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Recurrent umbilical cord accidents in a bottlenose dolphin *Tursiops truncatus*

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ABSTRACT: Three successive umbilical cord accidents (UCAs) were diagnosed in the same female bottlenose dolphin *Tursiops truncatus* during consecutive gestations. In 2 of these, transabdominal ultrasonographic examination revealed coiling of the UC around the peduncle of the foetus. All 3 foetuses were male, died *in utero* during the last third of gestation and were spontaneously aborted. The 3 UCs were elongated, flattened and congested. For 3 subsequent pregnancies, a different sire was used for mating, handling protocols and treatments were adjusted, and 3 live female calves were successfully delivered. UC lengths were normal. UCAs are associated with excessively long UCs and are not uncommon in humans and horses but are unusual in other species. We believe this is the first detailed report of recurrent UCAs in a dolphin.

KEY WORDS: Excessively long umbilical cord · Cetacean · Abortion · Stillbirth · Gestation

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Umbilical cord accidents (UCAs) occur when umbilical blood flow is compromised and may lead to foetal injury or death. Cessation or severe reduction of blood flow through foetal vessels, associated with UCAs, results in less oxygen reaching the placenta and foetus, leading to intrauterine hypoxia and acidosis. In turn, these may cause foetal hypotension, arrhythmia and ultimately cardiac failure (Baergen et al. 2001, Collins 2002). Excessively long umbilical cords (ELUCs) have been described in humans and are associated with maternal systemic disease, increased maternal age, cord entanglement, foetal distress during labour and respiratory distress at delivery (Rayburn et al. 1981, Sørnes & Bakke 1989, Baergen 2007). UCAs have also been reported in other mammals, particularly horses (Whitwell 1975, Naeye 1992), but this condition has been reported only once in bottlenose dolphins *Tursiops truncatus* (Tanaka et al. 2014). In this case, a true knot was found in the cord; however, cord length was not measured and not discussed. Here we present the first report of recurrent UCAs due to ELUCs and extend information about ELUC-associated UCAs in dolphins previously presented (Brook et al. 2007).

A female *Tursiops truncatus* (approx. age 20–30 yr) was observed for a period of 10 yr, during which time she was housed with a group of between 15 and 22 other dolphins at Oceanogràfic, Valencia, Spain. Compared to other individuals, staff considered this animal to be particularly nervous and hyperactive, performing higher jumps and swimming faster than other animals. When pregnant, she was excluded

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from exhibitions and moved to a back pool. Here she performed show behaviours on her own as soon as the music began, jumping and breaching vigorously, even during late gestation. Between May 2004 and September 2007 the female became pregnant 3 times. Each time, she mated with the dominant male of the group. Each of these pregnancies ended in abortion during the last third of gestation. All calves were male and were stillborn, with body tissues showing moderate autolysis. In all 3 calves, the umbilical cord (UC) was wrapped several times around the peduncle (Fig. 1a,b). The cords measured from 51 to 76 cm (Fig. 1c). There was no clinical evidence of maternal disease during these pregnancies.

After the first stillbirth, modifications were made to reduce dynamic training behaviours. Regular ultrasonographic monitoring of the UC position and perfusion was conducted throughout gestation. Although training was restricted, the female jumped and breached voluntarily several times daily, even in late pregnancy. During the ninth month of gestation, ultrasonography detected cord entanglement (Fig. 1e,f). UC blood flow was present and foetal heart rate was normal (114 bpm). Abortion of a stillborn male foetus occurred 25 d later (Fig. 1b). For the third pregnancy, the same training modifications were made, and in addition, the female was treated orally with 0.1 mg kg^{-1} diazepam twice daily (Valium

