

Surgical Anatomy of the Sternal Median and Paramedian Approaches on the Junction of the Veins and the Arteries of the Pig Heart

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흉골 정중선 절개와 방정중선 절개 접근술에 따른 돼지 심장 대혈관들의 외과적 해부구조의 육안적 비교

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요 약 : 돼지 심장의 해부학적 구조에 대해서는 많은 연구가 보고되어 있으나 흉골 정중선 절개와 방정중선 절개 후 절개선에 나타나는 돼지 심장 대혈관들의 외과적 해부구조에 대한 보고는 아직 없고 심장적출 및 수술에 외과적 해부구조의 숙지가 필수적이므로, 체중 15 kg-25 kg의 돼지 12마리를 4마리씩 3군, 즉 정중선절개군, 우측방정중선절개군, 좌측방정중선절개군으로 나누어 흉골열개 후 나타난 심장 대혈관들의 육안적 외과구조를 보고하고 심장적출술을 시도해 각 수술절개 접근법에 따른 수술의 용이성을 관찰하여 더 나은 수술접근법을 선택하는데 필요한 정보를 제공하고자 본 실험을 실시하였다. 그 결과, 우측과 좌측 방정중선절개법에 의해 흉골을 완전 열개시에는 제 1흉골과 갑상연골 부위에서 정중선으로 접근하는 초승달형 절개를 통해 internal mammary artery의 절개 위험성을 피할 수 있음을 발견하였고 흉골정중선절개에서는 상행대동맥의 정 중앙부에 aortic cannula를 쉽게 장착할 수 있었고 특히 비숙련자에게 더 적절한 수술 방법임을 알 수 있었다. 한편 숙련자가 심장적출이 아닌 동맥관개존증등과 같은 심장수술의 경우에는 방 정중선절개로써 환축의 수술 후 통증을 감소시키고 조기치유가 가능하다면, 초승달형 절개법을 응용한 방정중선 절개를 권할 수 있고 이에 따른 임상적 관찰이 요구되는 바이다.

Key words : surgical anatomy, sternal median approach, sternal paramedian approach, pig, and heart

Introduction

To the cardiac surgeons, it is more important to have an information on the relationship of the heart with the body and the vessels than the anatomical morphology itself. The surgical anatomy after the sternal median and paramedian approaches has not been studied yet on the pig heart.

Thus, there are many morphological anatomical reports about the pig heart. A pig has 6 sterna and 14 or 15 pairs of ribs at most, but rarely 13 to 17 pairs seen. The 1st sternum, called manubrium sterni or

presternum, articulates with the first two ribs. The first 7 ribs articulate directly to the sternum. A pig heart is characterized between ruminants and carnivores². In normal position that pig is on his feet, the heart occupies ventral side of the mediastinum. It is located in the middle of sternum from the 2nd to the 5th intercostal space^{2,7}. This is the same description done by Bourdelle and Bressou⁴ who say that the pig heart is obliquely situated in front of the 3rd, 4th, 5th, and 6th ribs. The apex of heart situated at the 6th costal cartilage². The heart apex is the lower border of the heart on the diaphragm. The base of it is upper border behind sternum at the 2nd intercostal rib. Pericardium adheres from the 4th sternum to the base of xyphoid

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process². Bourdelle⁴ says that the insertion of pericardial fiber starts from the 3rd rib. The ostium of the pulmonary trunk can be found below the 3rd rib with the aorta².

With these anatomical backgrounds, we described the surgical gross anatomy on the junction of the veins and the arteries of the pig heart after the paramedian and the median incisions. Then, the surgery of heart extraction was simulated in order to give a guideline to choose the better surgical approach in the pig cardiac surgery and heart experiments.

Material and Method

Twelve mongrel pigs were studied and divided into three groups, median sternotomy group (M group), right paramedian (parasternal) sternotomy group (RP group), and left paramedian sternotomy group (LP group). The body weight was from 15 to 25 kg.

