Pectoralis major muscle turnover flap reconstruction for treatment of deep sternal wound infection in infants and children

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Abstract

Objective: The aim of the study is to assess the therapeutic effect and applicability of pectoralis major muscle turnover flap reconstruction for treatment of deep sternal wound infection after cardiac surgery in infants and children. **Methods:** From march 2013 to october 2021, 23 patients with deep sternal wound infection after cardiac surgery underwent pectoralis major muscle turnover flap reconstruction.The data and outcomes of the patients were retrospectively analyzed. **Results:** 20 patients were treated with unilateral pectoralis major muscle turnover flap reconstruction,3 patients were treated by bilateral pectoralis major muscle turnover flap. All of the sternal wounds healed successfully. All patients survived and were discharged without evidence of infection. In a follow-up period, ranging from 15 to 83 months (mean 32.6 months), all patients demonstrated normal development with no limitations to limb movements. There were no signs of chronic sternal infection in all of them. **Conclusion:**Pectoralis major muscle turnover flap reconstruction is a simple,feasible and effective treatment of deep sternal wound infection after cardiac surgery in infants and children,with minimal developmental problems.

Introduction

Deep sternal wound infection(DSWI) after cardiac surgery is a rare but severe complication, with a reported rate of 0.5-7.5% in the pediatric population[1,2]. The infection is defined as deep or severe, when the sternum or mediastinal structures are involved, and it demands effective surgical and antimicrobial therapy[3]. In adult patients, various techniques have been used to treat DSWI with good results, such as vacuum-assisted closure**,** vascularized muscle flaps**.** However,only limited information are available concerning the treatment of DSWI in infants and children[4-6]. The optimal treatment of DSWI is still controversial in infants and children, due to the pathophysiological characteristics and developmental problems.

In this report, we present our experience in treating DSWI following cardiac surgery with pectoralis major muscle turnover flap(PMMTF) reconstruction in infants and children, including immediate and mid-term outcomes.

Materials and methods

Patients

A retrospective review of 23 patients with DSWI following cardiac surgery were treated in the Department of Pediatric Cardiac Surgery, The Seventh Medical Center of the PLA General Hospital from March 2013 to October 2021.Patients' data were retrospectively obtained from the hospital records.International Review Board approval, consent statement, and clinical trial registration are not applicable to our study.

The patients' characteristics,surgical management and outcomes were retrospectively analyzed. Follow up was completed with outpatient review and by telephone interviews

Surgical technique

DSWI is defined as infection involving fascia or deeper with at least one of the following: evidence of infection seen at re-operation or spontaneous dehiscence, positive culture of mediastinal fluid and/or positive blood culture and/or chest pain with sternal instability and temperature higher than 38 degrees Celsius[7]. All patients with DSWI are well prepared preoperatively, including early wound exploration and drainage, antibiotic therapy, nutritional support and cardiopulmonary function.

All patients are anesthetized with tracheal intubation. The infected tissue is resected in full layer along the edge of the incision and all sternal wires are removed. Use a rongeur to remove the infected sternum until healthy solid bone with briskly bleeding margins is found. If the bone is obviously necrotic, the entire sternum is resected. Explore the posterior sternum space to thoroughly remove infected tissue and foreign materials, such as residual pacemaker wires. If infection involves extracardiac conduit and patch, they must also be removed.Mediastinal secretions and infected tissue are sent for culture. The wound is irrigated with hydrogen peroxide and normal saline.

According to the size of the wound defect decide whether unilateral or bilateral pectoralis major flap. If an unilateral pectoralis major flap is used, the right pectoralis major is usually chosen because muscles are more developed on this side. Dissect the overlying skin off the pectoralis major muscle from medial to the anterior axillary line.Cut off the muscle at the junction of medial 2/3 and the lateral 1/3 by using electrotome.Dissect the medial muscle from lateral to medial until the perforating vessels are visible. Flip muscles to fill the mediastinum as a turnover flap. The turnover muscle flap is fixed with double-stranded no.7 silk sutures by methods of relieving tension. The drainage tube is placed in the mediastinum. skin is closed with interrupted silk sutures.Postoperatively,chest wall is pressurized with elastic bandage. The drainage tube is left in place for 4-7 days based on the amount of drained fluid. Postoperative antibiotic therapy was performed for 2-3 weeks according to culture results.

