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Ultrasonography of umbilical structures in calves.

Part 1: Ultrasonographic description of umbilical involution in clinically healthy calves

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Summary

The aim of the present study was to determine ultrasonographically the size of the umbilical structures in clinically healthy newborn calves and to evaluate their involution during the first three weeks of life.
A total of 13 ultrasonograms were obtained in each of 20 healthy newborn calves using a 7.5-Mhz sector scanner transducer placed across the linea alba of the abdominal wall. The umbilical vein was imaged at five defined cross sections from the umbilicus to the portal vein in the liver, whereas the urachus and the umbilical arteries were imaged at four defined cross sections from the umbilicus to the pelvis. The umbilicus was scanned at three defined locations. All ultrasonographic cross sections were compared to those of a frozen newborn calf. The results were further tested against in a single examination of 20 different calves between 2 hours and 34 days.
Standardized ultrasonographic examination is a safe and reliable method to image the umbilical structures in calves. The umbilical vein was imaged between the umbilicus and the caudoventral margin of the liver in calves up to three weeks of age. The umbilical vein, which at first was oval and thin-walled with a wide anechoic center (vertical diameter 11 ± 3 mm and horizontal diameter 19 ± 7 mm), diminished in diameter during the first week of life to 5 to 8 mm. The course of the umbilical vein in the liver was imaged in calves up to two weeks of age. The umbilical arteries could only be clearly imaged during the first seven days of life. They

Nabelultrasonographie beim Kalb. Teil 1: Sonographische Darstellung der Nabelinvolution bei klinisch gesunden Kälbern

Ziel dieser Ultraschallstudie war die Bestimmung der Durchmesser der Nabelstrukturen bei klinisch gesunden, neugeborenen Kälbern und die Beschreibung der physiologischen Involution während der ersten drei Lebenswochen.
Mit einem 7,5-Mhz Sektor-Scanner wurden 20 klinisch gesunde Kälber von Geburt bis zur dritten Lebenswoche je 13 mal sonographiert. Durch den Hautnabel wurden drei Querschnitte gelegt. Die Darstellung der Vena umbilicalis vom Nabel bis zur Vena portae in der Leber erfolgte entlang der Linea alba. Die Arterien und der Urachus wurden zwischen Nabel und Becken zusammen mit der Harnblase dargestellt. Anhand von Querschnitten durch ein tiefgefrorenes Kalb und anatomischen Präparaten wurde das sonographische Erscheinungsbild der Nabelstrukturen überprüft. Durch die einmalige Untersuchung von 20 Kälbern im Alter zwischen 2 Stunden und 34 Tagen konnten die Resultate überprüft werden.
Mit der beschriebenen standardisierten Untersuchungstechnik können die Nabelstrukturen beim Kalb zuverlässig dargestellt werden. Zwischen Nabel und kaudoventralem Leberrand kann die Nabelvene während den ersten drei Lebenswochen sonographisch erfasst werden. Der anfänglich dünnwandige, ovale Gefässquerschnitt mit weitem echofreiem Lumen (vertikal 11 ± 3 mm und horizontal 19 ± 7 mm) verkleinert sich in der ersten Lebenswoche auf 5–8 mm

had a mean diameter of 8 ± 2 mm and were seen as round, thick walled vessels with an echogenic to hypoechoic center. In all calves, the urachus was not well-defined and was difficult to image. The data of the umbilical structures accumulated in this study can be used as a reference in the diagnosis of abnormalities of the umbilical structures in young calves

Key words: **calf – ultrasound – umbilicus – involution**

Durchmesser. Der Verlauf der Nabelvene in der Leber ist sonographisch 2 Wochen lang sichtbar. Die Nabelarterien sind nur während der ersten Lebenswoche deutlich darstellbar. Der Durchmesser der runden Gefässquerschnitte mit dicker Wand und heterogen echoarmem Lumen beträgt 8 ± 2 mm. Sonographisch kann der Urachus schlecht dargestellt werden.
Die Grösse und die sonographische Gestalt der Nabelgefässe und des Urachus von gesunden Kälbern liefern die Referenzwerte zur Beurteilung von veränderten Nabelstrukturen.

Schlüsselwörter: **Kalb – Ultraschall – Nabel – Involution**

Introduction

Inflammation and infection of the umbilicus occurs commonly in calves. In cases with omphalitis, palpation of the umbilicus may not reveal if and to what degree the intraabdominal umbilical structures are affected. Often the extent of an umbilical infection can only be determined during surgery or at post mortem examination. Ultrasonography is a useful, non-invasive method of visualizing alterations in the intraabdominal umbilical structures of foals (Reef, 1986; Reef and Collatos, 1988; Reef et al., 1989; Collatos et al., 1989) and of calves (Craig et al., 1986; Steiner et al., 1988; Steiner et al., 1990; Steiner et al., 1992).
The purpose of this study was to visualize umbilical involution in healthy calves using a standardized ultrasonographic technique. Knowledge of the ultrasonographic appearance and size of the umbilical structures of calves from birth to three weeks of age can be used as reference during the evaluation of calves with suspected omphalophlebitis, omphaloarteritis or omphalourachitis.

