

Technical Bulletin

Principles of Thoracic Surgery in Swine

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Introduction

Many experimental procedures involve thoracotomies because of the common usage of swine in cardiovascular research. The reasons for using swine in these types of studies are the similarities in anatomy and physiology which are shared with humans. Common areas of cardiopulmonary research include hemodynamics, myocardial infarction, heart failure models, device testing, grafting techniques, wound healing and respiratory physiology.^{1,2} There are species-specific considerations to which the surgeon must pay attention to avoid complications and to achieve adequate surgical exposure.

Surgical Anatomy¹⁻⁴

The chest of the pig is massive with 14-15 ribs, which are very wide compared to other species. The width of the ribs, their angle and the narrow intercostal spaces necessitate changes in the approach to performing a lateral thoracotomy. The first seven ribs are sternal and the rest asternal forming the costal arch. If the fifteenth rib is present it may be floating. The width is greatest in the third to sixth ribs and the length greatest in the sixth to seventh. Overall the thorax tends to be more barrel shaped than other domestic animals. The backward slope and angle of the ribs tends to be more acute than other animals. The angle and size of the ribs varies substantially with the growth of the pig. Miniature pigs tend to have fewer ribs than farm pigs.

The sternum is similar in size and shape to other quadruped animals. It consists of six segments starting with the manubrium and proceeding caudally to the xiphoid cartilage. Median sternotomies are tolerated in the pig because the midline tends to remain cartilaginous except for the manubrium into sexual maturity.

The porcine heart is typical of most mammals, except for the presence of the left azygous (hemiazygous) vein. This vein provides drainage from the intercostal vessels into the coronary sinus. Thus, the blood flow from the coronary sinus includes systemic as well as myocardial blood. There is a vestigial hemiazygous vein which enters the precava. The large left azygous vein can be ligated or blocked with an interventional balloon if necessary for the study. The myocardial blood supply is similar to 90% of the adult population with right side dominance. The heart usually lies in full sternal contact from the second to sixth ribs and in smaller animals is in full contact with the lateral walls of the thorax.

The lungs are composed of apical (cranial), middle and diaphragmatic (caudal) lobes with an accessory lobe on the right lung. Interlobular fissures are incomplete. The bronchial tree divisions are typical of other species; however, the right apical lobe has a bronchus that stems from the trachea proximal to the tracheal bifurcation. The pulmonary arteries branch along the dorsal and lateral sides of the bronchioles while the pulmonary veins are mainly on the medial or ventral sides. The mediastinum is friable and cannot be considered functionally complete in smaller pigs because it tends to rupture when manipulated.

Lateral Thoracotomies^{1,3,4}

Lateral thoracotomies can be a challenge because of the narrowness of the intercostal spaces, which can result in minimal exposure of the structures of interest. Placing a rolled up towel or sandbag under the thorax to make the operative side more convex will increase surgical exposure. Also, the incisions should be performed within the intercostal spaces parallel to the ribs. This means that lateral thoracotomy incisions will be oblique rather than vertical because of the anatomy of the ribs in swine. Also the foreleg of the pig should be retracted cranially and tied in place.

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Cardiac and pulmonary tissue is very friable in swine. This tissue friability decreases with maturity and, consequently, miniature pigs tend to be easier to manipulate surgically at the same weight as farm breeds because of their greater age at the same weight. Gentle handling of tissues using appropriate instrumentation is imperative to prevent complications, such as tearing of atrial tissue and rupture of pulmonary tissue, which may cause emphysematous bullae.

Most of the structures of interest can be accessed through a left 4-6th intercostal space. A skin incision made along a line from the dorsocaudal aspect of the scapula towards the first rib will expose the position of the fifth intercostal space. From this incision the surgeon can enter any of those three intercostal spaces. The incision will transect the latissimus dorsi muscle which contains major branches of the thoracodorsal artery and vein which must be ligated. The other muscles which will be transected are the external abdominal oblique, serratus ventralis and pectoralis ascendens. The intercostal muscles are incised with a stab incision which is extended with Metzenbaum scissors taking care to avoid damage to the lung.

The edges of thoracotomy incisions should be protected with wetted gauze laparotomy sponges when using retractors. The self-retaining retractors indicated for most swine will need to be pediatric instruments with blunt blades in order to avoid injuring the underlying pulmonary tissue with retraction blades that extend too deep into the thoracic cavity. The mediastinum is thin and easily ruptured in swine. Chest tubes or instruments will readily injure the structure and, as a practicality, the mediastinum should be considered incomplete, because it is likely that fluids or surgical hemorrhage from one side of the thoracic cavity will extend into the other side through inadvertent rents. When packing away the lung to expose the heart, wetted laparotomy sponges should be used rather than manual traction.

Closure of thoracic surgical incisions is comparable to other species. Lateral thoracotomies are closed with heavy gauge (0-1) circumferential sutures that have been preplaced around the cranial and caudal ribs adjacent to the incision. Three to five sutures are usually required to close the incision adequately. Sutures may either be absorbable or nonabsorbable materials. Braided sutures provide better security and ease in knot tying under traction. After preplacing all of the sutures, the central one in the incision is tied first, followed by the peripheral ones, with alternated tying of sutures in both directions. Rib approximating forceps are helpful for tying the first suture. The latissimus dorsi always requires closure as a separate layer, even in the smallest pig. However, the decision whether or not to close the rest of the muscles in layers varies with the size of the pig. Muscle layers can be closed either with interrupted or continuous sutures of any of the synthetic absorbable materials. The subcutaneous tissues are also variable in thickness depending upon the size of the pig, but this layer is closed, if necessary, using synthetic absorbable materials. The skin layer is best closed with a subcuticular layer of 2/0 or 3/0 synthetic absorbable suture. Other types of closure may be used if preferred but the use of external staples is discouraged because they lead to an increase in inflammation by trapping foreign material into the incision.

