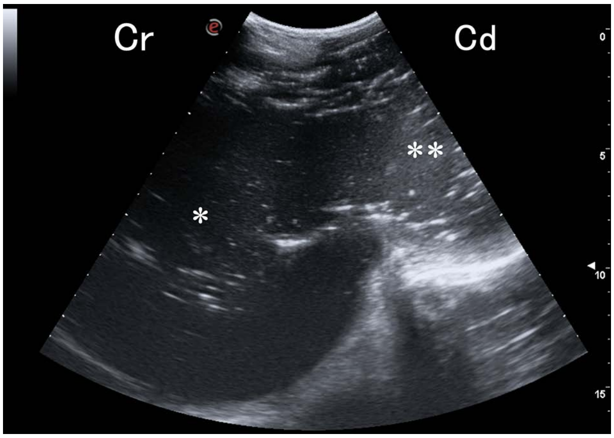

Figure 3—Abdominal ultrasound of calf 8. Umbilical abscess (*) and pyourachus (**) were depicted, but the adhesion of urinary bladder was not observed this time.

revealed a non–oval-shaped urinary bladder whose apex extended to the cranial ventral (aspect ratio, 2.08; Supplementary Table S1) and a contrast line, suggesting urachal diverticulum **(Figure 1)**. Despite the absence of dysuria, the prognosis was considered poor due to feeding problems caused by a shortened mandible. Thereafter, the calf was euthanized according to the clinical guidelines of Azabu University. Gross findings revealed an adherent urachal diverticulum on the ventral aspect of the urinary bladder **(Figure 2)**. This was classified as a type 2 urachal anomaly according to the report by Greene and Scott.[9]

Case 8 showed frequent small urinations and growth insufficiency. Ultrasound examination revealed an umbilical abscess and pyourachus **(Figure 3)**; however, adhesion of the urinary bladder was unclear this time. Though the urinary bladder was not depicted in plain radiographs, excretory urography depicted a fusiform-shaped urinary bladder, which sharply pointed apex with a folded urinary bladder wall **(Figure 4)**. This finding suggested that the apex of the urinary bladder was adherent to the urachal structure and retracted ventrally. A surgical procedure was performed to remove the urachal structure and urinary bladder in order to treat dysuria. The adherent persistent urachus was confirmed during surgery **(Figure 5)**. Following surgery, excretory urography demonstrated that the adherent urachal structure had been successfully released from the urinary bladder and that the urinary bladder returned to its normal position (Figure 5). The aspect ratio of the urinary bladder improved from 11.89 to 1.82 (Supplementary Table S1). Subsequently, this calf no longer exhibited frequent urination.

The aspect ratios for nondysuric and dysuric calves were 1.08 to 2.43 (1.90 in average) and 1.34 to 11.89 (4.75 in average), respectively, with the former having a significantly lower ratio ($P < .05$). Calves 7, 8, 9, and 11 underwent surgery, and the ratios for calves that underwent surgery were 3.21 to 11.89 (5.73 in average) before surgery and 1.77 to 3.50 (2.17 in average) after surgery. Accordingly,

Figure 4—Plain radiograph (left), excretory urogram (center), and magnified image (right) of calf 8 performed 15 minutes after contrast agent injection. A fusiform-shaped urinary bladder, which sharply pointed apex, with a folded urinary bladder wall (arrows) was revealed. Ureters, not dilated, were also depicted.

