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# Ultrasound findings in 34 newborn foals with uroperitoneum

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## Abstract

**Background:** Uroperitoneum is a typical disease of the newborn foal, which occurs rarely but regularly. Ultrasonography is considered the most important imaging method for diagnosing this disease. Thus far, only one older case series comprising 31 foals suffering from uroperitoneum has systematically listed results of ultrasound examinations.

**Objective:** This paper presents the findings of an ultrasonographic examination of 34 foals with uroperitoneum in order to inform future interpretation of ultrasonographic data in suspected uroperitoneum cases.

**Method:** Ultrasonographic data of 34 neonatal foals up to the age of 14 days diagnosed with uroperitoneum between 2006 and 2022 were analysed.

**Results:** Most foals demonstrated highly increased levels of free (97%), anechogenic (91%) fluid in the abdomen. Although the urinary bladder was frequently visible (50%), bladder wall discontinuity was only occasionally detectable (18%).

**Conclusion:** Transabdominal ultrasonography has proved to be a very reliable imaging method for diagnosing suspected uroperitoneum. It is recommended that it be used in every case of suspected uroperitoneum in order to exclude differential diagnoses.

KEYWORDS
bladder rupture, ultrasonography, urinary tract, urachus, ureter

## 1 | INTRODUCTION

Uroperitoneum is a rare but regularly occurring disease in newborn foals. It can be caused by a congenital or acquired defect in the urinary tract and results in accumulation of urine in the abdominal cavity. As it is always a life-threatening emergency (Adams et al., 1988; Bernick et al., 2021; Hardy, 1998; Hopster & Hopster-Iversen, 2012; Knottenbelt et al., 2007) due to metabolic dysfunction and electrolyte imbalances, rapid diagnosis and prompt treatment are of great importance for survival.

Transabdominal sonography has proved to be the most important imaging method for diagnosing the disease (Behn & Bostedt, 2000; Kablack et al., 2000). The diagnosis can be confirmed by performing abdominocentesis, by undergoing laparotomy (Bernick et al., 2021; Hardy, 1998) or by using the creatinine ratio of peritoneal fluid to serum of at least 2:1 (Adams et al., 1988; Bernick et al., 2021; Kablack et al., 2000; Richardson & Kohn, 1983).

The first step by conducting transabdominal ultrasonography is locating the urinary bladder, a positionally constant organ in the mid-caudal segment of the abdomen (Nieth & Wehrend, 2019). The literature describes observations of urinary bladders that often appear to be unusually shaped in foals with uroperitoneum (Knottenbelt et al., 2007). However, the defect itself is only visible in a few cases. Additionally, thickening of the intestinal wall is usually present due to inflammatory changes, especially after prolonged disease (Hopster & Hopster-Iversen, 2012).

A case study of 82 foals with acute abdomen has shown that abdominal sonography can provide a preliminary diagnosis or indication for therapy in 96% of cases (Behn & Bostedt, 2000). In this study, in which 12 foals had uroperitoneum, all 12 cases could be diagnosed reliably within a few minutes. Typical findings presented as a severely fluid-filled abdomen and a visibly collapsed urinary bladder.

Thus far, ultrasound examination results have only been systematically listed in an older case series comprising 31 foals suffering from uroperitoneum from 1988 to 1997 (Kablack et al., 2000). They performed ultrasonography in all cases by using a 5.0 MHz sector probe. The ultrasound device that was used in this study was not mentioned. All 31 foals demonstrated increased levels of free and anechogenic fluid in the abdomen, with bladder wall changes in 10 foals; and a pathological urachus structure in six foals. Overall, 45% of the foals showed more than one pathological ultrasound finding. In all foals in which discontinuity of the bladder wall was indicated, the diagnosis was confirmed in surgery.

The aim of this study is to present typical findings of ultrasonographic examination of a large number of foals with uroperitoneum in a clinic by using modern ultrasound equipment and to facilitate future interpretation of investigations into suspected uroperitoneum in foals.