Median Sternotomies^{1,3,4}

Median sternotomy incisions can be performed successfully in swine as a survival procedure, unlike in many other animals (Figure 6). Pigs experience relatively little discomfort with the procedure, especially if the manubrium sterni is left intact, as it can be for many cardiac procedures. Care must be taken when performing this procedure, because the heart is in sternal contact between the fourth and seventh costal cartilages in most pigs. The sternum may be bisected using a sternal saw if a scalpel handle or straight ribbon retractor is held along the interior surface of the sternum to prevent cardiac trauma. It may also be bisected using sternal cutters of all the various configurations used for humans. The apex of the heart is in close apposition to the diaphragm at its most cranial attachment to the sternum at the level of the seventh costal cartilage. The heart will remain in a pericardial cradle after this procedure is performed because of the close attachment of the pericardium to the sternum.

A median sternotomy is closed in a similar fashion to the lateral thoracotomy. Nonabsorbable heavy gauge (0-2) wire or braided nonabsorbable sutures or plastic lock ties are preplaced in the intercostal spaces from cranial to caudal. Care should be taken not to occlude unnecessarily the interior mammary artery with these sutures; however, it may be sacrificed if necessary. If the manubrium sterni was not transected, then the pig will have an

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easier recovery with less postoperative discomfort, and the surgical incision will be easier to close in proper alignment. If it was transected, then great care should be taken to ensure that closure of the sternotomy is performed in an anatomically correct fashion. Any misalignment of the boney closure will result in postoperative discomfort and impaired healing. Bone wax for hemostasis is usually not necessary if the sternum is properly aligned and heparin has not been administered. The sutures are tied sequentially from cranial to caudal. If the pericardium is opened it should not be sutured closed because of the possibility of developing a stricture or pericardial tamponade. A single-layer closure of muscle and subcutaneous suture using 2/0-3/0 synthetic absorbable suture should be placed next. In larger pigs this may require a double layer of closure. The skin is closed in the same fashion as for the lateral thoracotomy with a subcuticular suture.

Perioperative Care^{1,5}

The pulmonary tissues are friable and must be handled gently during thoracic surgery. Overinflation of the lungs with a respirator can cause alveolar rupture and emphysematous bullae. The tidal volume is approximately 10-15 ml/kg and the inflation pressure on a respiratory should not exceed 18-20 cm H₂O. Oxygen flow rates will differ between anesthetic machines but 5-15 ml/kg/min is a general starting range

Evacuation of air from the chest can be performed by a variety of methods. The lungs should be expanded to their maximum capacity to reduce the air volume of the thorax while closing the initial layer of the thoracotomy, whether it is a lateral or median incision. For simple procedures in which postoperative bleeding and leakage of air are not expected, the chest may be evacuated with a needle or preferably a small-gauge catheter and syringe with an attached three-way valve. The insertion is in the dorsocaudal area of the thoracic cavity, taking care to avoid damage of the lung with the needle or catheter. This evacuation may be performed after closing the internal muscle layers so that a watertight seal exists. If a chest tube is to be placed, it is inserted while the incision is still open. It is placed in a dorsocaudal position at least two intercostal spaces caudal to the lateral thoracotomy. The tube is passed through the skin after making a stab incision, and then advanced into the thoracic cavity. For a median sternotomy, single or double chest tubes are placed on the ventrolateral aspects of the midthorax cranial to the attachment of the diaphragm. Tubes may either be the one-way valve Heimlich type for short- or mid-term usage, or the use of water-sealed systems may be required for more involved procedures that have the possibility of increased complications. Chest tubes are placed with purse-string sutures around them in the skin, and the chest tubes are removed and the purse-string sutures are tightened after it has been determined that pneumothorax or hemorrhage are no longer likely.

Summary

The purpose of this technical bulletin is to discuss the surgical access issues related to performing thoracotomies. Related links⁵ on the Sinclair website discuss the issues of anesthesia, analgesia, cardiac emergency drugs, and prolonged postoperative care.

The major difficulties encountered in thoracic surgical procedures are likely to be cardiac arrhythmias and cardiodepression. Methods of preventing these common complications are detailed in the technical bulletin on anesthesia and emergency care. Inherent in the design of these surgical protocols is the necessity of designing an appropriate anesthetic and analgesic protocol for the procedure being performed. Good surgical technique alone is not sufficient to have a successful outcome for a thoracic surgery. Intraoperative and postoperative monitoring of heart rate, electrocardiogram, blood pressures, and blood gases is essential in these cases if survival is expected.

References

1. Swindle, MM: *Swine in the Laboratory: Surgery, Anesthesia, Imaging, and Experimental Techniques, 2nd Edition*, Boca Raton, FL: CRC Press, 2006 (in press).
2. Swindle MM (ed): *Swine as Models in Biomedical Research*, Ames, IA: Iowa State University Press, 1992.
3. Swindle MM, Horneffer PJ, Gardner TJ, Gott VL, Hall TS, Stuart RS, Baumgartner WA, Borkon AM, Galloway E, Reitz BA: Anatomic and anesthetic considerations in experimental cardiopulmonary surgery in swine, *Lab Anim Sci*, 36(4):357-61, 1986.
4. Swindle MM, Bobbie DL (Illustrator): *Basic Surgical Exercises Using Swine*. New York: Praeger Publishers, 1983.
5. Related Links: <http://www.sinclairresearch.com/literature.htm>