Anatomy

The umbilicus of the mature fetus contains two veins, two arteries, and the urachus. The umbilical vasculature and the urachus enter the abdominal cavity through the inner umbilical ring, an oval opening in the abdominal wall (Figure 1). The umbilical veins become one vascular structure at the level of the inner umbilical ring. In contrast to the umbilical arteries and urachus, the umbilical vein tightly adheres to the surrounding tissue. The umbilical vein ascends cranially and slightly to the right, passing through the umbilical venous sulcus of the liver to join the left branch of the portal vein. The umbilical vein carries oxygenated and nutrient-rich blood from the placenta through the Ductus venosus directly into the caudal vena cava. The umbilical arteries originate dorsally near the pelvic inlet from the left and right internal iliac arteries. They pass along the sides of the bladder en route to the umbilicus and carry oxygen-poor blood from the fetus to the placenta (Fischer, 1932).

Umbilical involution

At birth, the umbilical cord breaks, and the amniotic sheath remains as the only visible structure at the umbilicus. Within four days, it becomes dry, and after approximately two weeks, the extraabdominal umbilical stump falls off leaving a scab which remains until the third or fourth week of life (Stöber, 1990). The umbilical arteries and the urachus retract into the abdomen immediately after the umbilical cord breaks. In contrast, the remnants of the umbilical veins remain in the umbilicus and become incorporated into the scarring process (Cheli, 1968). After parturition, the intraabdominal part of the umbilical vein often contains a large amount of blood which gradually coagulates during the first week of life. The lumen of the umbilical vein gradually becomes occluded by the proliferation of connective tissue and by contraction of the vessel wall. This process is normally finished after the third week of life (Noden and De Lahunta, 1985). In some adult animals, the atrophied umbilical vein may persist to form the round ligament of the liver along the edge of the falciform ligament (Ducharme, et al., 1982). Immediately after the umbilical cord breaks, the stumps of the umbilical arteries close and retract to two to 3 cm behind the caudal edge of the inner umbilical ring. During the first few weeks of life, the arteries retract to the level of the urinary bladder and form the round ligaments of the bladder that pass along its lateral aspects (Schnorr, 1985). Shortly after the umbilical cord breaks, the cranial end of the urachus becomes situated several millimeters closer to the inner umbilical ring than the arteries. The urachus then shrinks and atrophies (Baxter, 1989), leaving a scar on the bladder apex. This scar is clearly identifiable in young animals (Schummer and Nickel, 1987).

Calves, Materials and Methods

The ultrasonographic examination of the umbilical structures consisted of three parts. In Part A, the ultrasonographic appearance of the umbilical structures was compared with anatomical preparations. In Part B, the process of umbilical involution was determined ultrasonographically in 20 healthy calves, and in Part C, another group of calves of various ages was examined once ultrasonographically to investigate whether daily manipulation of the umbilical structures during ultrasonography in the 20 calves of part B had influenced involution.

Calves

Four calves (3 Brown Swiss, 1 Holstein; 12 hours to 7 days old) were used for the ultrasonographic-anatomic comparison (Part A). These calves were euthanatized because of fracture of an extremity (3 calves) and Atresia coli (1 calf). Twenty healthy calves (9 Simmental, 7 Brown Swiss, 4 Holstein) were used for the ultrasonographic study of umbilical involution (Part B). Twenty additional calves (9 Brown Swiss, 5 Simmental, 6 Holstein; 2 hours to 34 days old) with apparently normal umbilical involution were used for the single ultrasonographic examination (Part C).

Ultrasongraphic examination of the umbilical structures

A 20 cm wide area from the xyphoid to the pelvis was carefully clipped. Contact gel (AQUASONIC®, Polymed, Industriestrasse 59, CH-Opfikon, Glattbrugg) was applied to the clipped area, and a portable sector scanner and a 7.5-Mhz transducer with a standoff pad (AUSONICS AG, Avenue Beauregard 9, CH-Fribourg) were used for the examination. All calves were imaged in a standing position from the right side without sedation.
The extraabdominal umbilical structures were imaged in three horizontal cross sections; the transducer was placed on the base of the umbilicus (Position I), on the middle of the umbilicus between the abdominal wall and distal end of the umbilicus (Position II), and on the distal end of the umbilicus (Position III).
Figure 1 depicts the defined positions for imaging the intraabdominal umbilical structures. To locate the umbilical vein, the transducer was placed cranially to and at the base of the umbilicus, at right angles to the median plane, with the ultrasound waves directed caudally. Then the transducer was rotated upwardly so that the direction of the ultrasonic waves changed from horizontal to vertical. The course of the intraabdominal umbilical vein from the umbilicus to the portal vein could be clearly visualized from this position. Five cross sections (Position 5–9) of the umbilical vein were defined from the umbilicus to the liver. To identify the umbilical arteries and the urachus, three cross sections (Positions