Table 1 Preoperative characteristics of patients

Case No.	Sex	Age (months)	Weight (kg)	Diagnosis	Initial operation	Time from surgery to infection(days)
1	M	11	6.5	DORV,VSD	Intraventricular tunnel repair	12
2	M	4	3.6	PA,VSD,PDA	Melbourne shunt	9
3	M	51	17.2	TOF	Complete repair	15
4	F	2	3.2	TAPVC	TAPVC correction	11
5	M	12	6.5	VSD	VSD repair	17
6	M	5	4.9	CAVSD,PH	CAVSD repair	23
7	M	33	12.5	PA,VSD	VSD repair,extracardiac valved conduit	16
8	F	52	16.2	MR	MVP	25
9	F	20	9.3	VSD	VSD repair	13
10	F	31	11.6	TA	BDG	14
11	M	3	4.2	IAA,VSD,PDA	One stage correction	8

Case No.	Sex	Age (months)	Weight (kg)	Diagnosis	Initial operation	Time from surgery to infection(days)
12	F	6	6.2	CAVSD,PH	CAVSD repair	21
13	M	13	8.5	TOF	Complete repair	10
14	M	4	5.1	TAPVC	TAPVC correction	8
15	F	3	5.3	TGA,VSD,PDA	Switch,VSD repair	11
16	M	22	11.2	DORV,VSD,PH	Intraventricular tunnel repair	13
17	F	18	8.7	VSD ,PH	VSD repair	18
18	F	6	6.8	CAVSD,PH	CAVSD repair	12
19	M	9	7.3	PAS,TS	PAS repair, slide tracheoplaty	10
20	M	10	6.7	TGA,VSD,PDA	Switch,VSD repair	9
21	F	21	13.6	TOF	Complete repair	19
22	M	5	4.6	Coa,VSD	One stage correction	11
23	F	11	9.8	CAVSD,PH	CAVSD repair	17

DORV: double outlet of right ventricle; VSD: ventricular septal defect; PA: pulmonary atresia; PDA:patent ductus arteriosus; TOF:tetralogy of Fallot; TAPVC:total anomalous pulmonary venous connection; CAVSD: complete atrioventricular septal defect; PH: pulmonary hypertension; MR: mitral regurgitation; MVP: mitral valvuloplasty; TA: tricuspid atresia; IAA: interrupted aortic arch; TGA: transposition of great artery; PAS: pulmonary artery sling; TS: tracheal stenosis; CoA: coarctation of aorta

Statistical analysis

Data were analyzed with SPSS 25 software. Continuous data are expressed as mean±SD. Inferential comparisons were made using the two-sample mean comparison t test. p values of less than 0.05 were considered significant.

Results

A total of 23 patients with DSWI following cardiac surgery were treated in our center from March 2013 to October 2021, including 14 patients who underwent initial cardiac operation at other hospitals. During the same period, 2079 consecutive pediatric cardiac procedures via median sternotomy were performed in our center and 9 patients were diagnosised DSWI(0.4%). The patients' preoperative characteristics are summarized in Table 1. Postoperative DSWI developed an average of 14 days after the initial operation. The average interval between diagnosis of DSWI and PMMTF reconstruction was 4.7 days(Table 2).