## 2 | MATERIALS AND METHODS

### 2.1 | Animals

The analysis of the sonographic findings included 34 neonatal foals up to the age of 14 days of life with suspected uroperitoneum. The foals were admitted to the clinic between 1 January 2006 and 15 March 2022. The diagnosis was confirmed by transabdominal ultrasound and abdominocentesis, and the gold standard was to verify the defect in the urinary tract (urinary bladder wall, urachus or ureter) in subsequent laparotomy or dissection.

### 2.2 | Conducting the sonographic examination

The sonographic examination of the abdomen was performed according to a standardised examination procedure under fixation in lateral position by one or two examiners (Nieth & Wehrend, 2019). Sonography was performed on all foals in which uroperitoneum was suspected on the basis of clinical symptoms. This was within 8 h of the first symptoms appearing. The foal's coat was soaked with medical alcohol (Spitacid, Ecolab Healthcare, Düsseldorf) and not shorn. Between 2006 and 2014, the Sonoline Prima (Siemens company) ultrasound device was used, which was replaced in 2015 by the 'z.one ultra' (ZONARE Medical Systems, Mountain View) ultrasound equipment. It was used in B-mode, using two different multimodal transducers from the same company (convex transducer C6-2 with 6 MHz and 16 cm penetration depth and linear transducer L10-5 with 8 MHz and 8 cm penetration depth).

### 2.3 | Data collection and evaluation

Until 31 December 2009, data collection was based on printouts and handwritten notes in index cards archived in folders. As of 1 January 2010, the examination results were documented using the practice management software easyVET (VetZ GmbH).

All examinations and treatments from admission to discharge were recorded. Retrospective data analysis was conducted. Search terms were uroperitoneum and colic in newborn foals up to the age of 14 days.

Following factors were recorded on each set of images: presence of free fluid in the peritoneal cavity (yes/no), the level of free fluid in the peritoneal cavity (highly increased, moderately, low), the echogenicity of the free fluid (anechogenic or presence of corpuscular components), presentability of the bladder (yes/no), diameter of the bladder (highly filled, moderately filled, low filled, collapsed/empty), thickness of the bladder wall, presentability of the discontinuity in the urinary tract (yes/no) and the presence of floating small intestine (yes/no).

Highly increased levels of free fluid in the peritoneal cavity were defined by maximum diameter >12 cm, moderately increased levels by a maximum diameter from >1 to 12 cm and low levels of free fluid by a maximum diameter ≤1 cm in the ultrasonographic examination. A highly filled bladder was defined by a diameter >10 cm (DeNotta, 2022), a moderately filled bladder by a diameter from >2 to 10 cm, a low-filled bladder by a diameter ≤2 cm and in a collapsed bladder, the cavity of the bladder was empty. The physiological thickness of the bladder in newborn foals up to the age of 14 days was defined from 1 to 2 mm. It depends on the distention of the bladder.

## 3 | RESULTS

### 3.1 | Ultrasound findings

An overview of the age at diagnosis, sex, breed, location of the discontinuity and ultrasonographic findings is shown in Table 1. The mean age at the time of diagnosis by ultrasound was 4.4 ± 3.7 days (median: 3 days, range: <1–14 days). In Figure 1, the ultrasonographic findings are ordered by frequency of occurrence.

All foals demonstrated increased levels of free fluid in the abdomen (Figure 2). In 33 cases (97%), this was described as highly increased. In one foal, a mild degree of free fluid was presented.

In 31 cases (91%), the free fluid was anechogenic (Figure 2). Three cases showed free-floating corpuscular components in the fluid.

In 17 cases (50%), the bladder could be seen during the sonographic examination and was seen as low filled or collapsed. In three cases, the bladder wall was thickened (thickness of the bladder wall >2 mm).