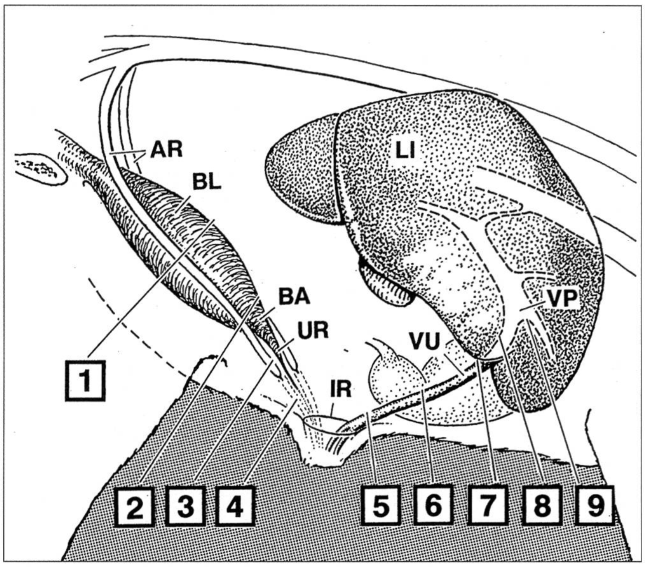

Figure 1: The defined positions for ultrasonographic examination of the intraabdominal umbilical structures.
The umbilical arteries (AR) are imaged passing along the side of the urinary bladder (BL) (Position 1) and near the bladder apex (BA) (Position 2). The urachus (UR) and the umbilical arteries are imaged approximately half way between the bladder and the inner umbilical ring (IR) (Position 3) and directly caudal of the inner umbilical ring (Position 4).
The umbilical vein (VU) is visualized immediately cranial to the inner umbilical ring (Position 5), half way between the inner umbilical ring and the liver (LI) (Position 6), at the caudoventral margin of the liver (Position 7), and at the level of the venous sulcus of the liver (Position 8). Position 9 shows the junction of the umbilical vein with the left branch of the portal vein (VP).

2–4) were defined between the umbilicus and the apex of the bladder. The shape of the apex of the bladder was imaged in longitudinal section (Position 2). The umbilical arteries were also imaged on each side of the urinary bladder (Position 1).
The ultrasonographic appearance of the cross sections of the umbilical structures was described at the defined positions. In addition, the vertical and horizontal diameters of the umbilical structures were measured. Because the umbilical structures ascend cranially and caudally from the ventral abdominal wall, the vertical position of the transducer had to be slightly corrected so that the ultrasonic waves hit the umbilical structures at a right angle. By doing so, the smallest vertical diameters could be imaged and measured. When the wall and lumen of an umbilical structure were clearly recognized, the thickness of the wall was measured in the region which was directly in the path of the ultrasound waves. Finally, the distance between the umbilical structures and the outer abdominal wall was measured.

Comparison of ultrasonograms with anatomical preparations (Part A)

The umbilical vasculature, urachus and urinary bladder were dissected in a total of three calves (1 day, 3 days and 7 days of age), which had to be euthanatized due to unrelated causes. The structures were subsequently examined ultrasonographically in a water bath. The ultrasonographic appearance of the umbilical structures was compared to the anatomic preparations to ensure correct interpretation of the ultrasonograms.
The topography of the intraabdominal umbilical structures was also determined ultrasonographically in a newborn calf, which died within hours after birth. The carcass was frozen at -20° C in a standing position, and cut into sections from the pelvis to the xyphoid using a bandsaw. The cross sections, at defined positions, were compared to the corresponding ultrasonograms.

Ultrasonographical determination of umbilical involution (Part B and C)

In Part B of this study, 20 calves were ultrasonographically examined every day during the first week of life and every second day through out the second week, by means of the previously described method. From day 16, the calves were examined once every three days until the umbilical structures could no longer be detected.
In Part C, 20 other calves, apparently healthy, with normal umbilical involution underwent a single ultrasonographic examination. The cross section images of their umbilical structures were compared with those of the calves from Part B of the study at the corresponding age.

Statistical analysis

The mean (x), standard deviation (SD), and range (minimal and maximal values) were calculated for the most important variables measured.

Results

Comparison of water bath ultrasonograms and anatomic preparations

The umbilical vein examined via ultrasonography in a water bath had a one to two mm thick, homogeneously hypoechogenic wall which was clearly demarcated from the anechoic lumen. Fine and at times extremely hyperechogenic lines were imaged between the wall and lumen of the umbilical vein when the ultrasound waves hit the vein at right angles. These lines, termed wall reflections, were orientaded at right angles to the ultrasound beam and were only observed in the seven-day- old calf. In the anatomic preparations of all three calves, the umbilical vein contained red to black, viscous blood from the umbilicus to the liver. The wall of the umbilical vein was one mm thick.
The lumen of the umbilical arteries was more hyperechogenic than the lumen of the umbilical vein. The echogenicity of the contents of the umbilical artery increased with an increase in their viscosity. Vessels containing small clumps of coagulated blood displayed a heterogeneous, coarsely granular pattern of varying echogenicity. A thin, irregularly anechoic ring was interpreted as the border between the wall and lumen of the umbilical artery. In comparison to the umbilical vein, the wall of the umbilical artery was more heterogeneous and more hyperechogenic. No wall reflections could be observed.
A cylindrical urachus with a diameter of five mm could only be dissected out in neonatal calves. In the other calves, the urachus formed the short continuation of the apex of the cone-shaped bladder. Ultrasonographically, the urachus appeared as a fine, homogeneous, hyperechogenic structure which was not clearly demarcated and in which the lumen and wall could not be identified. In longitudinal sections through the apex of the bladder, the urachus had the same echogenicity as the urinary bladder wall from which it exited. The anechoic lumen of the empty urinary bladder appeared as a thin fissure at the apex of the bladder in ultrasonograms; it was pear-shaped when the bladder was filled with water. In the one week old calf, filling the bladder with water caused the lumen of the urachus to open slightly; it then appeared as a small diverticulum at the apex of the bladder.

Topography of the intraabdominal umbilical structures

Directly craniad of the umbilicus, the umbilical vein was situated against the abdominal wall. From there it ascended in cranial direction to the right joined the liver at the umbilical venous sulcus (Figure 2). At this position, the ventrocaudal edge of the liver was observed adjacent to the umbilical vein in ultrasonograms (Figure 3). At the level of the xyphoid, the umbilical vein joined the left branch of the portal vein (Figure 4). Ultrasonographically these vascular structures could be seen completely surrounded by liver tissue (Figure 5).
At the caudal edge of the base of the umbilicus no umbilical structures were seen neither in any frozen section nor on ultrasonograms. The apex of the bladder, flanked by both umbililical arteries, was observed in cross sections taken through the third lumbar vertebra. This corresponded to a position located approximately 5 cm caudal to the base of the umbilicus.

