Minimal Access Surgery for the Repair of Simple Congenital Heart Defects

Factors Affecting Hospital Stay after Surgery

Objective: **We reviewed our experience of minimal access surgery to elucidate the efficacy and safety of this approach and determine the factors affecting hospital stay.** ***Methods:*** **Seventy-seven patients (age, 11.8±11.0 years), with body weight of more than 10 kg, were operated using various forms of minimal access approach for repair of simple congenital heart defects [atrial septal defect (ASD) in 40, ventricular septal defect in 37]. These included lower partial sternotomy (n=68) and mini-thoracotomy (n=9, ASD only) with limited skin incision of 4–11 cm. The anesthetic protocol was modified to wean all patients from ventilator soon after operation. The protocol of discharge from hospital (critical pass) was 14 days in the early period (n=30) and 10 days in the late period (n=47).** ***Results:*** **There were no hospital or late death, and no hospital re-admission. None of patients required blood transfusion. The endotracheal tube was extubated in the operating room in 48 cases (62%). Twenty-four patients (31%) failed to fulfill conditions of the critical pass. Univariate analysis of factors affecting unfavorably the critical pass demonstrated that the median approach, retention of pericardial effusion and social reasons were statistically significant, while an opened pleura and aortic cross-clamp time were marginally significant. Multivariate analysis indicated that the retention of pericardial effusion was the only significant factor that failed critical pass [p=0.007, odds ratio (OR) 5.7, 95% confidence interval (CI) 1.61 –19.8]. In addition, a pericardio-pleural fenestration was the only significant factor that affected favorably the pericardial effusion (p=0.035, OR 0.2, 95%CI 0.47–0.89) by multivariate analysis.** ***Conclusions:*** **Our experience demonstrated that minimal access surgery of the simple congenital heart defects provided excellent cosmetic results. Retention of pericardial effusion, possibly due to pericarditis, was a major risk factor of the prolonged hospital stay. The pericardio-pleural fenestration could reduce the risk of retention of effusion.**
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Key words: minimally invasive cardiac surgery, minimal access surgery, partial sternotomy, congenital heart defect, hospital stay

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In the current era, the "minimally invasive" cardiac operation has become increasingly popular for the repair of both acquired and congenital heart diseases. The term minimally invasive is used in a rather broad sense to mean new or smaller incisions, modified approaches to cardiac access, and operation on a beating heart. For patients with congenital heart disease, the primary benefits of minimally invasive surgical technique are likely to be better cosmetic result and possibly shorter convalescence period. In conjunction with a "fast-track" strategy, such technique may be used to decrease hospital stay and cost. These objectives, however, should not take precedence over safety and meticulous repair. Recent reports[1-7] demonstrated that ministernotomy or trans-xiphoid approache is equivalent to conventional approaches in terms of efficacy and safety for repair of atrial septal defect (ASD), ventricular septal defect (VSD), and complex cardiac defects.[5,8] In

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our institute, we applied the minimal access surgery to simple congenital heart defects with ASD or VSD provided their weight exceeded 10 kg. The technique included a limited midline skin incision along with a lower partial sternotomy, which allowed us to achieve both superior cosmetic results and optimal safety and exposure with standard techniques of cannulation and cardiopulmonary bypass, but without the need for the special surgical instrument.[9] Furthermore, our patients were considered to be the candidates for simple intraoperative anesthetic management that allowed early tracheal extubation, shortening of the stay in intensive care unit (ICU), and the clinical practice guideline protocol, the so-called critical pass, that enabled us to shorten the hospital stay. In this study, we reviewed our experience of minimal access surgery to elucidate the efficacy and safety of this approach and the factors affecting hospital stay after application of critical pass.

