A Technique for the Venous Cannulation of the Mammary Gland in the Lactating Sow

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ABSTRACT: The objective of this study was to develop a technique to cannulate the mammary venous system of the lactating sow in conjunction with the carotid artery. A total of 16 sows were subjected to surgery between d 3 and 6 of lactation. The dams were separated from their litter during the full surgical procedure and the post-surgical recovery period. The carotid artery was cannulated according to a previously described method. The mammary vein cannulation immediately followed the carotid artery cannulation. A small venous branch (approximately 4 mm in diameter) located on the lateral side of the thoracic region was used to obtain access to the mammary vein. It was isolated 4 to 5 cm above the plica lateralis, between the first and second anterior gland. The venous branch was exposed and a cannula inserted slowly for a distance of 16 cm or until the tip of the cannula would reach the most cranial point of the mammary vein. The cannula was allowed to follow the normal path of blood flow, running in a caudal to cranial direction. After recovery from surgery (1 to 2 h), the dams were returned to their respective litters and treated with antibiotics for a minimum of 6 d. All sows nursed and weaned normal litters. Cannulas were flushed with heparinized saline (20 U/mL) every 8 h and both arterial and venous blood samples (10 mL) were collected simultaneously at 0700, 1500, and 2300. Arterial and venous cannulas remained patent for a minimum of 15 d. The location of the cannula in the mammary vein was confirmed by postmortem examination.

Key Words: Veins, Cannulation, Mammary Glands, Sows, Lactation, Pigs

Introduction

Mammary gland metabolism in the lactating sow is a relatively poorly investigated field. Other than the classic papers by Linzell et al. (1969) and Spencer et al. (1969), which examined the uptake of plasma constituents by the porcine mammary gland, there is a paucity of data regarding nutrient need during lactation based on mammary gland metabolism and kinetic studies, especially in comparison to the abundance of information available in the ruminant. Much of our knowledge about the mammary gland is based on the cow model. Lactation efficiency represents a major economic factor in meat-producing mammals and further progress requires more basic understanding of mammary gland uptake and metabolism of milk precursors. A system permitting in vivo arterio-venous difference measurements of blood metabolites across the porcine mammary gland is needed. The objectives of this experiment were first to develop a technique that would allow an easy, repeated, and long-term sampling of mammary venous blood in lactating sows. A second objective was to obtain frequent blood samples in conscious, undisturbed, and physiologically normal sows.

Materials and Methods

Preparation of the Catheter

The catheters were prepared according to a modified method from Ford (1993). Catheters were formed using medical grade microbore tubing (Tygon, Fisher Scientific, Pittsburgh, PA) of .96 mm i.d. × 1.68 mm o.d. in size with a wall thickness of .36 mm (Figure 1). A 110-cm piece of tubing was cut and treated with TDMAC (tridodecylmethyl-ammonium chloride) heparin complex 7% wt/wt (Polysciences, Warrington, Pennsylvania).
Animal Management

A total of 16 sows were used. Three to six days after farrowing, individual sows were transferred from the farrowing unit to the surgery room. The litters remained in the farrowing crate and were provided with an additional heat lamp and warm liquid milk replacer (37°C) during the period of separation from the dam. The sows were moved to the surgical preparation area, restrained, and anesthetized with an initial dose of 1 mg/kg of a mixture of 250 mg of zoalazepam, 250 mg of telatamine, 250 mg of ketamine, and 250 mg of xylazine, diluted in 9 mL of physiological saline administered through the distal end of an ear vein.

Each sow was placed in left lateral recumbency and the hair was clipped over the entire exposed side of the mammary gland, the region between the anterior glands and the right shoulder, and above the shoulder itself. The sow was then rotated to a position of dorsal recumbency, the head was extended to expose the ventral side of the neck, and the hair was clipped. The skin was scrubbed using standard surgical procedures. Surgical anesthesia was maintained using halothane given to effect (2.5 to 3%) via a closed-circuit gas anesthesia (Dziuk et al., 1964).

Surgical Procedure

Carotid Artery Cannulation. All instruments, drapes, and towels were sterilized by autoclave before surgery. The cannulation of the carotid artery was performed before the mammary vein cannulation and was based on a modified method from Diehl and Day (1974) and Shipley (personal communication). An 8-cm incision was made on the right aspect of the ventral portion of the neck parallel to the trachea. The fat and muscle layers were dissected and the thick layers of connective tissues around the carotid were removed by blunt dissection. The exposed carotid was gently pulled upward using the index finger. The carotid was held in place with a retractor while two lengths of umbilical tape were passed under the artery at locations approximately 2 cm apart to control blood flow. A 16-gauge needle was inserted to create an opening through the arterial fascia and the catheter was inserted for a distance of 32 cm. The first cuff was sutured on the external fascia of the carotid while holding it with the index finger. The carotid was released and the remaining two cuffs were sutured on the muscle tissues surrounding the carotid. The distal end of the catheter was passed subcutaneously using a 15-cm-long straight trocar to the right lateral side of the neck where it was exteriorized.