Ultrasonography of normal umbilical involution (Part B and C)

During the first week of life, the umbilicus was funnel-shaped and oval in cross section. It gradually became cylindric in shape, and in cross section, it decreased in

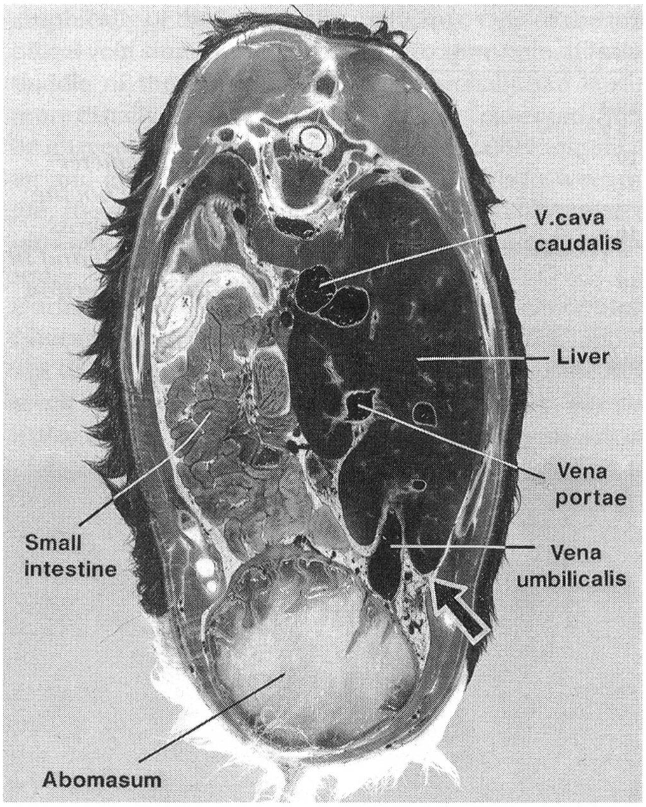

Figure 2: A section through the trunk of a frozen newborn calf at the level of the caudoventral margin of the liver (Position 7 on figure 1).
In this section, the umbilical vein is cut tangentially because it ascends cranially. The arrow indicates the apex of the caudoventral lobe of the liver which is located adjacent to the abdominal wall.

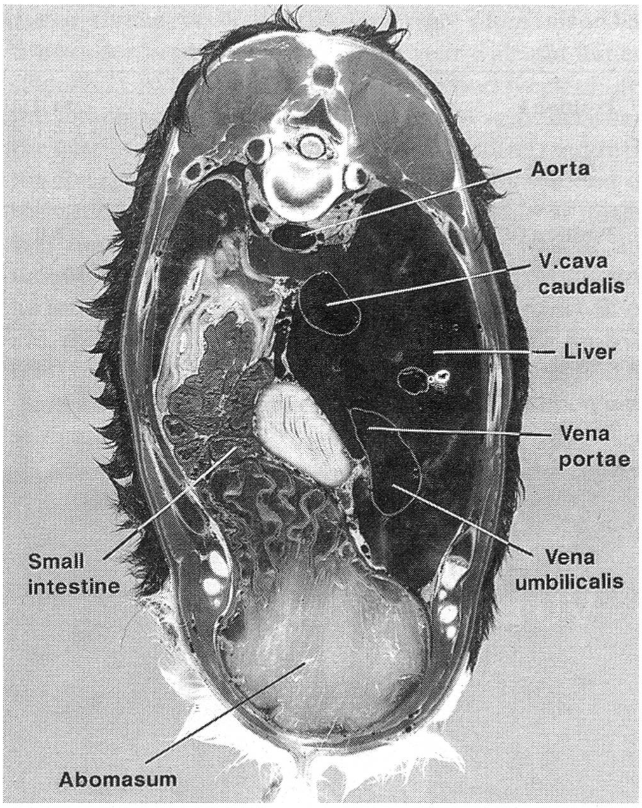

Figure 4: A section through the trunk of a frozen newborn calf at the level of the 13th thoracic vertebra (Position 9 on figure 1).
It depicts the junction of the umbilical vein with the left branch of the portal vein.

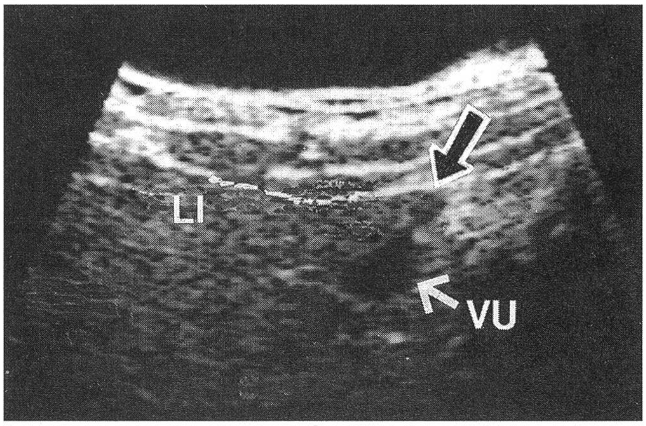

Figure 3: Ultrasonographic cross section through the umbilical vein (VU) of a newborn calf at the level of the caudoventral margin of the liver (Position 7; see figure 2).
The arrow indicates the apex of the caudoventral lobe of the liver (LI) which lies adjacent to the abdominal wall.

