

## Application of Lower Sternal Incision with On-Pump, Beating Heart Intracardiac Procedures in Congenital Heart Disease

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### ABSTRACT

**Background:** The purpose of this study was to explore the application of lower sternal incision with on-pump, beating heart intracardiac procedures for the treatment of congenital heart disease.

**Methods:** A total of 106 cases with congenital heart disease were performed with lower sternal incision under the beating heart condition. The sternum was sawed open to the third sternocostal joint through a small incision in the lower sternum. Cardiopulmonary bypass was developed without aortic cross-clamping. The simultaneous left atrium and ventricle suction and integrating sequential de-airing procedure was established to improve the exposure of the surgical field and intraoperative de-airing. We also randomly selected 100 patients with similar disease and age as controls. These control patients underwent middle sternal incision surgery with arresting heart.

**Results:** The results showed that all the patients were successfully completed with the surgery without death and serious complications, eg, air embolism, residual shunt, and complete atrioventricular block. The operative and cardiopulmonary bypass time in the experimental group was not significantly different from that in the control group. The length of the skin incision in the experimental group was shortened by 4.8 cm compared to that in the control group. The incidence of sternal deformity in patients under 3 years old in the experimental group was significantly lower than that in the control group.

**Conclusions:** Lower sternal incision with beating heart can reduce the surgical injury, simplify the operation procedure, and improve the therapeutic efficacy. It is a safe and effective approach for the treatment of congenital heart disease.

### INTRODUCTION

Currently, the majority of surgeries for the treatment of congenital heart disease utilize a fully split sternal incision in the middle of the chest, which has the advantages of clear exposure and easy operation. However, it also has the disadvantage of large areas of trauma, chicken breast in infants, and

poor appearance. With the improvement of cardiac surgical techniques, various types of small-incision heart surgery have emerged in pursuit of better appearance and small trauma [Chan 2001; Nicholson 2001; Komai 2002]. Lower sternal incision with beating heart technique used in direct-vision intracardiac surgery has the advantage of small trauma, easy and safe operation, wide application, fast recovery, and short hospitalization time. We applied lower sternal incision with beating heart technique to 106 patients with congenital heart disease and reported the results below.

### MATERIALS AND METHODS

From November 2009 to March 2011, we performed low sternal incision surgery with on-pump beating heart for 106 patients with congenital heart disease. In addition, we

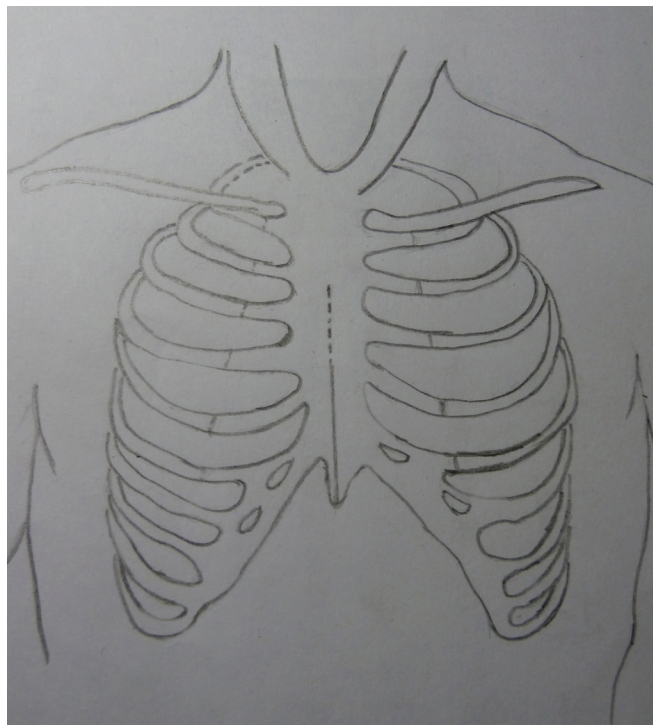


Figure 1. The skin incision was about 4 to 10 cm with the upper end to the tissue 2 cm below the sternal angle and lower end to the xiphoid (solid line). The sternum was sawed open to the third sternocostal joint (dotted line).

Received December 9, 2011; accepted May 9, 2012.