Subjects and Methods

Patients. From October 1997 to May 2002, 77 patients with congenital heart disease underwent minimal access surgery. Our inclusion criteria for this approach were simple congenital heart defects and a body weight of more than 10 kg. There were 41 male and 36 female patients. The mean age was 11.8±11.0 years (median 9.3 years), with a range from 1 to 52 years. Of those, 61 patients were less than 14 years old, with a mean age of 7.5±3.6 years (median 7.6 years), whereas the remaining 16 patients were more than 15 years old and considered to be adults, with a mean age of 26.3±15.3 years (median 18.2 years). Informed consent was obtained from all the patients.

The present study comprised 40 patients with ASD and 37 patients with VSD. One patient had ASD associated with partial anomalous pulmonary venous drainage, while 2 patients had VSD associated with a double chambered right ventricle. The majority of patients (32 of 37 patients) with VSD had subarterial defect. The diagnoses were made all the patients using cross-sectional and Doppler echocardiography.

Anesthetic management. Rapid induction of anesthesia was achieved by administering high concentration (8%) of sevoflurane with the "single breath" technique, a bolus of fentanyl (20–30 μg/kg), and weight-related dose of vecuronium bromide (0.1 mg/kg). After endotracheal intubation, anesthesia was maintained with sevoflurane (2 to 3%) and additional vecuronium bromide in 40 minute intervals. During cardiopulmonary bypass, the anesthetic gas was discontinued and a continuous infusion of chlorpromidine (1–2 μg/kg/min) was commenced. When the chest was closed, bupivacaine (1 ml/kg) was given locally around wound and skin where a drainage tube was inserted. At the end of the operation, the effect of vecuronium bromide was reserved by administration of neosigmine bromide and atropine sulfate. This anesthetic protocol permitted us to wean all the patients from ventilator on the day of operation.

Operative technique. Operative methods of lower partial sternotomy used for subarterial defect type VSD have been described in detail elsewhere[9] and were modified for ASD repair. Briefly, a lower sternal split subsequent to a 4 to 10 cm skin incision was employed for minimal access. The lower part of the sternum was split with a sternum striker from the xiphoid up to the level of 2nd intercostal space level for closure of VSD (including membranous type defect) and 3rd intercostal space for ASD closure. A short horizontal incision toward the left 2nd intercostal space was added for closure of VSD, whereas a short horizontal incision toward the right 3rd intercostal space was added for closure of ASD. No patient incurred accidental injury of the left or right internal thoracic artery. Mobilization of the subcutaneous tissue up to the level of manubrium steri and dawnward traction of the ascending aorta provided us good exposure to perform conventional cannulation without requiring any specialized equipment. Typical skin incisions for ASD closure and subarterial defect VSD closure are shown in Figures 1 and 2, respectively.

In recent nine female patients with ASD, repairs were performed through right mini-thoracotomy. In here, the patient was positioned in a right semi-decubitus position. A small lateral thoracotomy incision, usually 5–10 cm, was made depending on the patients' size and did not extend beyond the anterior axillar line, as shown in Figure 3. Again, this approach permitted conventional techniques of cannulation without requiring any specialized equipment.

Cardiopulmonary bypass flow was maintained at higher than 2.6 L/min/m^2. Cardiac arrest was achieved by administration of the cold blood cardioplegic solution. The administration was repeated at 30-minute intervals as needed. Immediately after aortic cross clamping, right atriotomy (n=45) was performed for closure of ASD and perimembranous defect VSD, while main pulmonary arteriotomy (n=32) was performed for closure of subarterial VSD. ASD was closed directly, whereas VSD was closed with a patch using either interrupted (n=23) or continuous (n=9) sutures. One patient with ASD and partial anomalous pulmonary venous drainage underwent a patch re-

Fig. 1. Postoperative view of the small incision and partial sternotomy in a patient with ASD.

Fig. 2. Postoperative view of the small incision and partial sternotomy in a patient with subarterial VSD.