Table 2 postoperative characteristics of patients

Case No.	Time from DSWI to PMMTF(days)	Time from DSWI to PMMTF(days)	Culture	Reco

Case No.	Time from DSWI to PMMTF(days)	Time from DSWI to PMMTF(days)	Culture	Reco
1	3	Staphylococcus aureus	Staphylococcus aureus	Righ
2	7	(-)	(-)	Righ
3	5	Pseudomonas aeruginosa	Pseudomonas aeruginosa	Bila
4	6	Staphylococcus aureus	Staphylococcus aureus	Righ
5	7	Acinetobacter baumannii	Acinetobacter baumannii	Righ
6	7	(-)	(-)	Righ
7	7	Staphylococcus aureus	Staphylococcus aureus	Righ
8	6	Staphylococcus epidermidis	Staphylococcus epidermidis	Bila
9	4	Staphylococcus epidermidis	Staphylococcus epidermidis	Righ
10	5	(-)	(-)	Righ
11	8	Pseudomonas aeruginosa	Pseudomonas aeruginosa	Righ
12	4	Staphylococcus aureus	Staphylococcus aureus	Righ
13	4	Staphylococcus epidermidis	Staphylococcus epidermidis	Righ
14	7	(-)	(-)	Righ
15	5	Staphylococcus aureus	Staphylococcus aureus	Righ
16	6	(-)	(-)	Bila
17	5	Staphylococcus epidermidis	Staphylococcus epidermidis	Righ
18	3	Staphylococcus aureus	Staphylococcus aureus	Righ
19	3	Staphylococcus aureus	Staphylococcus aureus	Righ
20	5	(-)	(-)	Righ
21	5	Staphylococcus epidermidis	Staphylococcus epidermidis	Righ
22	6	Pseudomonas aeruginosa	Pseudomonas aeruginosa	Righ
23	4	(-)	(-)	Righ

Wound cultures were positive in 16 patients (69.6%). Staphylococcus aureus in 7 patients (30.4%), Staphylococcus epidermidis in 5 patients (21.7%), Pseudomonas aeruginosa in 3 patients(13.0%), Acinetobacter baumannii in 1 patient (4.3%). There were no statistically significant differences in clinical characteristics between patients with and without wound culture positive(Table 3).

20 patients were treated with unilateral(right) pectoralis major muscle turnover flap,3 patients were treated by bilateral pectoralis major muscle turnover flap. All of the sternal wounds healed successfully in one stage. All patients survived and were discharged without evidence of infection.The mean hospital stay from PMMTF reconstruction was 17.1 days.

Follow-up ranged from 15 to 83 months with an average of 32.6 months. During the follow-up, there were no signs of chronic sternal infection, and all wounds healed well. All patients were between 25 to 75 percentile in their weight and height nomograms and appropriately developed for their age according to the Denver development scale[8]. In 3 patients,chest wall were mild asymmetry.There were no limitations in upper trunk or limb movements in all patients.

Table 3 comparision of clinical characteristics of wound culture negative and positive

Characteristic	Wound culture negative (n=7)	Wound culture positive (n=16)	Wound culture positive (n=16)	*P*
Age(month)	12.42±10.34	16.56±15.92	0.537	0.537
Weight(kg)	7.56±3.27	9.36±5.12	0.404	0.404

Characteristic	Wound culture negative (n=7)	Wound culture positive (n=16)	Wound culture positive (n=16)	*P*
Time from surgery to infection(d)	13.29±5.38	14.31±4.67	0.647	0.647
Time from DSWI to PMMTF(d)	5.86±1.21	5.06±1.53	0.238	0.238
Hospital stay after reconstruction(d)	14.86±4.81	18.13±5.86	0.211	0.211

Discussion

Median sternotomy is the most frequently used incision for pediatric cardiac operation. However,DSWI after cardiac surgery is a severe complication that not only increases mortality and morbidity[9,10], but also prolongs hospital stays and increases treatment costs[11,12]. Risk factors for sternal wound infection in infant include low gestational age,prolonged ICU stay and open chest, cyanotic congenital heart diseases, high complexity of the surgical treatment, quality of the operative field treatment and surgical team experience[13-16].

