Research in Veterinary Science 90 (2011) 521–525

Contents lists available at ScienceDirect

Research in Veterinary Science

journal homepage: www.elsevier.com/locate/rvsc

Percutaneous, ultrasonographically guided technique of catheterization of the abdominal aorta in calves for serial blood sampling and continuous arterial blood pressure measurement

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ARTICLE INFO

Article history:
Received 12 April 2010
Accepted 20 July 2010

Keywords:
Arteriopuncture
Aortic catheter
Arterial blood pressure
Ultrasound-guided
Cattle

ABSTRACT

The study describes a technique of ultrasonographically guided transcutaneous catheter implantation into the abdominal aorta of 29 6- to 8-week-old German Holstein calves. Catheters were implanted between the left transverse processes of L3 and L4, left in place for 2 days and used for serial blood sampling and continuous measurement of blood pressure. Complete cell counts and clinical examination were performed before, as well as 1 and 5 days after implantation. Catheterization was successful in all calves. The catheter was patent for blood sampling and pressure recordings at all times. A significant decrease in red blood cells was found in all animals after catheterization, which remained reduced for 5 days. Clinical signs of anaemia were absent. In conclusion, ultrasonographically guided catheterization of the abdominal aorta provides a continuous arterial access in calves, whereby the minimal invasive technique and the ultrasonographical guidance reduces accidental tissue trauma and pain for the animal.
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1. Introduction

Long-term access to arterial vessels is a prerequisite of many experimental protocols involving repeated arterial blood sampling or continuous invasive monitoring of arterial blood pressure (ABP) (McGilliard, 1972; Amory et al., 1992; Rioja et al., 2008). Various accesses for catheter implantation designed for permitting repeated arterial sampling and continuous pressure recording have been described. For cattle, these sites include the auricular artery (Oakley et al., 1980; Parker and Fitzpatrick, 2006), the saphenous artery (Donawick and Baue, 1968), the carotid artery (Gustin et al., 1988), the coccygeal artery (Kotwica et al., 1990), the palmar common digital artery (Muylle et al., 1996) and the abdominal aorta (a. abdominalis) (Stowe and Good, 1960; Weber et al., 1992; Junhold and Schneider, 2002). The major disadvantages in using small vessels, such as the auricular artery, is that they are associated with a high risk of thrombosis and are easily traumatized, resulting in haematoma and loss of the site for subsequent sampling. It is therefore advisable to puncture vessels with a larger diameter such as the abdominal aorta. Furthermore, due to the close proximity to the heart, intra-aortic catheterization offers the advantage of accurate measurements of ABP and arterial blood gases (Fisher et al., 1980; Collie, 1991; Nagy et al., 2001).

There are two different approaches to implanting catheters into the abdominal aorta: direct puncture (Weber et al., 1992; Junhold and Schneider, 2002) or access via a peripheral vessel. For ruminants, introducing an aortic catheter via a peripheral vessel has been described in sheep (via the femoral artery (Katz and Bergman, 1969; Yelverton et al., 1969)), cows (via the circumflex iliac artery (Olsen et al., 1967)), as well as in very young calves under 21 days of age (via the umbilical artery (McGilliard, 1968)). These methods require general anaesthesia, in addition to extensive surgical intervention in exteriorization of the accessing vessel, thus rendering the animal more liable to infection. A technique of direct puncture of the abdominal aorta of calves in standing position under local anaesthesia without visual control has been described (Weber et al., 1992; Junhold and Schneider, 2002). However, repeated attempts to puncture the vessel, which are sometimes inevitable using this technique lacking visual control (blind puncture), hold the risk of causing extensive trauma to the abdominal aorta or adjacent organs, with subsequent development of severe haematoma. Such complications may be avoided by the use of ultrasonographically guided arteriopuncture (Braun et al., 2003; Mohamed et al., 2003).

The purpose of the study reported here was to investigate a novel technique for ultrasonographically guided percutaneous

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0034-5288/$ - see front matter © 2010 Elsevier Ltd. All rights reserved.
doi:10.1016/j.rvsc.2010.07.016

catheterization of the abdominal aorta in the unsedated, standing calf to provide a reliable continuous arterial access.

2. Materials and methods

2.1. Animal housing and care

Twenty-nine healthy German Holstein calves (seven female, 22 male; average age: 46.3 ± 6.3 (mean ± SD) days; body weight (BW) of 66.0 ± 6.3 kg were included in this study. Calves were housed in individual pens on straw bedding, were fed whole milk (10% of BW/d) divided into four feedings and had free access to hay, calf-starter and water. Daily clinical examination of the calves commencing 2 weeks prior to the start of the study ensured they were acclimatized to handling. The study was conducted under the guidelines and ethical review of the Research Animal Act of the Lower Saxony Federal State Office for Consumer Protection and Food Safety (research permit number 33.9-42502-04-08/1572).

2.2. Experimental procedures

In all calves, an indwelling catheter was introduced into the abdominal aorta on Day 0 and left in place for 48 h (Day 2). On the day after the implantation (Day 1) all calves underwent umbilical surgery, whereby the umbilical stalk of the calves was removed (Baird, 2008). Calves were randomly allocated to one of three anaesthetical protocols, which were compared for analgesic quality and cardiovascular impact in a further study.

Protocol 1: injection anaesthesia, whereby first xylazine (0.2 mg/kg i/m, Rompun, Bayer Vital GmbH, Leverkusen, Germany), then, after 10 min, ketamine (5.0 mg/kg i/v, Ketamin 10%, Selectavet; GmbH, Weyarn-Holzolling, Germany) was applied (Waterman, 1981). Anaesthesia was maintained with intermittent redoses of 2.5 mg kg^{-1} ketamine i/v at preset 15 min intervals.