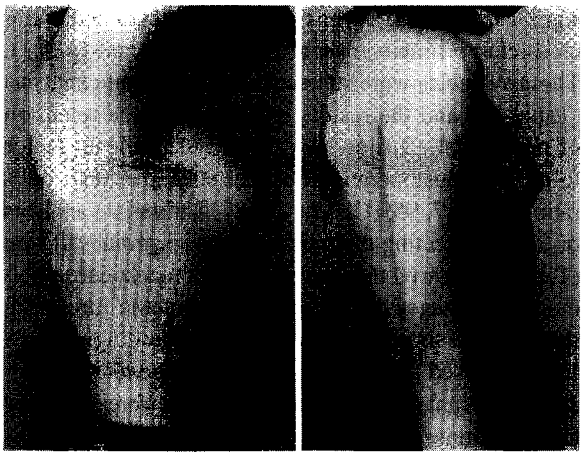

Fig. 3. Postoperative view of the small incision and right thoracotomy in a patient with ASD.

routing so as to drain the right upper pulmonary vein to the left atrium. Two patients with VSD associated with a double chambered right ventricle underwent anomalous muscle resection with patch closure of perimembrous VSD through the right atrium. Before completing the closure of defects, de-airing was carried out with the patient in the Trendelenburg position. Residual air in the left atrium or ventricle was investigated in all the patients with the transesophageal echocardiography.

Critical pass. All the patients in this study were managed under the same clinical practice guideline protocol (critical pass) established at our institute, which included patient admission 2 to 3 days before surgery and early tracheal extubation. The protocol of discharge from the hospital was 14 days after operation between October 1997 and March 1999 (early period, n=30), while this postoperative hospital stay has been reduced to 10 days since April 1999 (late period, n=47). Routine postoperative echocardiography was performed by pediatric cardiologist in all cases on the 7–10th postoperative day in the early period and 6–8th postoperative day in the late period. All patients with pericardial effusion were treated with a regimen of aspirin (5 mg/kg/day) and diuretics. Because half of the patients came from distant areas, the decision of discharge was made by a pediatric cardiologist.

Statistical methods. Statistical analysis was performed with StatView software for Macintosh, version 5.01 (SAS Institute, Cary, NC, USA). The data are presented as the mean±standard deviation, and proportional data are presented with their 95% confidence interval (CI). The categoric variables were analyzed using the χ^2 test or Fisher's exact test as appropriate. The Mann-Whitney U test was used for comparison of continuous variables between two groups. A p value of less than 0.05 was considered significant, while a p value raging from 0.05 to 0.10 was considered marginally significant. Both significant and marginally significant variables were then subjected to stepwise logistic regression analysis to identify the significant independent predictors.

Results

All the patients underwent complete repair according to the preoperative intent to treat. The length of the skin incision was 4 to 11cm, which corresponded to 3.6 to 8.6 cm per height in meters. Average length of the skin incision was 6.1±1.2 cm per height (m). The cosmetic result of the wound was excellent in both lower partial sternotomy (Figs. 1, 2) and right mini-thoracotomy (Fig. 3) except a patient who developed complication of the wound. There were no operative deaths, no late deaths, and no hospital re-administration. None of the patients required perioperative blood transfusion. Durations of cardiopulmonary bypass and aortic cross-clamp times were 82±38 minutes and 37±26 minutes, respectively, although in the learning period, these times were prolonged. After the initial 10 cases, junior residents performed operations (n=21) with a staff surgeon assisting. Forty-eight patients were extubated in the operating room, 39 patients were returned to the high-care unit in the ward and 9 patients to the ICU as needed. The remaining 29 patients were extubated in the ICU. Of those, 26 patients were extubated within 2 hours and 3 other patients were extubated within 6 hours. There was no complication related to early extubation or re-admission to the ICU.