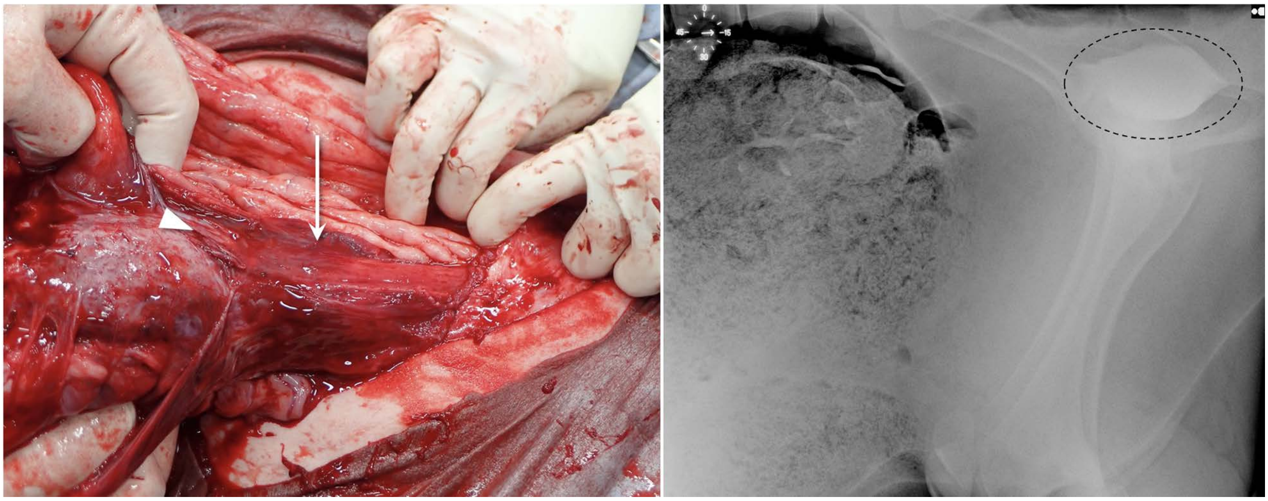

Figure 5—Adherent persistent urachal (arrow) and the urinary bladder (arrowhead) were confirmed during surgery (left) of calf 8. Excretory urogram (right) of calf 8 performed 15 minutes after contrast agent injection following surgery. A fusiform-shaped urinary bladder before surgery returned to its normal position (dashed circle) after surgery, which indicated the successful release of the urinary bladder adhesions with the urachal structure.

a decrease in the aspect ratio was observed after surgery (P = .10).

Discussion

In recent years, the incidence of omphalophlebitis, umbilical arteritis, and pyourachus has increased.[10] One potential explanation for this increase is the increased opportunities for performing ultrasonography, which has allowed for improved detection of calves associated with omphalitis. Despite being nondysuric, calves 1 and 4 exhibited urachal diverticula at the apex of the urinary bladder, suggesting that calves with urachal anomalies have remained undetected for a long time and may have been overlooked in the field.

Subclinical bladder dysfunction may be present even in calves with urachus anomalies that do not exhibit clinical signs. Although often asymptomatic, urachal diverticula indicate a weakening in the urinary bladder wall, increasing the susceptibility to rupture and urinary tract infections.[11] When left untreated, calves with adhesions due to urachal anomalies gradually develop retraction of the urinary bladder as they grow, causing not only dysuria but also urinary leakage into the abdomen and eventually bladder rupture.[12] Therefore, early detection and early surgery are essential. Pyourachus also often adhere to the abdominal wall, digestive tract, or urinary bladder, which increases the difficulty of complete resection in grown adults and leads to poor outcomes. Prompt diagnosis is important to prevent substantial economic losses considering the cost of raising the calves. As such, urachal anomaly should be included in the differential diagnosis of calves presenting with intermittent urination, frequent small urinations, prolonged urination, inability to urinate after raising their tails, or inability to urinate after curving back posture. Moreover, to ensure early diagnosis, proactive excretory urography should be considered.

Cystography has been commonly used in small animal practice to evaluate the urinary bladder.[13] Kamimura et al[14] reported that cystography was able to diagnose urinary bladder rupture caused by urachal anomaly in a calf.[14] However, cystography requires deep sedation sterile catheterization of calves, which are then placed in the lateral recumbency position. In contrast, excretory urography requires no sedation and can be performed with the calf in the standing position.[15] Furthermore, the urologic system, including ureteral dilatation and hydronephrosis, can be evaluated simultaneously. In addition, none of the calves exhibited deterioration in their general condition after excretory urography, suggesting the safety of the procedure. These advantages make excretory urography a practical approach for the diagnosis of urinary bladder conditions among calves in field settings. Fistulography, the injection of a contrast agent through the umbilicus, allows us to evaluate the extension of an abscess. The presence of a draining fistula could indicate communication between the pyourachus and urinary bladder[16]; however, adhesions between pyourachus and the urinary bladder could not be evaluated.[17] In addition, the concern of pushing pus into the abdomen cannot be ruled out during fistulography.