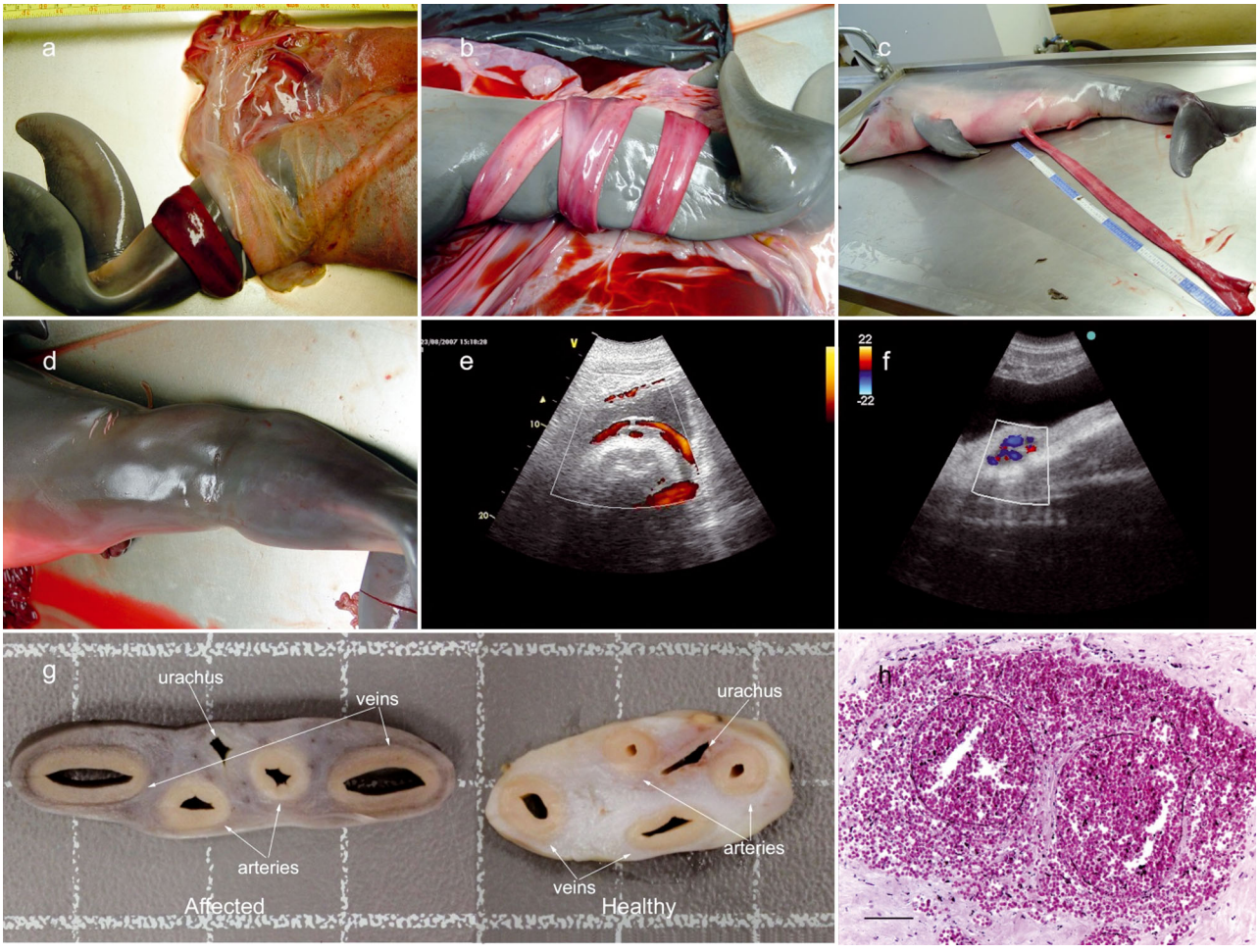

Fig. 1. *Tursiops truncatus*. (a,b,c) Flattened and congested umbilical cords (UCs) surrounding peduncles (a,b) and extended cord (c). (d) Peduncle of the foetus shown in (b) with compression grooves. (e) Power Doppler ultrasound showing a transverse section of a foetal peduncle with the UC wrapped around it. Note the presence of blood flow (coloured) inside the umbilical and placental vessels. (f) Colour Doppler ultrasound showing a longitudinal section of a foetal peduncle with the UC wrapped around it. Note the presence of opposed blood flow in the umbilical veins and arteries (in red and blue) inside UC loops. The presence of 8 vessels reveals that 2 loops overlap at this point. (g) Transverse sections of affected (left) and healthy (right) UCs. Note the flat shape of the section and the greatly dilated veins in the affected UC. The dark brown colour of the affected UC is due to diffuse congestion (both are formalin-fixed samples). Each small square = 1 cm^2. (h) Histological image of haemorrhages affecting the vasa vasorum of a UC vein. H&E stain. Scale bar = 50 µm

10 mg, Roche Farma Laboratories) in an attempt to curb her activity during the second half of pregnancy. Diazepam was given later to minimize risk to the foetus and because it has been postulated that the risk of umbilical cord entanglement is higher when the foetus is larger (Plumb 2008). This was not successful, and a third abortion occurred at 11 mo gestation. Again, a stillborn male foetus was delivered (Fig. 1c).

For the next 3 pregnancies, further measures were taken. Firstly, the breeding male was changed to minimize any potential genetic component of the condition. Secondly, sedation was increased to an oral dose of 0.3 mg kg^{-1} diazepam twice daily, as this was the minimum dose required to reduce highly dynamic behaviours. These 3 pregnancies resulted in the delivery of 3 healthy female calves.