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Table 1. Primary Disease and Ages of the Patients in Both Groups

	Small Incision with Beating Heart (n = 106)	Control Group (n = 100)	P
Age			
<3 years	37	35	.106
3–14 years	46	46	.278
>14 years	23	19	.060
Diseases			
Atrial septal defect	29	26	.058
Ventricular septal defect	62	61	.178
Partial atrioventricular septal defect	13	11	.061
Right coronary artery right atria fistula	1	0	.484
Ruptured sinus of valsalva aneurysm	1	2	.207

randomly selected 100 patients with similar disease and age as control in the same period. The patients in the control group underwent incision surgery in the middle sternum with arresting heart. The diagnosis of all cases was confirmed by cardiac echocardiography, chest x-ray, and electrocardiography (ECG). The patients' basic information is shown in Table 1.

The patient was in supine position during the surgery. A small incision was made in the middle portion of the lower sternum. The skin was cut open for 4 to 10 cm with the upper end to the tissue 2 cm below the sternal angle and lower end to the xiphoid (Figure 1). The sternum was sawed open to the third sternocostal joint, and the sternal retractor was used to distract the sternum. Because the sternal retractor was easy to move in the infants, it could be sutured on the sternum. The pericardium was suspended, and the upper edge of the incision was pulled toward the upper-forward direction using a thyroid retractor. The aorta was ascended, and aortic intubation was performed by using a straight tube. Thin walled venous cannulas are particularly helpful in allowing standard cannulation and yet leaving adequate space for intracardiac operation (Figure 2). The left ventricular drainage tube was placed via the root of the upper pulmonary vein to establish the cardiopulmonary bypass. Aortic cross-clamping and cardioplegia infusion were not applied in all the patients. After clamping the superior and inferior vena cava, the lesions were explored through the right atrial incision. The atrial septum was cut open, and the left atrial drainage tube was placed into the left ventricle through the mitral valve. The mitral valve was maintained in an open status, and the atrial septum was suspended. Consequently, the returning blood of coronary sinus flew into the left atrium via the incision of the atrial septum and absorbed through the left atrial drainage tube, which resulted in a clear surgical field. Nasopharyngeal temperature was maintained at 30° to 32°C, and perfusion pressure was maintained at 40 to 70 mmHg during the surgery. The heart was maintained at weak beating condition. After the cardiac malformations were corrected using the conventional method, the incision of the atrial septum was sutured. Before the closure of atrial septum incision, a de-airing needle was placed in the root of the aorta. The surgical bed was maintained in a left-leaning and lower-head position. Left

atrial drainage was temporarily suspended, and the lung was expanded by the anesthetist, which resulted in the exhausting of the left ventricular air through 2 mitral, left atrium, and atrial septum. A very small amount of the residual air was discharged through the de-airing needle in the root of the aorta. For patients with a weight of less than 20 kg, polyester thread, instead of steel wire, was used to fix the sternum.