The pig was anesthetized according to the protocol mentioned below. Ketalar 50[®] (ketamine chlorhydrate, Parke-davis) 10 mg/kg was mixed with Rompun[®] (xylazine chlorhydrate, Bayer) 2 mg/kg and Droleptan[®] (droperidol, Janssen-Cilag s.a.) 0.5 mg/kg in one syringe. This preparation was injected into the pig intramuscularly to induce sedation just enough to put an intravenous catheter into the auricular vein without any difficulty. Once the intravenous catheter was placed, Diprivan[®] (propofol, Zeneca Pharma) 3 mg/kg was injected to induce the surgical anesthesia.

Heparin 660 units/kg was intravenously administered to avoid any formation of microemboli during the excision and the cannulation. Once propofol and heparin were injected, the tracheostomy was followed immediately with the insertion of 6 inches endotracheal tube into the trachea to control ventilation mechanically. The respiration was set to ventilate automatically at 20 ml/min in a constant pressure providing 50% of oxygen mixed with 50% of air.

After the deep anesthesia, the pig was placed ventrodorsal recumbency. Four pigs in the M group had their skin cut above the middle of the sternum. The sternum was exposed. The xyphoid cartilage was cut in a half with the bone cutting scissors. The index finger was inserted beneath the xyphoid cartilage to

make a way to locate the bone cutting scissors in the incision line without damaging the apex of the heart. Until the 8th or 9th sternum from the xyphoid, the sterna were cut with the bone cutting scissors. The rest were cut with the bone cutting knife and mallet. Four pigs in the RP group had the right articulation of the costal cartilage and the sternum dissected by bone cutting scissors. Four LP groups had the left junction cut. The small vessels were coagulated by electrocoagulator (Supratome CT[®], EMC, France) at level 4. The thorax was kept open by self-retaining retractor.

The macroscopic surgical anatomy of different approaches was described on the heart and its great vessels before and after the pericardium was opened. Then, aortic root cannula (DLP[®], 14gauge, 7French, USA) was inserted into an ascending aorta. The cardioplegic solution (SLF 103, Laboratoire Aguettant, Lyon, France) was used at -5°C. Heart was extracted to see which approach is more apt to perform cardiac surgery and heart extraction.

Results

The bone scissors more easily cut the thorax in the RP and the LP group than the M group. In the M group, the right and left internal mammary arteries were found away from the median sternal incision line, except that they were located just 2-3mm below from the 1st sternum incision line. These arteries were much safer from being cut while sterna were incised in the M group than in the RP group or the LP group. In the RP and the LP group, these arteries were seen just below the sternal paramedian incision line. It could be very easily cut while dissecting costosternal junction. The right and the left mammary arteries were gathered at the front part of the 1st sternum and separated at the end side of the 1st sternum. They flowed below the costosternal junction. The arteries flowed down 1~2 mm away from the costosternal junction and the median xyphoid cartilage. From the xyphoid cartilage, the internal mammary arteries flowed down to the paramedian abdomen.

The amount of thymus was very variable depending on the body weight of a pig. In the M group, thymus was seen at the surgical incision line and seemed

to cover all the pericardium at the base of heart. The vena cava superior (VCS) was very hard to be seen without removing thymus. After removing thymus and dissecting the pericardium above aorta, the ascending aorta was located profoundly in the incision area between the right atrium and the pulmonary trunk as shown in Fig 1(A). The length of the ascending aorta and the profoundness were very varied from each species.

Unlike the M group, the RP group seemed to have the VCS and the aorta straighter in the view with less thymus. Therefore, the VCS outside of the pericardium was very clearly seen even without removing the thymus at the surgical incision site as Fig 1(B). The VCS seemed to be protruded at the incision line between the 1st and 2nd costosternum junction. After cutting the pericardium, the aorta was felt a little below and beside from the VCS. The VCS should be pulled aside a little not to damage itself while a pressure was placed to have a cardioplegic cannula injected into the ascending aorta. The pulmonary trunk (PT) was not in the face of the surgical incision area.