Discontinuity in the urinary bladder wall itself could only be observed in three foals (18%) in ultrasound examinations in which the urinary bladder was presentable. The ultrasonographic finding that led to the conclusion of a bladder wall defect was the presentability of discontinuity in the physiological smooth and echoic bladder wall. The edges of the defected bladder wall were slightly rough.

**TABLE 1** Age at time of diagnosis, sex, breed, location of discontinuity and sonographic findings of foals with uroperitoneum.

| Case | Age in days | Gender | Breed | Localisation | Sonographic findings |
|---|---|---|---|---|---|
| 1 | 3 | m | Warmblood | d ub | cp, hi fr fl, ub+, dis− |
| 2 | 14 | f | Connemara Pony | d ub | ae, hi fr fl, ub− |
| 3 | 3 | m | Black Forest Cold Blood | d ub | ae, hi fr fl, ub+, dis− |
| 4 | 13 | m | Warmblood | le ureter | ae, hi fr fl, ub− |
| 5 | 4 | m | Warmblood | d ub | ae, hi fr fl, ub+, dis+ |
| 6 | 3 | m | Haflinger-Arabian mix | v ub | ae, hi fr fl, ub+, dis− |
| 7 | 7 | m | Warmblood | urachus | ae, hi fr fl, ub− |
| 8 | 4 | m | Warmblood | d ub | ae, hi fr fl, ub−, si+ |
| 9 | 2 | m | Warmblood | v ub | ae, hi fr fl, ub+, dis− |
| 10 | 3 | f | Warmblood | d ub | ae, hi fr fl, ub+, dis− |
| 11 | 2 | f | Warmblood | d ub | ae, hi f. fl, ub+, dis− |
| 12 | 11 | m | Warmblood | ri ureter | ae, hi fr fl, ub− |
| 13 | 3 | m | Appaloosa | d ub | ae, hi fr fl, ub+, dis−, si+ |
| 14 | 3 | m | Warmblood | v ub | ae, hi fr fl, ub+, dis+ |
| 15 | 5 | f | Warmblood | d ub | ae, hi fr fl, ub+, dis+, si+ |
| 16 | 2 | m | Warmblood | urachus/cr ub | ae, hi fr fl, ub−, si+ |
| 17 | 2 | m | Warmblood | v ub | ae, hi fr fl, ub− |
| 18 | 5 | m | Quarter Horse | d ub | ae, hi fr fl, ub−, si+ |
| 19 | 0 | f | Warmblood | ub | ae, hi fr fl, ub+, dis− |
| 20 | 3 | m | Warmblood | d ub | ae, hi fr fl, ub− |
| 21 | 3 | m | Warmblood | ub | cp, hi fr fl, ub− |
| 22 | 2 | f | Friesian | ub | ae, hi fr fl, ub+, dis− |
| 23 | 1 | m | Icelandic Horse | ub | ae, hi fr fl, ub+, dis− |
| 24 | 1 | m | Warmblood | leaky ub wall | ae, lw fr fl, ub−, si+ |
| 25 | 5 | m | Warmblood | d ub | ae, hi fr fl, ub− |
| 26 | 4 | m | Warmblood | d ub | ae, hi fr fl, ub− |
| 27 | 4 | m | Arabian | d ub | ae, hi fr fl, ub− |
| 28 | 1 | m | Warmblood | d ub | ae, hi fr fl, ub− |
| 29 | 7 | m | Quarter Horse | d ub | ae, hi fr fl, ub+, dis− |
| 30 | 2 | m | Warmblood | v ub | ae, hi fr fl, ub+, dis− |
| 31 | 3 | m | Warmblood | urachus/cr ub, le | ae, hi fr fl, ub+, dis− |
| 32 | 8 | m | Warmblood | d ub | cp, hi fr fl, ub+, dis−si+ |
| 33 | 3 | f | Warmblood | d ub | ae, hi fr fl, ub− |
| 34 | 4 | m | Warmblood | d ub | ae, hi fr fl, ub− |

Abbreviations: −, not presentable; +, presentable; ae, anechogenic; cp, corpuscular; cr, cranial; d, dorsal; dis, discontinuity; f, female; fl, fluid; fr, free; hi, highly increased levels; le, left; lw, low levels; m, male; ri, right; si, small intestine; ub, urinary bladder; v, ventral.