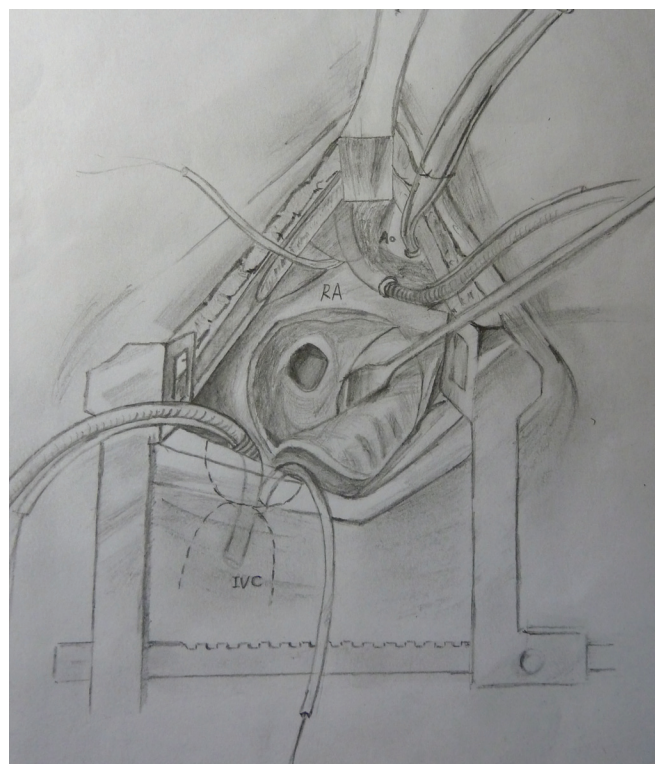


Figure 2. After establishment of cardiopulmonary bypass, the pericardium was suspended, and the upper edge of the incision was pulled toward the upper-forward direction using a thyroid retractor. Thin walled venous cannulas are particularly helpful in allowing standard cannulation and yet leaving adequate place for intracardiac operation. Aortic cross-clamping and cardioplegia infusion were not applied in all the patients.



Figure 3. Skin incision after surgery. A, Lower sternal incision under the beating heart. B, Middle sternal incision surgery with arresting heart. The length of the skin incision in the small incision group was shortened compared to that in the control group.

All values are expressed as the mean  $\pm$  standard deviation (SD). Differences between the 2 groups were analyzed using independent-sample *t* tests or  $\chi^2$  tests. A probability value less than .05 was considered significant in all analyses (Statistical Product and Service Solutions Statistical Software; SPSS Inc., Chicago, IL, USA).

## RESULTS

Surgery was successfully completed under the beating heart condition for all 106 patients without the need to extend the incision or change the position of aortic cannulation. Complications of complete atrioventricular block and embolism did not occur. Air embolism and residual shunt were not observed by transesophageal echocardiography monitoring during the surgery. In the early stage after surgery, no patients required second thoracotomy for bleeding. All patients had stage wound healing. The length of the skin incision in the small incision group was shortened by 4.8 cm compared to that in the control group (Figure 3). Echocardiography examination revealed no residual shunt before discharge. Statistical analysis showed that there was no significant difference in operating time and cardiopulmonary bypass time between the 2 groups. However, the bleeding within 24 hours after surgery and the incidence of sternal deformity in patients under 3 years in the small incision with beating heart group were both lower than those in the control group (Table 2).

## DISCUSSION

Conventional thoracic surgery in the middle chest has a good exposure, and unexpected problems are easy to deal with. However, it may cause chest infections, chicken breast, and chest scars, leading to a poor body appearance. The anterolateral incision is long and located in the prothorax, which affects the breast development for some women. In addition, sternocostal joints and right breast arteries are easily damaged during the surgery [Bleiziffer 2004; Murala 2005].

Since the 1990s, the technique, which includes incision of the skin in the lower sternum, partial splitting of the upper sternum and maintaining an intact upper part of the sternum, has been used for clinical purposes. This technique was initially applied in off-pump coronary artery bypass graft. Similar to conventional incision, coronary arteries on both sides are exposed [Niinami 2000; Niinami 2001]. Postoperative follow-up showed that this technique can reduce the incidence of postoperative sternal infection, bone nonunion, and chest deformity. Recently, cardiovascular surgeons have applied this technique to open heart surgery under cardiopulmonary bypass conditions. However, because of certain defects in the surgical field exposure, high technical requirement for the doctors, and limited indications of the patients, this technique can be used only in patients with simple lesions and appropriate ages. In addition, due to the small incision, the spaces for the remaining aorta are decreased after aortic cannulation, which results in difficulties in aortic cross-clamping. Furthermore, it is difficult to place the electrodes into the pericardial cavity in order for defibrillation after intracardiac operation. All these disadvantages limited wide application of this technique.

Surgery on the beating heart does not clamp the ascending aorta and does not need to place arresting intubation during cardiopulmonary bypass. Therefore, the requirement for the aorta exposure is relatively small. In addition, due to the reduction of intubation number and the position of the instruments, the surgical fields are more easily exposed. In this study, we applied the technique of lower sternal incision with on-pump, beating heart intracardiac procedures, which improved the surgical field exposure, reduced the incidence of complications, increased surgical therapeutic efficacy, and expanded the surgical indications. During the surgery with beating heart, we should pay attention to the following technical issues. Firstly, perfusion pressure should be maintained