The UC length (UCL) in the 3 aborted foetuses was 62, 51 and 76 cm; UCL in the first 2 surviving calves was 37 and 34 cm. It was not possible to retrieve the placenta to measure the UCL in the final delivery. Foetal weight, body length and a comparison of UCL to body length are shown in Table 1.

Umbilical cords, membranes and tissue samples of stillborn foetuses were collected for histological analyses, fixed in 10% neutral buffered formalin, processed routinely and stained with haematoxylin and eosin.

All stillbirths showed gross and histological findings consistent with UCA. Grossly, all UCs were coiled 3 to 4 times, ascending along the left flank around the peduncles, which showed compression grooves on the surface (Fig. 1d). Cords were clearly flattened and congested (Fig. 1g). Histology showed moderate oedema, congestion and vascular thrombi in foetal membranes, with congestion and perivascular haemorrhages in UCs (Fig. 1h).

Increasing UCL causes greater resistance to flow through umbilical and placental vessels (Baergen et al. 2001). Our findings are consistent with foetal blood flow disruption (Collins 2002), venous stasis, reduced oxygen levels, hypoxia, foetal stress and, eventually, foetal death (Baergen et al. 2001, Baergen 2007). ELUCs have been associated with both maternal and foetal risk factors. Women with a history of ELUC have been found to have an increased risk of long cords in subsequent pregnancies (Baergen et al. 2001). The present report describes a recurrent case of UCA associated with ELUC in a dolphin. Average UCL in the stillbirths was 63 ± 5.94 cm but only 35.5 ± 1.5 cm in the 2 live calves. There are few formally reported data for normal UCL in dolphins. Slijper (1966) reported umbilical cord lengths of 45 to 50% of foetus length in odontocetes. However, K. Benirschke (unpubl.) measured a range of 25 to 45 cm and C. E. Van Elk (unpubl.) registered cord lengths between 20 and 44 cm, with an average measurement of 31.3 cm from the umbilicus breakpoint until bifurcation into both uterine horns in a total of 18 bottlenose dolphin placentas between 2002 and 2013. This has also been our experience, and that of others, in more than 50 normal births.

Table 1. *Tursiops truncatus*. Body weights (BW) and lengths (BL) and umbilical cord lengths (UCLs) of stillborn bottlenose dolphin calves. UCL was measured up to the bifurcation of the uterine horns; na: not available

Calf	BW (kg)	BL (cm)	UCL (cm)	UCL to BL (%)
1	na	79	62	78.48
2	13.6	103	51	49.51
3	14.8	106	76	71.69

UCLs are generally longer in males than in females (Collins et al. 2010), and male foetuses are associated with a higher risk of ELUC in humans (Baergen et al. 2001). It is interesting that the 3 affected foetuses in this case were all males and that the 3 surviving calves were females. Because other factors, including a different sire, were involved in the final 3 pregnancies, it is not possible to determine whether gender was a risk factor for UCA. Other calves from different females mated with the sire of the first 3 pregnancies were unaffected. Further research is required to determine whether gender or genetic factors pose higher risk factors for UCAs in dolphins.

ELUCs appear to correlate with foetal activity *in utero* (Baergen 2007). Experiments in rat foetuses have indicated that tensile forces on the cord secondary to foetal movement are important UCL determinants (Moessinger et al. 1982). In this case, foetal movements and reactions observed during ultrasonographic examination were more frequent and stronger in the affected foetuses. The use of diazepam in this case was intended to reduce both maternal and foetal movement, and this may have impacted favourably on the outcomes of the last 3 pregnancies, but again, more data are needed to establish whether this is the case.

Appropriate ultrasonographic monitoring of foetal development, placenta, membranes and UC is very useful and can identify UCAs in dolphins. Reported patterns/directions of coiling are similar in UCAs, and Collins et al. (2010) speculated that this may be due to a specific foetal behaviour or instinct, although this is not yet understood. There are reports

of human foetuses escaping from cord entanglements (Bakotic et al. 2000); however, in our opinion, the morphology of the bicornuate uterus and extreme flexion of the foetus in later pregnancy would make this highly unlikely to occur in dolphins. Although it is possible to intervene and deliver a foetus at risk in some species, this remains far more problematic in dolphins. The value of antenatal diagnosis in this species at this time is in alerting caretakers to the potential for intrauterine death, abortion and stillbirth, rather than intervention. Few data are available to definitively establish normal UCLs in this species, and further research is required to achieve this.

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