Protocol 2: high volume caudal epidural anaesthesia using 2% xylazine (0.2 mg/kg) diluted with 2% Procaine solution (Procasel 2%, Selectavet GmbH, Weyarn-Holzolling, Germany) to a corresponding final volume of 0.6 ml/kg (Meyer et al., 2007).

Protocol 3: inhalation anaesthesia with 1.5–2 vol.% isoflurane to effect (CuraMED Pharma GmbH, Karlsruhe, Germany) and an oxygen flow rate of 1–2 L min^{-1} (CONOXIA med. O_2, Linde Gas Therapeutics GmbH, Unterschleißheim, Germany), using a semi-closed circle system (Sulla 808, Dräger, Lübeck, Germany), after induction with 0.1 mg/kg 2% xylazine i/m and 2.0 mg/kg ketamine i/v.

In the sense of multimodal pain management, rhomboid infiltration of local anaesthetic around the umbilicus, as well as preemptive (30 min prior to surgery) and postsurgical NSAID treatment (flunixine meglumine, 2.2 mg/kg BW i/v for three consecutive days; Finadyne RPS, Intervet GmbH, Unterschleißheim, Germany) was carried out.

During surgery, the aortic catheter was connected to a calibrated transducer via a fluid-filled extension set for continuous measurement of arterial blood pressure. For recording blood pressures, the electromechanical transducers were connected to a cardiovascular monitor (IntelliVue MP50, Phillips Medizin Systeme, Hamburg, Germany). The level of the scapulohumeral joint was used as the reference zero level in the standing calf and the centre of the thorax was considered as the reference zero level in dorsal and sternal recumbency for calibrating the transducer (Amory et al., 1992; Wagner et al., 1990). The arterial access was furthermore used for serial blood sampling for arterial blood gas analysis in 15 min intervals during surgery to monitor the quality of anaesthesia provided by the three protocols.

Due to the umbilical surgery, all calves received 2.5 mg/kg enrofloxacin i/v (Baytril®, Bayer Vital GmbH, Leverkusen, Germany) for 5 days, starting on Day 0. To investigate the effect of the catheterization procedure on the health status of the calf, animals underwent repeated clinical and laboratory examinations from Day 0 to Day 5. In addition, local reactions at the implantation site were monitored.

2.3. Methodology of ultrasonographically guided arteriopuncture

The transcutaneous ultrasound examination (Power Vision 6000 scanner, Toshiba Inc., Tokyo, Japan) was carried out in B-mode on the non-sedated, standing animal. To obtain adequate restraint, calves were tied to a stanchion and held by an attendant. Skin around the flank region was clipped and covered with ultrasound contact gel. The linear array transducer (linear transducer of 3–13 MHz, PLM–805AT; Power Vision 6000, Toshiba Inc., Tokyo, Japan) was set to a depth of 6–8 cm, positioned on the flank of the left abdominal wall below the transverse processes of the lumbar vertebrae (L3 and L4) and angled in a slight dorsal position (Fig. 1).

The puncture site, located on the animals' left hand side, between the transverse processes of L3 and L4 on the lateral border of the longissimus lumborum muscle was shaved 20 × 40 cm and aseptically prepared. Skin, subcutaneous tissue and muscle layers were anaesthetized by infiltrating 5 mL of 2% procaine hydrochloride. The calf was then draped with a sterile plastic cover. To preclude the risk of causing a tissue embolism (Andrew, 1976; Donhuijsen and Schmidt, 1983), the skin was pre-punctured using a 15 G hypodermic needle (supra cannula, length 40 mm, OD 1.8 mm, Erhard Medizinprodukte GmbH, Geislingen, Germany). Guided by the obtained ultrasonographic image, a stainless steel needle (TSK-supra cannula, length 120 mm, OD 2 mm, Tochigi, Japan) was inserted percutaneously and directed towards the abdominal aorta. The needle was angled at 45–70° to the transverse process in a ventromedial direction and advanced until visualized in the sonographic image. When the needle appeared on the screen as a sharp bright line, the operator guided the needle centrally into the aorta (Fig. 1).

Free pulsating arterial blood confirmed successful puncture of the abdominal aorta. The needle was rotated until the bevel of the needle was re-directed in caudal direction and a flexible J-tip guide wire (OD 0.71 mm, length 125 cm, Walter Veterinär Instrumente e. K., Baruth/Mark, Germany) was introduced and placed 10 cm into the aorta. In contrast to the Seldinger technique (Seldinger, 1953), the needle was not immediately withdrawn, but a 45 cm long sterile polyurethane catheter (Cavafix® Certo® Mono, OD 1.4 mm, ID 0.8 mm, B. Braun Melsungen AG, Melsungen, Germany), of which the proximal end was cut off using sterile scissors, was introduced over the wire and through the needle. The Seldinger technique was modified in this way, as 6–8 cm of skin and underlying muscle tissues proved to be too much resistance to thread the catheter over the wire into the aorta without additional stabilization from the needle. Furthermore, the J-tip guide wire enabled the perpendicular insertion of the catheter into the vessel. Finally, the wire and the needle were withdrawn successively, leaving 15 cm of the catheter in the lumen of the abdominal aorta. Control ultrasonography was carried out immediately after catheterization to check for correct catheter placement and the occurrence of haemorrhages. The catheter was then connected to a Luer-lock adapter (Teflon AD 1.5 mm, Walter Veterinär Instrumente e. K., Baruth/Mark, Germany) and a three-way stopcock before it was sutured to the skin. The catheter was flushed immediately after insertion and henceforth six times a day with heparinised (10,000 IU heparin × L^{-1}, Heparin-Calcium, Ratiopharm) 0.9% sterile saline solution to maintain patency. Sterile bandages and padding were used and changed daily to prevent physical damage during natural movements of the calves, to

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