Mammary Vein Cannulation (Figure 2). For the cannulation of the anterior mammary vein, the sow was turned to be positioned in left lateral recumbency. An incision was made approximately 4 to 5 cm above the plica lateralis between the first and the second gland, parallel to the ventral border of the fold, on the lateral thoracic region. A small venous branch of approximately 4 mm in diameter, draining the skin and running dorsal to ventral, was exposed by carefully dissecting the fat and the connective tissue. It was then retracted by passing tissue forceps underneath. The index finger was then used to hold the vein and a 16-gauge needle was inserted to create an opening through the fascia. The needle was withdrawn and the cannula, filled with heparinized saline, was inserted slowly for a distance of 16 cm. The cannula was premeasured to extend into the main mammary vein for a distance of approximately 6 cm so that the distal end of the cannula would reach the most cranial point of the main mammary vein, near the xiphoid process. At this position, the first cuff blocked further entry. The cannula was fixed in position by suturing the cuffs horizontally to the connective tissue bed underlying the vein.

The distal end of the cannula was passed s.c. from the site of cannulation to the dorsal midline approximately 10 cm anterior to the point of the shoulder, where it was exteriorized. This was done by attaching

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Figure 1. Segment of cannula illustrating the location of the cuffs.

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Animal use protocol no. A3R166. Approved by the University of Illinois Laboratory Animal Care Advisory Committee.
Figure 2. Top left: Lateral view of the mammary gland before the venous cannulation. Arrow indicates site of incision. Middle, left: Enlarged view of the vein to be cannulated. The vein is held by finger to facilitate the cannulation. The vein is indicated by an arrow. Bottom, left: A 16-gauge needle is inserted to create an opening through the fascia of the vein. Top, right: Cannula insertion into the vein after withdrawing the needle. Cannula and vein are indicated by arrows a and b, respectively. Middle, right: Cannula is inserted into the vein. The first cuff blocks further entry into the vein. Each cuff is sutured to the fat underlying the vein. Bottom, right: The trocar is passed subcutaneously from the site of cannulation to the dorsal midline between the two shoulders.

The cannula was passed to a 30-cm-long trocar. The arterial cannula was exteriorized at the same final point, approximately 3 cm from the venous cannula. The surgical site for the mammary vein cannulation was closed by suturing the skin layer only. The distal ends of both cannulas were adapted for sampling by inserting a 1-cm-long, blunt 18-gauge needle fixed to a luer-lock injection cap. The cannulas were folded and placed in a protective purse, which was directly glued to the skin. Several layers of porous tape and cotton bandage were wrapped around the sow's neck and over the purse to protect and hold it in position.
Post-Surgical Monitoring. After surgery, sows were allowed to recover in a holding pen adjacent to the surgery room. After recovery (approximately 1 to 2 h), sows were returned to their respective farrowing crates and allowed to nurse their litter normally. Body temperature and feed intake were recorded daily. A 70% alcohol solution was sprayed daily on the area where the cannulas were exteriorized. Antibiotics (Procaine penicillin G, $3 \times 10^5$ U/mL, Pfizer, New York) were administered daily at recommended dosage (22,400 IU/kg) during the sampling period. Pigs were weaned on d 21 of lactation.

Sampling Procedure. The cannulas were flushed with a sterile heparinized (20 U/mL) saline solution (1.9%) every 8 or 12 h and a heparin block was maintained. Samples were obtained at 0700, 1500, and 2300. Both arterial (10 mL) and venous blood (10 mL) were taken simultaneously in non-heparinized syringes. In each case, the first 3 mL of fluid withdrawn was discarded. Subsequent withdrawals were considered to be representative blood samples.

Results and Discussion

A technique to cannulate the mammary gland venous system in conjunction with the carotid artery was developed. Both arterial and venous cannulas remained patent for a minimum of 15 d in 10 sows and 7 d in one sow, allowing for daily blood sampling. All sows nursed normally until weaning (Table 1). In one sow, there was development of localized abscesses 14 d after surgery at the wound sites, and a systemic infection was apparent on the postmortem examination of the abdominal cavity on d 28 after surgery. The

Table 1. Performance of sows subjected to mammary venous and arterial cannulation

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Experimental$^a$</th>
<th>Non-experimental$^b$</th>
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<tbody>
<tr>
<td>No. of pigs at birth</td>
<td>9.75 ± 1.25</td>
<td>10.1</td>
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<tr>
<td>Litter wt at birth, kg</td>
<td>16.55 ± 2.70</td>
<td>14.41</td>
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<tr>
<td>Pig wt at birth, kg</td>
<td>1.51 ± .15</td>
<td>1.43</td>
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<tr>
<td>No. of pigs at d 21</td>
<td>9.75 ± 1.25</td>
<td>8.5</td>
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<tr>
<td>Litter wt at d 21, kg</td>
<td>44.83 ± 7.33</td>
<td>42.76</td>
</tr>
<tr>
<td>Pig wt at d 21, kg</td>
<td>4.55 ± .16</td>
<td>5.09</td>
</tr>
<tr>
<td>Avg daily gain, g</td>
<td>1,392 ± 259</td>
<td>1,350</td>
</tr>
<tr>
<td>Parity no.</td>
<td>2.75</td>
<td>2.13</td>
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$^a$Mean ± standard error of the mean.