In seven foals, it was also documented that the loops of small intestine floated in the fluid in the peritoneal cavity (Figure 2).

## 4 | DISCUSSION

The aim of the present study was achieved. It is the largest sample ($n$ = 34) describing typical sonographic abdominal findings in foals with suspected uroperitoneum by using modern ultrasound equipment, and it helps to facilitate future interpretation of investigations into suspected uroperitoneum in foals.

The current sonographic findings were largely consistent with those described in the literature (Adams, 1990; Kablack et al., 2000; Knottenbelt et al., 2007; Velde, 2011). The main finding was the visibility of increased levels of free, anechogenic fluid in the peritoneal cavity. In a single case, low levels of free fluid were detected. This foal presented with a congenitally malformed urinary bladder wall, in which the urine seeped slowly through the entire wall. There is no case report in the

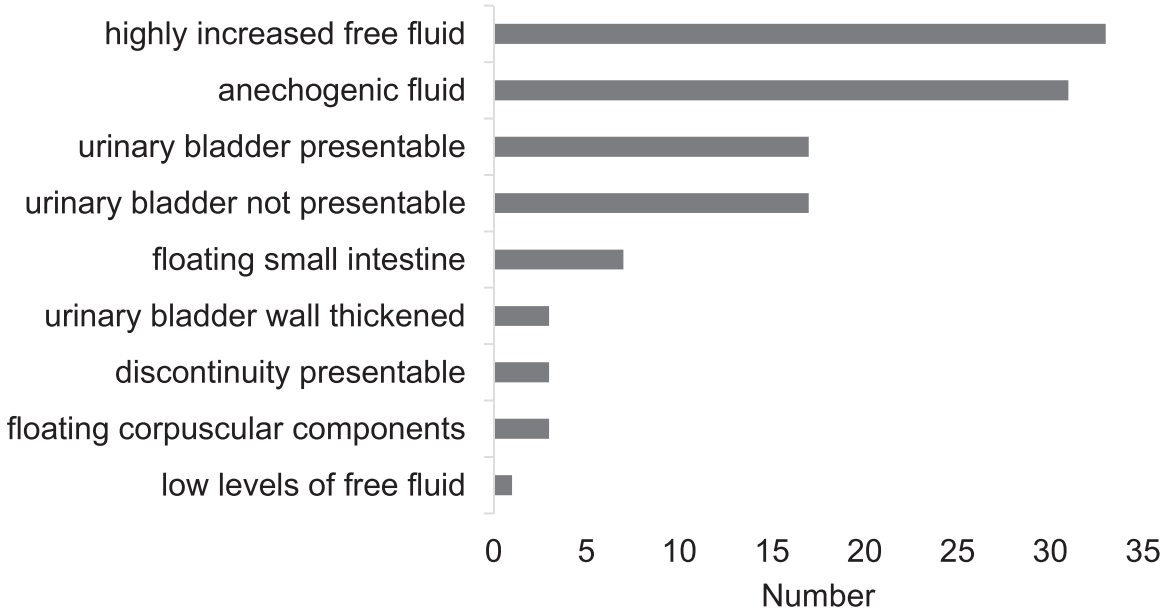


**FIGURE 1** Sonographic findings in foals ($n = 34$) with uroperitoneum at the time of diagnosis.


**FIGURE 2** Sonographic image of anechogenic free fluid and floating loops of small intestine in the abdomen of a foal with uroperitoneum.

present literature about such a congenital malformation of the urinary bladder in a foal.