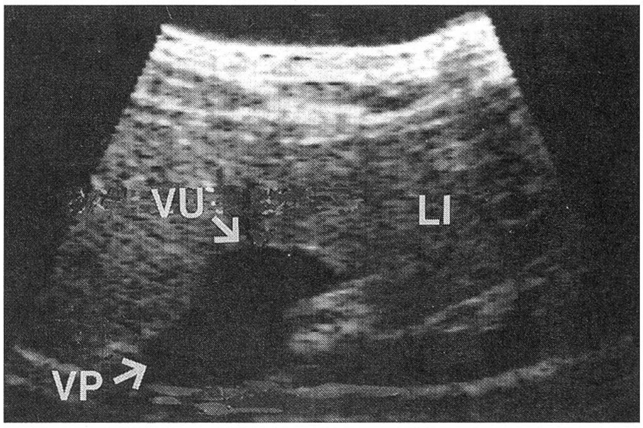

Figure 5: Ultrasonographic cross section through the umbilical vein (VU) at its union with the portal vein (VP) in the liver (LI) of a newborn calf (Position 9; see figure 4).
The umbilical vein is completely surrounded by liver tissue.

size and became rounder (Table 1). The umbilicus was surrounded by an anechoic ring on ultrasonograms (Figure 6). The umbilical tissue appeared with a fine, granular and homogeneously hypoechogenic pattern. By the third week of life, the umbilicus was more echogenic than the surrounding tissue. During the first week of life, the two large anechoic lumina of the extraabdominal umbilical veins were often observed ultrasono-

		Day 1		Day 11		Day 22	
		cross	long	cross	long	cross	long
Position I	x̄	**15.4**	**23.4**	**11.2**	**19.1**	**9.1**	**13.7**
	SD	4.8	5.3	5.4	7.7	4.4	6.7
	min.	8	15	6	10	5	6
	max.	25	31	22	31	19	28
Position III	x̄	**9.2**	**16.9**	**8.0**	**16.0**	**8.1**	**13.6**
	SD	3.4	5.0	3.3	5.1	3.9	3.5
	min.	5	9	4	10	4	9
	max.	16	24	15	24	16	21

x̄ = mean, SD = standard deviation, min. = minimal value, max. = maximal value

Table 1: Diameter (mm) of the bovine umbilicus in cross section (cross) and in longitudinal section (long).

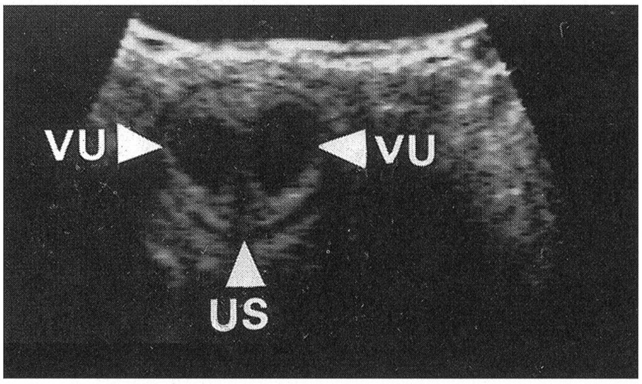

Figure 6: Cross section through the extraabdominal umbilical structures (US) at the base of the umbilicus of a two-day-old calf (Position I).
Both stumps of the umbilical veins (VU) appear completely anechoic.

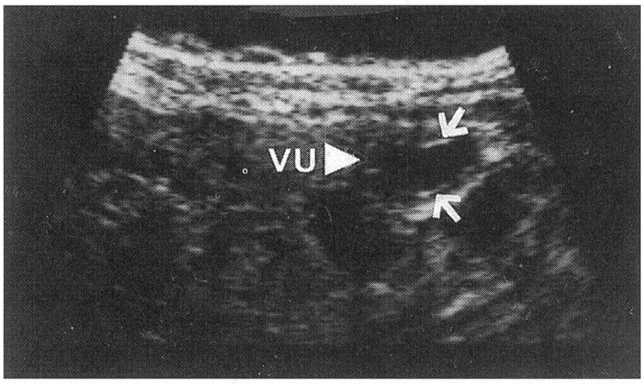

Figure 7: Cross section through the umbilical vein between the inner umbilical ring and the liver of a two-day-old calf (Position 6).
The two arrows indicate the wall reflections seen at the border between the hypoechoic wall and anechoic lumen of the vein.

		Day 1		Day 11		Day 22	
		hor.	vert.	hor.	vert.	hor.	vert.
Position 5	x̄	**19**	**11**	9	6	**7**	**5**
	SD	6.8	3.4	3.4	1.7	2.5	1.2
	min.	6	4	5	2	3	3
	max.	30	18	18	9	11	7
	n	20		20		10	
Position 6	x̄	**11**	**8**	**5**	**5**	**5**	**4**
	SD	3.3	2.8	1.1	1.3	0.8	0.8
	min.	4	4	3	2	4	3
	max.	10	16	9	7	6	5
	n	20		20		4	
Position 7	x̄	**10**	**8**	**5**	**4**	**5**	**4**
	SD	3.2	3.0	1.2	0.6	0.0	0.0
	min.	4	4	2	3	5	4
	max.	15	17	7	5	5	4
	n	20		19		2	
Position 8	x̄	**10**	**7**	**5**	**4**	**6**	**8**
	SD	3.9	2.3	1.8	1.5	0.0	2.1
	min.	4	4	2	2	6	6
	max.	23	13	8	7	6	9
	n	20		13		2	

hor. = horizontal diameter, vert. = vertical diameter, x̄ = mean, SD = standard deviation,
min. = minimal value, max. = maximal value, n = number of veins imaged in cross section

Table 2: Horizontal and vertical diameter (mm) of the bovine umbilical vein in cross section.

graphically of the base of the umbilicus. One of the umbilical vein stumps usually reached to approximately the middle of the umbilicus; only occasionally did it run more distally. The walls of the umbilical vein could often be imaged; with time, the anechoic lumina became smaller and gradually disappeared. After the third week of life, the vascular structures could not be differentiated ultrasonographically from the rest of the umbilical tissue.