The principles of treatment for DSWI are adequate debridement,removal of all infected tissue and foreign materials, a well-vascularized tissue transfer to promote wound healing, anterior mediastinal protection, and chest wall stability[3]. If the wound infection is suspected, early wound exploration and drainage are necessary, empirical broad spectrum intravenous antibiotics should be initiated. when culture results are available, targeted antibiotics should be used. once deep sternal infection is definite, surgical debridement should be performed as soon as possible. During debridement, the presence of residual foreign materials and infection involving implants should be carefully examined.In our study, 4 patients were found to have residual pacemaker wires and one patient was found to have infection involving the extracardiac conduit.we removed residual pacemaker wires,replaced the extracardiac conduit.

There is no consensus as to the best specific treatment for close the sternum after thorough surgical debridement.At present,the main treatment methods include sternal rewiring after debridement, Vacuum-assisted closure(VAC) therapy and flap reconstruction. For deep sternal wound infections, part of the sternum is often resected, resulting in unsatisfactory outcomes with the method of sternal rewiring. VAC can improve wound healing by increasing parasternal blood flow, reducing bacterial loads, enhancing formation of granulation tissue [17,18].But, using a vacuum system over an open sternum has raised concerns that the strong negative pressure could cause right ventricle rupture and other bleeding complications[19],and for sternum necrosis and severe infection, the failure rate of VAC is still high[20,21].

Currently, flap reconstruction is regarded as the gold standard in DSWI where there is inadequate sternum following debridement or uncertainty whether the infectious process has been controlled[22]. There has been a variety of flap choices for reconstructing sternal wounds, such as the pectoralis major flap, rectus abdominis flap and omental flap. The pectoralis major is a broad flat muscle that lies close to the sternum, allowing for easy dissection and providing adequate coverage. It has rich blood supply from thoracoacromial artery, segmental pedicles from the internal thoracic artery and some branches of the lateral thoracic and intercostals arteries. Based on the above advantages, pectoralis major muscle flap is the most commonly used flap and has achieved good results in adult patients [23].However, there are only a few reports about these techniques in pediatric patients.In this study, we used the pectoralis major muscle turnover flap technique. This technique preserves the lateral one third of the muscle with its dominant vascular pedicle and motor nerves, and preserves the contour of the chest wall, producing a better cosmetic result[24]. We consider the technique is easy and unilateral flap can completely fill stermal defect in most patients.It may be related to the relatively short sternum in infants. If unilateral flap does not completely close the defect, the residual sternal

defect can be filled by splitting the opposite pectoralis major muscle turnover flap. Zahiri demonstrated the turnover flap to be associated with less postoperative complications when compared to the advanced pectoralis major flap[25]. Many studies suggest the use of VAC therapy to bridge definitive primary closure or flap reconstruction. However, we consider that immediate flap reconstruction after debridement may improve outcomes and shorter treatment time. In our study,all patients underwent one-stage debridement and flap reconstruction,and all of the sternal wounds healed successfully.

In pediatric patients, long-term development and limb function should be of special concern. During the follow-up,we found no evidence of any upper limb or upper trunk movements disorder,and chest walls were stable in all patients.Erez and colleagues [3] reported similar results in 5 neonates who were treated with unilateral PMMTF reconstruction. In female patients, the use of pectoralis major flap may have potential impact on breast development, should be long-term follow-up.

The study is subject to the usual limitations of a retrospective, uncontrolled study design. Our experience with pectoralis major turnover flap reconstruction over the past 10 years and have achieved good therapeutic results. Therefore, pectoralis major turnover flap reconstruction is our first choice for the treatment of DSWI. This is one of the reasons we did not have a control group. Another limitation of this study is the number of cases is small, so further large-scale controlled studies are needed.

Conclusion

DSWI after cardiac surgery is a potentially life-threatening complication. Early recognition and thorough debridement are important for the management of DSWI. Pectoralis major muscle turnover flap reconstruction is simple,feasible and effective treatment of DSWI in infants and children,with satisfactory mid-term outcomes, almost no complications. Developmental problems require long-term follow-up.

Competing interests

The authors declare that they have no competing interests.

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