The literature has described the manner in which the urinary bladder is often visible, but the defect itself can rarely be visually detected (Knottenbelt et al., 2007). In this work, the urinary bladder was presented in 17 cases (50%). In contrast to an older case series (Kablack et al., 2000), in which bladder wall defects were visible in 10 out of 25 cases (40%), the current study only observed discontinuity in the urinary bladder wall in 18% of the foals. Therefore, expecting to preoperatively localise the defect, is not viable.

The present study has proven like other authors that transabdominal ultrasonography is a very reliable imaging method for a suspected diagnosis of uroperitoneum (Behn & Bostedt, 2000). Although sonography is the most important imaging method for diagnosing suspected uroperitoneum, there are potential differential diagnoses for free fluid in the peritoneal cavity, for example peritonitis, intraabdominal bleeding or gastrointestinal diseases (Bartmann et al., 2002; Behn & Bostedt, 2000; Green et al., 1988; Orsini, 1997) and should be excluded by further diagnostic examinations.

In this study, the diagnosis of every case was confirmed by subsequent laparotomy or dissection. This was the gold standard. The ratio of peritoneal fluid creatinine to serum creatinine is described as a good additional method for verifying the diagnosis (Adams et al., 1988; Bernick et al., 2021; Kablack et al., 2000; Richardson & Kohn, 1983). It was not used in this study because we found sufficient indications for the presence of an uroperitoneum by performing transabdominal ultrasonography and abdominocentesis and confirmed the diagnosis by laparotomy or dissection.

A rapid diagnosis is important for prognosis of survival because uroperitoneum is a life-threatening emergency that needs prompt treatment (Adams et al., 1988; Bernick et al., 2021; Hardy, 1998; Hopster & Hopster-Iversen, 2012; Knottenbelt et al., 2007).

In a previous study involving 31 cases (Kablack et al., 2000), they used a 5.0 MHz sector probe. Information regarding the ultrasound device that was used was not included. The present research was carried out with modern technical equipment, by performing ultrasound with convex transducer with 6.0 MHz and 16 cm penetration depth and linear transducer with 8.0 MHz and 8 cm penetration depth. The ultrasound devices are described in Section 2. Additionally in the present study, ultrasound was performed by using a standardised examination procedure (Nieth & Wehrend, 2019). In the previous study, it was not mentioned if they used a standard examination procedure for ultrasonography (Kablack et al., 2000).

One of the most frequent complications after surgical treatment of uroperitoneum is recurrence due to suture dehiscence or incomplete closure of the defect (Ford et al., 2022; Hardy, 1998). Four case studies

of 18, 25, 31 and 45 post-operative foals respectively showed recurrence rates of 12%–20% (Dunkel et al., 2005; Ford et al., 2022; Kablack et al., 2000; Richardson & Kohn, 1983). Therefore, performing post-operative follow-up sonography is recommended, as overlooked minor defects, suture dehiscence or tears elsewhere in the urinary tract may lead to recurrence (Adams, 1990; Behn & Bostedt, 2000; Münnich et al., 1995; Richardson & Kohn, 1983). Without sonographic control examination, recurrences are often only detected after clinical symptoms become evident, which may take up to five days (Münnich et al., 1995).

## 5 | CONCLUSION

As uroperitoneum is considered a neonatal emergency, rapid diagnosis and treatment are necessary. Transabdominal sonography has proved to be a very reliable imaging method for diagnosing this suspected condition, and therefore, its use is recommended in every case of suspected uroperitoneum. It should be kept in mind that ultrasound findings could be variable. Other differential diagnoses should be excluded.

### AUTHOR CONTRIBUTIONS

Axel Wehrend proposed and designed the study. André Bernick collected and analysed data. André Bernick and Axel Wehrend drafted and edited the manuscript. Lukas Stephan Demattio examined a large part of the foals. All authors read and approved the final manuscript.

### CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest to declare.

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None

### DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding authors upon reasonable request.

### ETHICS STATEMENT

The authors confirm that the ethical policies of the journal, as noted on the journal's author guidelines page, have been adhered to.

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### PEER REVIEW

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