Table 2. Comparison of the Efficacy between the Two Groups\*

	Small Incision with Beating Heart (n = 106)	Control Group (n = 100)	P
Operating time, min	135.3 $\pm$ 22.1	141.2 $\pm$ 23.6	.057
Cardiopulmonary bypass time, min	57.1 $\pm$ 6.6	56.7 $\pm$ 6.6	.704
Bleeding within 24 hours of surgery, mL	131.9 $\pm$ 62.1	152.8 $\pm$ 68.6	.024
Thoracic deformity in patients under 3 years old	2	11	.007
Length of skin incision, cm	6.4 $\pm$ 1.5	11.2 $\pm$ 3.6	<.001

\*Data are presented as mean  $\pm$  standard deviation, except the *P* value of operating time and cardiopulmonary bypass time, the rest of them in 2 groups have significant differences (*P* < .05).



at 40 to 70 mmHg based on the age and weight of the patient. The coronary perfusion flow rate should be maintained at 0.8 to 1.0 mL/g (myocardium)/min [Borowski 1997]. Maintaining a certain level of perfusion pressure can ensure not only adequate myocardial perfusion, but also that the aortic valve remains in a closed condition, which prevents the air from entering the systemic circulation [Mo 2008]. Second, maintaining a surgical field without blood is necessary for successful operation. The approach we used was to cut the atrial septum open and place the left atrial drainage tube into the left ventricle through the mitral valve, which can ensure that the left ventricle was connected with the atmosphere and that the pressure of the left ventricle was lower than that of aorta. Consequently, the air can be prevented from entering the systemic circulation. In addition, the blood from the coronary sinus can be returned to the left ventricle through the incision of the atrial septum and then absorbed by the left ventricular drainage tube. Therefore, the surgical field was relatively clear, and the operation was not affected. Surgery with beating heart allows sustainable supply of oxygenated blood for the myocardium, and most of the time the heart maintained regular beating. When the perfusion flow rate was sufficient, myocardial ischemia-reperfusion injury can be effectively prevented. In the course of cardiopulmonary bypass, the nasopharyngeal temperature was maintained at 30° to 32°C. Thus, it is close to the physiological condition. Studies have shown that surgery with beating heart can reduce the release of inflammatory cytokines [Wan 1996], which is beneficial to the protection of the brain, lung and liver [Xiao 2001; Karadeniz 2008; Mo 2011].

Incision of the lower sternum under the beating heart condition is easy to operate and does not require specific surgical equipment and techniques. In the event of special circumstances, it can be easily transitioned to a conventional mid-chest incision without heart beating. Therefore, it is a safe procedure for the treatment of congenital heart disease. However, there were several points that we need to pay attention to during the process of the operation. First, it is important to select the appropriate type of disease for this procedure. Those patients who require a lot of operations in the bottom of the heart, eg, tetralogy of Fallot and ventricular septal defect, should be excluded. In addition, patients with aortic valve regurgitation should be excluded in order to ensure myocardium and systemic perfusion rate as well as to ensure a good surgical field. Second, in order to ensure a good surgical field, the chest must be sawed in the middle of the sternum. Otherwise, the sternal retractor is easily tilted to one side, which affects the surgical field exposure. Since children have soft sternums and the sternal retractor is easy to shift, the sternal retractor should be fixed on the sternum to prevent its displacement. Third, aortic intubation is the key procedure of the operation. The surgery assistant should gently pull down to the aorta to expose the places for intubation. The cannula with a straight head should be used, and after successful intubation, it should be fixed firmly to prevent sliding out. Fourth, de-airing and prevention of air from entering into the systemic circulation is the key for the success of the surgery. During the process of exposing the surgical

field, stretch-induced aortic valve regurgitation should be avoided. De-airing should be performed strictly according to the comprehensive sequential approach as described above. De-airing can be monitored by transesophageal ultrasound examination. Finally, in the event of unforeseen circumstances, eg, aortic intubation accident and combination with other malformations, transition to regular incision should be performed to reduce the occurrence of any accidents.

In summary, the lower sternal incision with beating heart technique can be applicable to many diseases, can further simplify the surgical procedure, and can improve the therapeutic efficacy. It is a safe, effective, and cosmetic approach for the treatment of congenital heart disease.

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