The urinary bladder was not depicted in plain radiographs because the radiopacity of the soft tissue of the trunk itself is close to that of the urinary bladder with urine. In addition, calves have little fat in the abdomen, and therefore less fat is present around the urinary bladder. Thus, no difference in radiopacity was observed between the urinary bladder and surrounding tissue, which resulted in no contrast. The IV-administered iodine contrast agent was excreted via the kidneys and reached the urinary bladder, where it served as a positive contrast. The purpose of the positive contrast in the current study was not to observe the kidneys or ureters but to evaluate the morphology of the urinary bladder.

Given their dependence on the amount of urine in the bladder, various aspect ratios had been obtained. However, a significant difference between calves with and without dysuria had been noted, which could be a useful objective indicator of bladder extension. However, no significant difference in postoperative improvement of aspect ratios was observed between all 4 calves that underwent surgery due to individual differences. This indicator could potentially be used to assess the success or failure of surgery.

Iopamidol, a nonionic and water-soluble contrast agent used in humans since the 1980s,[18–20] has currently been widely used in cats and dogs.[21] Pharmacokinetics studies[19,20,22–24] revealed that it is distributed in the extracellular space and is rapidly excreted from kidneys to urine in rats, rabbits, dogs, and humans. Nevertheless, there are some concerns about its use in food animals. The pharmacologically active ingredient of iopamidol is iodine, which is not present on the "positive list" of the Japanese regulatory agency on substances that could potentially be detrimental to human health. Iodixanol, another nonionic iodinated contrast agent, has been used to estimate renal function in dairy cows,[25] beef cattle,[26] and calves based on its clearance due to its metabolic properties.[27,28] Accordingly, the mentioned studies reported that iodixanol clearance was delayed in animals with renal impairment. Therefore, further studies are warranted on the use of iopamidol during excretory urography in calves with impaired renal function.

Omphalitis, pyourachus, umbilical abscess, and persistent urachus had been detected via ultrasonography before excretory urography. The purpose of ultrasound examination is to observe the structures associated with the umbilicus, whereas excretory urography is used to observe the morphology of the urinary bladder as prementioned. Moreover, morphological observation is easier with radiography because radiographs capture the entire urinary bladder in the caudal abdomen, whereas ultrasound depicts the local area. Ultrasonography can help determine the structure involved and the severity of infection, thereby assisting with preoperative planning.[1,29] Our clinical experience has led us to believe that diagnosing calves with positive findings is easy; however, diagnosing those with negative findings is quite difficult. In addition, diagnosing adhesions through ultrasonography remains difficult given the need for detecting a lack of movement between the abdominal wall and digestive tract.[17] Although experienced veterinarians can readily image the contents of umbilical masses, those without experience may have variable diagnostic accuracy.[17] Nonetheless, we do not avoid ultrasound examination. In fact, we believe that excretory urography and ultrasound examination are complementary and that excretory urography provides alternative information.

Reports have shown that calves with a shortened mandible are prone to urachal diverticulum.[30] Case 1, which was necropsied due to poor prognosis caused by feeding problems, also had a shortened mandible. Hence, a shortened mandible may be associated with urachal diverticulum and may predispose calves to infection from the umbilicus. Further investigations involving genetic analysis to uncover the genes predisposing calves to urachal anomalies are required.

Among calves with dysuria, urachal anomaly should be included in the differential diagnosis. Excretory urography is proposed as an alternative option for early diagnosis among calves presenting with dysuria to improve livestock productivity.

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Disclosures

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ORCID

K. Yamada https://orcid.org/0000-0002-7516-5737

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Supplementary Materials

Supplementary materials are posted online at the journal website: avmajournals.avma.org