$^b$Represents average sow performance at the Swine Research Center over the 10-mo period during which surgeries were performed and blood samples collected. Approximately 400 litters are represented in this data set.
Figure 4. Sow Mammary Circulatory System. The above illustration was prepared to represent our understanding of mammary circulation based on information available in the literature and on dissection completed in our laboratory. Anastomosis of the anterior and posterior mammary arteries (lateral basal branch of the pudendal artery) to the dorsal point of the mammary system has been suggested, and we have attempted to illustrate it. In addition, we suggest that the arterial system is largely located inside the abdominal cavity and dorsal to the abdominal wall, whereas the venous system is completely located on the ventral side of the abdominal wall (i.e., outside the abdominal cavity). (a) internal thoracic vein; (b) external thoracic vein; (c) anterior mammary vein or abdominal; (d) posterior (inguinal) mammary vein or abdominal; (e) external pudic vein (pudendal); (f) internal thoracic artery; (g) middle cranial branch of the pudendal artery; (h) medial cranial branch of the pudendal artery; (i) external pudendal (pudic) artery; (j) lateral basal branch of the pudendal artery; (k) caudal superficial epigastric artery; (l) body wall. Arrows indicate blood flow direction; arrows below (ventral) body wall indicate venous, those above (dorsal) body wall indicate arterial.

Other sows did not show any presence of infection upon postmortem examination of the mammary glands. Presence of the cannulas in the main mammary vein from dissection of the anterior mammary glands in the first four successfully cannulated sows on d 6 postweaning confirmed location of the cannula. The cannula was located in a venous branch running dorsal to ventral and reaching the main mammary vein, following the blood flow in a caudal to cranial direction (Figure 3). The blood leaving the mammary glands uses two different pathways (Turner, 1952). The anterior glands (thoracic and abdominal region) are drained through two large longitudinal mammary veins, also referred as the subcutaneous abdominal veins. These veins run parallel on each side of the mammary system. They are found running along the plica lateralis and drain mainly into the internal thoracic vein; some side branches drain into the external thoracic vein, in a caudal to cranial direction (Figure 4). Blood exists the posterior mammary glands in the inguinal region by way of the same subcutaneous abdominal vein but in a cranial to caudal direction and drains into the external pudic vein (Turner, 1952; Linzell, 1974). We have chosen to concentrate our technique on the anterior portion of the mammary system. Cannulation at the cranial end of the anterior portion allows for sampling blood that is representative of the major mammary venous
output. Cannulation at the posterior end of the mammary system may not allow accurate sampling of the major mammary venous output. In addition, mammary gland involution seems to be initiated in the inguinal region in smaller litters, whereas the abdominal and thoracic glands usually remain functional.

The advantages of using a skin branch draining from the lateral thoracic region are as follows: it is less invasive, there is less risk of reducing blood flow in the main mammary vein, and there is no trauma to the mammary gland itself; thus decreasing the chance of discomfort to the sow during nursing. To our knowledge, this is the first technique proven to be useful over a long-term period for the study of in vivo porcine mammary gland milk precursor uptake. Linzell et al. (1969) and Spincer et al. (1969) were pioneers in the study of porcine mammary gland metabolism; however, their cannulation techniques have never been described sufficiently to reproduce their work. Linzell et al. (1969) measured arteriovenous differences of amino acids and glucose. However, none of the sows used were under the same physiological state or same lactation stage; days in lactation at the time of sampling varied from 12 to 61. In addition, only one sample per sow was obtained. The technique suggested herein allows for sampling under the conscious state. In the research of Spincer et al. (1969), two sows were sampled once during lactation and no indication on the sampling day was provided.

In contrast to Linzell et al. (1969), the presence of the litter with the dam never caused problems to the cannulas during the experiment, proving the protective purse to be an effective, simple, and non-traumatic device to protect and maintain the cannulas intact. The device used by Linzell et al. (1969) was heavy, complicated, and presumably traumatic to the sow. Finally, our technique is simple and enables daily multiple blood sampling, over more than a 2-wk period. The technique reported herein is aimed at providing a detailed description of the mammary venous system cannulation.

**Implications**

The cannulation technique described for the mammary venous system and the carotid of the lactating sow allows long-term acquisition of venous and arterial blood samples from animals in a conscious, normal physiological state. This technique offers a new approach for studying in vivo mammary gland metabolism.

**Literature Cited**