The LP group had much thymus seen like the M group. After the pericardium was cut, the PT protruded in the face of incision area as shown in Fig 1(C). The aortic arch and the descending aorta were in view. The ascending aorta was below the PT. The VCS was a little far away from the incision area to the right side. In one pig, the VCS seemed not on the incision area and was difficult to be clamped.

Since the ventral view of the aorta is clearer in the

M-group, the aortic cannula was easily placed. That gave a reason to have the median sternotomy more preferred approach for the access of ascending aorta. The access to the VCI was not much different among the three groups. The VCS could be fully accessed in the RP group.

Discussion

The pig is an ungulate animal that has hoofs and walks on tips of its digits. It has a very short life span till it will be slaughtered in 5 to 6 months after birth. This animal doesn't have much interference or inter-relationship with men. Therefore, when making an experiment with a pig, it is really important not to harm or excite them before anesthesia. Specially to carry out the cardiac experiment, the anesthesia has to be administered without exciting the pig. Roger⁶ explains which anesthesia is used in swine. For the surgical operation of a pig, ketamine 12 mg/kg are used as sedatives and isoflurane is used as an anesthetic. As for the pre-surgical medicine, butorphanol is used at 0.2 mg/kg intramuscularly with 1 g of cefoxitin intravenously. The endotracheal tube is intubated, and the ventilation through it is set automatically. The anesthesia was maintained by isoflurane at the volume of 1.0% to 2.5%. Oxygen was supplied at 1 L/min. Bloor *et al.*³ used ketamine about 25 mg/kg intramuscularly in the combination of 1/30 mg of atropine. Then, 20 mg/kg of thiamylal was injected in auricular vein. The state of anesthesia was maintained with halothane in 1% and oxygen. Hof-

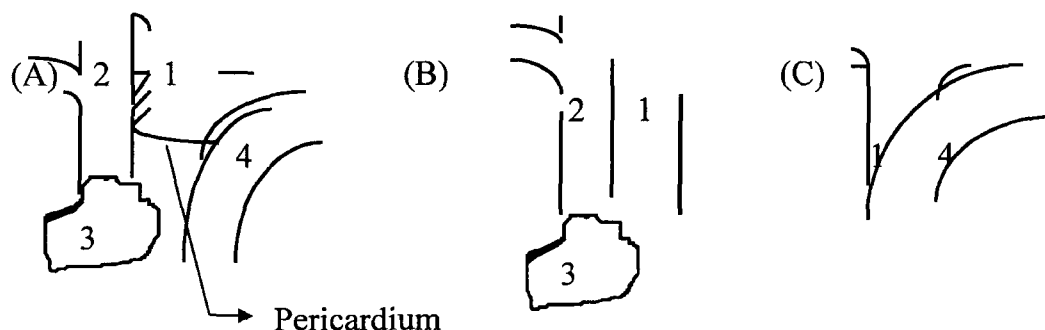


Fig 1. Typical different surgical gross views found after the pericardium cut in (A) the M group, the median sternotomy, (B) the RP group, the right paramedian sternotomy, and (C) the LP group, the left paramedian sternotomy. (1. aorta, 2. vena cava superior, 3. right atrium, 4. pulmonary trunk).

fenberg used, in his experiment, ketamine 20 mg/kg with xylazine 2.2 mg/kg and atropine 0.03 mg/kg, mixed them in one syringe, and injected intramuscularly. Then, he sprayed topical xylocaine on the larynx for insertion of the endotracheal tube and maintained the anesthesia by Isoflurane at 1~1.5% and oxygen 2L/min. For this study, ketamine 10 mg/kg was enough with the combination of droperidol for preanesthesia.