During the first week of life, the umbilical vein of most calves were clearly imaged from the base of the umbilicus to the ventrocaudal edge of the liver. After the first week of life, it was difficult to ultrasonographically visualize the umbilical vein in the umbilical venous sulcus of the liver. On the 22nd day of life, the umbilical vein of many of the calves could only be imaged immediately cranial to the base of the umbilicus. The mean distance between the umbilical vein and the abdominal wall directly cranial to the umbilicus was 7 ± 1 mm. The distance from the abdominal wall to the junction of the umbilical vein and the portal vein was 27 ± 4 mm. The mean diameter of the umbilical vein at various positions is reported in Table 2. The ultrasonographic appearance and the diameter of the umbilical vein changed markedly during the first week of life. In the first few days of life, the large, oval, anechoic lumen of the umbilical vein was imaged at the inner umbilical ring shortly beyond the union of the two umbilical veins. The cross-sectional diameter of the umbilical vein became smaller toward the liver and did not broaden again until the opening into the portal vein. The wall of the umbilical vein could rarely be imaged. By the end of the first week of life, the diameter of the umbilical vein had regressed substantially. Additionally, the wall of the umbilical vein could occasionally be imaged, and the anechoic lumen was still clearly visible. In the second week of life, the umbilical vein, immediately craniad to the umbilicus, had a distinct, homogeneously hypoechogenic wall up to three mm in thickness. Wall reflections were often imaged at the border between the umbilical vein wall and lumen (Figure 7). At the beginning of the second week of life, the lumen and the wall of the umbilical vein, between the base of the umbilicus and the caudoventral margin of the liver, could be clearly differentiated. By the end of the second week, however, the cross-sectional image was homogeneously hypoechogenic. The wall of the umbilical vein in the umbilical venous sulcus could not be differentiated from liver tissue. In the third week of life, the umbilical vein was usually only visible up to a few cm cranial to the base of the umbilicus; it was homogeneously hypoechogenic. A small anechoic lumen was seldom imaged.

The umbilical arteries were imaged most clearly in the first week of life; afterwards, they could be identified only sporadically. The arteries could neither be imaged in the umbilicus nor in the abdomen caudal to the inner umbilical ring (Position 4). However, they were always identified along both sides of the urinary bladder where they made a depression in the full bladder or were in close contact with the tissue of the empty bladder (Figure 8). The course of the umbilical arteries could often be followed cranially past the apex of the bladder in the first few days of life. By the end of the first week of life, the stumps of the umbilical arteries had retracted to a position caudal to the apex of the bladder. They were surrounded by a typical, small, anechoic ring. The relatively thick arterial wall and the small lumen were often difficult to differentiate. The echogenicity of both was heterogeneous and irregular. In cross section, the umbilical artery was round and had a mean diameter of 8 ± 2 mm.

The urachus could rarely be imaged. Occasionally, a hypoechogenic structure cranial to the apex of the bladder and between the two umbilical arteries was interpreted as the urachus. However, it could not be well-differentiated from surrounding tissue. This poorly defined structure could only rarely be followed cranially from position 3. A short continuation of the bladder apex was sometimes be imaged in longitudinal sections of the

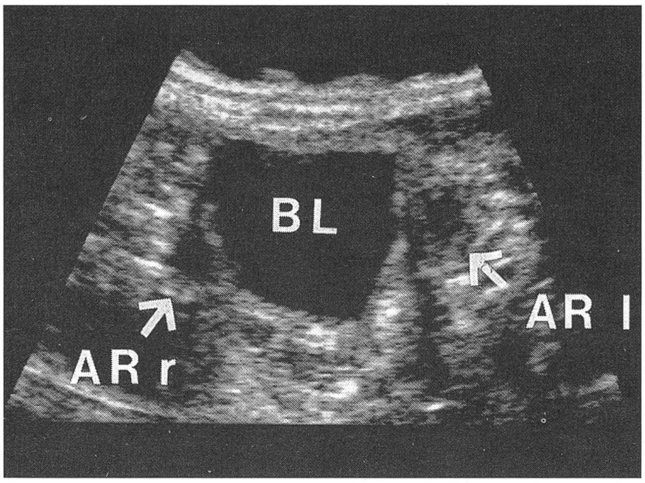

Figure 8: Cross section through the umbilical arteries passing along the sides of the urinary bladder of a two-day-old calf (Position 1).
A depression in the urinary bladder (BL) is made by the right umbilical artery (AR r).