The pig chest is not flat like most of the human. The sternum area was pointed downward to the ground. The first and second sternum were very thick and protrude. The first sternum was very difficult to be cut exactly in the middle, even in the median sternotomy group (M group). In the right (RP group) and the left paramedian sternotomy group (LP group), a bone cutting scissors easily cut the costosternal junctions.

As Anderson and Becker¹ describes that the aorta of a human heart is located very much deep from the ventral area and springs out between the right atrium (RA) and the pulmonary trunk, we found the same result in the aorta of the pig heart.

By cutting the side of the xyphoid cartilage, the internal mammary artery can be easily damaged. Therefore, even in the procedure of the paramedian approach, either the right or the left, the xyphoid cartilage and the first sternum should be incised as center as possible like the median sternotomy. By following the above instruction, the paramedian sternum approach should accompany by cutting in the elliptical shape.

The thymus is a lymph-like organ which variously covers the base of the heart just below the 1st, 2nd, and 3rd sternum. In this experiment, the thymus was distributed a lot because the pig used here was rather young with the body weight from 15 to 25 kg. The amount of the thymus was very variable among the body weight of 15 to 25 kg. Occasionally, some pig with 25 kg had greater thymus than the pig with 20 kg.

The M group had the full ventral view on the ascending aorta along with VCS outside the pericardium covered by the thymus. A part of the pulmonary trunk is rarely viewed after cutting the pericardium.

In order to put a cannula in the center of the ascending aorta before the aortic arc, it was better to push tenderly the PT and the right atrium aside and downward.

As the PT is not on the view, the RP group was easier to put a cannula into the aorta than the LP group. The RP group needed more attention not to damage VCS with the needle of stay suture in the aorta. Care must be taken not to mistake the brachiocephalic trunk as an ascending aorta. The full ventral view of the ascending aorta was more clearly seen in the M group with the starting point of brachiocephalic trunk. In the LP group, the PT must be pushed down and outward in order to pinch the aortic cannula properly in the ascending aorta. If the cannula was near the side of PT instead of the ventral center of ascending aorta, it is very often damaging the junction of the aorta and the PT. The cannula should not go into the aortic arc nor the descending aorta.

In the human medicine, the paracostal approach or the median sternotomy approach is the most performed procedure to approach the heart. Minimally invasive cardiac surgery (MICS) has been performed through the right parasternal approach for the aortic valve replacement by the incision between 3rd and 4th cartilages and with the resection of the 2nd cartilage.

In dogs and cats, there is a review given on the technique and complications of median sternotomy by Burton and White⁵. The complications that Burton and White⁵ found in their clinical cases are thoracic limb neurological deficits, excessive postoperative discomfort, sternal fracture, sternal osteomyelitis, or delayed wound healing.

I believe there could be many different methods to approach the thoracic cavity and the heart, contrary to the idea of Burton⁵ that median sternotomy is the only approach. I could actually approach them not only through the median sternotomy but also through the paramedian sternotomy on each side of right and left. Of course, there is a danger of cutting the internal mammary artery. But, if the after-operation pain could be reduced through the paramedian sternotomy, it is worth to try and there comes the skill of the surgeon. It is in the hand of the surgeon to make the difficult surgery possible.

When the heart is approached to the means of paramedian sternotomy, it is necessary to be very cautious not to damage the internal mammary artery either right or left, especially near the xyphoid cartilage and the first sternum. For the surgery on the side of the VCS and the aortic arch, it is better to approach to the right paramedian incision.

Conclusion

Through this study, we found that the elliptical incision of the right or the left paramedian sternotomy approach could avoid the risk of cutting the internal mammary arteries at the area of the 1st sternum and the xyphoid cartilage. Because the median sternotomy approach showed the easiness of inserting an aortic cannula into the middle of ascending aorta, the surgical extraction of a pig heart can be easily and safely approached by the median sternotomy, even for the unskilled practitioners. With the surgery like patent ductus arteriosus (PDA) or something concerning on the PT and the aorta, the left paramedian incision approach could provide a better view in combination of the elliptical incision.

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