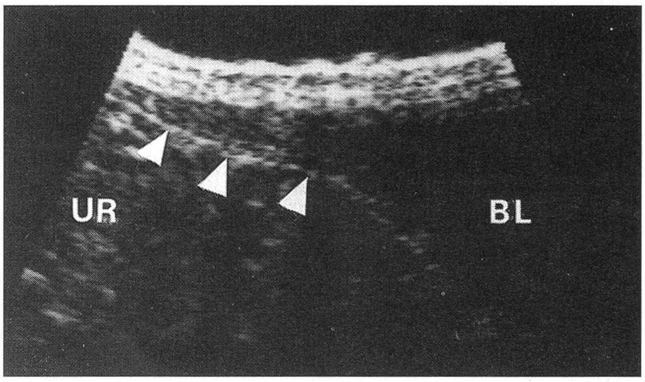

Figure 9: Longitudinal section through the apex of the urinary bladder (BL) of a three-day-old calf (Position 2).
The arrows indicate the homogeneously hypoechogenic tissue of the urachus (UR).

bladder (Figure 9). A clearly defined urachal lumen was not imaged in any of the calves. In cross section, the full bladder was oval and had a thin hypoechogenic wall. In longitudinal sections, it was usually pear-shaped. In two calves, a small bladder diverticulum was occasionally observed.

Surrounding organs

The pylorus and umbilical vein were occasionally imaged between position 5 and 7 if the calf had not had milk for six hours. In cross section, the pylorus was round and demarcated from the surrounding tissue by a 2 to 3 mm wide, hypoechogenic ring. Although not distinct, hyperechogenic lines appeared to run from the outside to the center of the pylorus (Figure 10). While the calf was drinking, filling of the abomasum and subsequent dislocation of the pylorus to the right and dorsally could ultrasonographically be imaged. The hepatic tissue had a typical uniform echogenic pattern. The gallbladder could sometimes be imaged; it was round and had a thin wall and anechoic lumen. The falciform ligament could not be positively identified ultrasonographically.

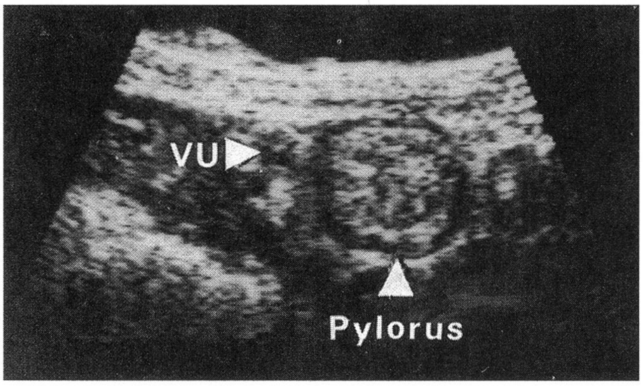

Figure 10: Cross section through the umbilical vein between the liver and the umbilicus of a seven-day-old calf (Position 6).
The pylorus is seen in cross section to the right of the umbilical vein (VU).

Comparison of the results of Part B and Part C

The results of the single ultrasonographic examination of calves up to three weeks of age (13 calves; one to 18 days old) corresponded to those of calves which underwent repeated ultrasonographic examinations.
The measurements of the umbilical structures of calves older than 22 days (seven calves; 23 to 34 days old) were always less than the means of those obtained on the 22nd day of life of calves that underwent repeated ultrasonographic examinations. When the umbilical vein could be imaged in position 5, it often had a small anechoic lumen and a distinct hypoechogenic wall.
In one 23-day-old calf, an artery with a distinct anechoic border and a heterogeneously hypoechogenic appearance was imaged beside the bladder (position 1; cross-section). This structure was not likely small intestine because it was not motile and was in close contact with the bladder.

Discussion

The results of this study indicate that ultrasonography is an excellent technique for visualization of umbilical involution in calves. The intra- and extraabdominal umbilical structures of calves can be reliably imaged by use of a standardized ultrasonographic technique.

Ultrasonographic criteria of normal bovine umbilical involution

A maximum of two cross sections of the two, anechoic extraabdominal umbilical veins can be imaged ultrasonographically in the umbilicus. During the first week of life, these structures are occasionally filled with a large amount of blood. By the end of the third week of life, the extraabdominal umbilical structures are homogeneously hypoechogenic, and the vascular structures cannot be identified.
During the first week of life, the umbilical vein can be distinctly imaged from the base of the umbilicus to the left branch of the portal vein in the liver. After the third week of life, the umbilical vein is only ultrasonographically visible outside of the liver. The lumen of the umbilical vein is always anechoic and disappears near the end of the third week of life. The wall of the umbilical vein can only be imaged after the first few days of life. Wall reflections may be visualized at the border between the wall and lumen of the umbilical vein. In the first days of life, the horizontal diameter of the umbilical vein immediately cranial to the umbilicus is seldom more than 2 to 3 cm. After the third week of life, the diameter of the umbilical vein, imaged in all positions, is never more than 11 mm.
The umbilical arteries can best be imaged during the first week of life. Ultrasonographically, the ends of the arteries have no connection to the umbilicus and can be first imaged several cm caudal to the base of the umbilicus. In cross section, the umbilical arteries are round and have a mean diameter of 8 ± 2 mm. The anechoic ring around the arteries represents the adventitia. The blood in the umbilical arteries coagulates faster than that in the umbilical veins. Therefore, after a few days of life, the lumen of the arteries appears heterogeneously hypoechogenic and is difficult to differentiate from the wall. This is also the reason why the ultrasonographic appearance of the arteries is not as distinct as that of the umbilical vein. In a three-week-old calf, an artery, ultrasonographically visualized beside the bladder, can be judged normal if its diameter does not exceed 14 mm and its ultrasono-

graphic appearance is normal. Ultrasonographic characteristics of an artery which are used to differentiate it from a cross section of an empty loop of small intestine include; an anechoic border, lack of motility, and close contact with the wall of the urinary bladder.
Ultrasonographically, cross sections of the urachus of calves with normal umbilical involution are difficult to identify. During the first few days of life, a homogeneously hypoechogenic continuation of the bladder, imaged in longitudinal sections through the apex of the bladder, might represent the urachus; a urachal lumen cannot be seen.

Application of umbilical ultrasonography

It is difficult to evaluate the extent of an umbilical infection by palpation. Retrograde contrast radiography of

Etude echographique des structures ombilicales chez le veau. Première partie: Description echographique de l'involution ombilicale chez des veaux cliniquement sains

Le but de cette étude est la description échographique de l'involution physiologique des structures ombilicales chez le veau.
A l'aide d'une sonde sectorielle de 7.5 Mhz, 20 veaux cliniquement sains, ont été sonographiés 13 fois depuis leur naissance et pendant trois semaines. La représentation échographique de la veine ombilicale à partir du nombril jusqu'à la veine porte se fait en suivant la linea alba. Les artères et l'urachus sont représentés avec la vessie entre l'ombilic et le bassin. Les images sonographiques des structures ombilicales ont été contrôlées à l'aide de préparations anatomiques et de coupes à travers un veau congelé. Les résultats ont pu être confirmés par l'examen de 20 veaux âgés entre deux heures et 34 jours.
Avec l'examen standardisé décrit on peut représenter sonographiquement de manière sûre les structures ombilicales du veau. Entre le nombril et le bord caudoventral du foie on peut voir la veine ombilicale pendant les trois premières semaines de vie. Au début, sa section est ovale, à paroi mince, avec une large lumière anéchoique (diamètre vertical 11 ± 3 mm et horizontal 19 ± 7 mm) qui rétrécit pendant la première semaine pour atteinder un diamètre de 5–8 mm. Le cours de la veine ombilicale en direction du foie est visible aux ultrasons pendant deux semaines.
Les artères ombilicales ne peuvent être clairement représentées que durant la première semaine. Leurs sections sont rondes, à paroi épaisse et leurs lumières hétérogènes, peu échogènes présentent un diamètre de 8 ± 2 mm. L'urachus est difficilement mis en évidence.
La diamètre et la structure sonographique des vaisseaux ombilicaux et de l'urachus de veaux sains servent de références pour juger de l'altération des structures ombilicales.

Ricerca sonografica delle strutture ombelicale nel vitello. Prima parte: Descrizione sonografica dell'involuzione ombelicale in vitelli clinicamente sani

Scopo di questa ricerca sonografica é stata la descrizione dell'involuzione fisiologica delle strutture ombelicali nel vitello.
20 vitelli clinicamente sani sono stati sonografati 13 volte a partire dalla nascita fino alla terza settimana di etá tramite un 7.5 Mhz Settore Scanner. Attraverso il cordone ombelicale sono state fatte tre incisioni. La rappresentazione della vena ombelicale a partire dall'ombelico fino alla vena portae nel fegato é stata ottenuta seguendo la linea alba. Le arterie e l'uraco vengono rappresentati tra l'ombelico e il bacino, assieme alla vescica. La rappresentazione sonografica delle strutture ombelicali é stata verificata tramite sezini trasversali di un vitello congelato e preparati anatomici. I risultati sono stati confermati per mezzo di un unico esame di 20 vitelli di etá compresa tra le due ore e i 34 giorni.
Le strutture ombelicali del vitello possono essere rappresentate attendibilmente tramite la tecnica di analisi standardizzata descritta. La vena ombelicale puó essere inquadrata sonograficamente tra l' ombelico e il bordo caudoventrale del fegato durante le prime tre settimane di vita. La sezione trasversale dei vasi sanguinei inizialmente ovale e con pareti sottili con un lume largo e privo di eco (verticalmente 11 ± 3 mm e orizzontalmente 19 ± 7 mm) si rimpiciolisce nella prima settimana di vita fino a raggiungere i 5–8 mm di diametro. Il corso della vena ombelicale nel fegato é visibile sonograficamente per due settimane. Le arterie ombelicali invece possono essere rappresentate solo nella prima settimeana di vita. Il diametro delle sezioni trasversali rotonde dei vasi sanguinei, con una spessa parete e lume eterogeneo e povero di eco, misura 8 ± 2 mm. L'uraco puó essere rappresentato male sonograficamente.
La grandezza e la configurazione sonografica dei vasi ombelicali e dell'uraco di vitelli sani forniscono i valori campione per la valutazione di strutture ombelicali alterate.

umbilical fistulas (Bouckaert and De Moor, 1965) and intravenous contrast urography (Dieffenderfer and Brightling, 1983) are involved techniques which have been used to evaluate the extent of involvement of the umbilical structures before surgery. However, until recently a precise morphologic diagnosis was only possible at surgery or at post mortem examination.
As an aid in the diagnosis of bovine umbilical disease, ultrasonography has a number of advantages: it is a non-invasive technique that can be used on standing, non-sedated calves; there are no known risks for human beings or for animals; an experienced clinician can complete an ultrasonographic examination in ten minutes; and calves can be examined in the barn by means of a portable ultrasound machine.
Knowledge of the ultrasonographic appearance of the umbilical structures of healthy calves together with a standardized method of ultrasonographic examination are required for the use of this technique in the diagnosis of umbilical diseases. Ultrasonography can be used to evaluate the umbilicus as a source of infection in cases of neonatal septicemia, pneumonia, polyarthritis, and fever of unknown origin, even if the extraabdominal umbilical structures appear normal. Ultrasonography allows the clinician to evaluate the umbilical structures when the results of palpation are not clear or when palpation is not possible e. g. large abdomen, tense abdominal wall.
In a later publication, typical ultrasonograms of umbilical structures of calves with pathological involution will be presented.

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