Postoperative echocardiography demonstrated no residual lesion in patients with ASD, whereas trivial leakage in a patient with VSD. Likewise, postoperative echocardiography demonstrated no regurgitation of the aortic valve in patients with subarterial VSD nor the pressure gradient across the right ventricular outflow tract in those with double chambered right ventricle. In patients with repair of ASD with mini-thoracotomy approach, no complication, such as phrenic nerve palsy, was found.

The mean hospital stay after operation was 13.7±4.1 days (range 8 to 22 days) and 11.0±3.3 days (range 7 to 21 days) in the early and late periods, respectively. Twenty-four patients (31%) failed to fulfill the protocol for the critical pass. Factors that affected unfavorably the duration of hospital stay are listed in Table I. One patient had a minor wound complication of lower edge of skin incision, which was treated conservatively, and discharged on the 18th postoperative day. One patient developed convulsive seizure immediately after the extubation, however with no abnormality detected by the repeated computed tomography and electroencephalography. The patient was on the anticonvulsive agent for 3 months and is currently, 3 months after the surgery, free from medication and seizure.

Table I. *Reasons for failure of critical pass (n=24)*

Reasons	*No. of patients (%)*
Pericardial effusion	15 (63%)
Social reasons	4 (17%)
Fever of unknown cause	1 (3%)
Cardiomegaly in CXR	1 (3%)
Minor seizure	1 (3%)
Wound complication	1 (3%)
Trauma	1 (3%)

CXR, Chest roentgenogram.

Univariate analysis was conducted to detect factors in the failure of critical pass. Eleven categoric variables and 9 continuous variables were entered for analysis and the results are shown in Tables II and III, respectively. The median approach, retention of pericardial effusion and social reasons were statistically significant ($p<0.05$), while an opened pleura and aortic cross-clamp time were marginally significant ($p<0.1$). These variables were subjected to multivariate analysis (Table IV) and the results indicated that the retention of pericardial effusion was the only significant factor to prolong postoperative hospital stay [$p=0.007$, odds ratio (OR) 5.7, 95%CI 1.61–19.8]. Univariate analysis of factors affecting the retention of pericardial effusion (Table V) showed that the median approach, cardiopulmonary bypass time and aortic cross-clamp time were statistically significant ($p<0.05$), while diagnosis of VSD, a closed pleura and operation time were marginally significant ($p<0.1$). These variables were subjected to multivariate analysis (Table V) and the results indicated that the opened pleura was the only significant factor to affect pericardial effusion ($p=0.035$, OR 0.2, 95%CI 0.47–0.89), suggesting that opening the pleura could reduce the risk of pericardial effusion to one-fifth compared to patients with a closed pleura.

Discussion

As the mortality and morbidity following pediatric congenital heart surgery have continued to decline, the cosmetic result has been important determining factor of the long-term outcome. Various approaches[10] have been proposed to achieve an improved cosmetic result after pediatric cardiac operations, the so-called minimally invasive or less invasive techniques. Ini-

Table II. *Univariate relations between categoric variables and failure of critical pass*

Categoric variables	*No. of patients*	*Failure of critical pass*		*p value*
		%	*Odds Ratio (95%CI)*	
Gender			1.55 (0.58–4.19)	0.381
Male	41	34		
Female	36	25		
Approach			1.79 (0.19–17.0)	0.051
Median	68	100		
Rt. thoracotomy	9	0		
Diagnosis			2.09 (0.74–5.67)	0.142
ASD	40	39		
VSD	37	61		
Surgeon			0.66 (0.21–2.08)	0.477
staff	56	32		
resident	21	24		
Staff surgeons			1.96 (0.51–7.79)	0.722
TM	26	34		
MI/TK	12	41		
Learning case			0.59 (0.51–2.34)	0.453
Initial 10 cases	10	40		
Other 70 cases	67	28		
Critical pass			0.99 (0.36–2.69)	0.984
early	30	30		
late	47	29		
Extubation			0.63 (0.22–1.80)	0.393
In OR	48	33		
In ICU	29	24		
Pericardial effusion			4.91 (1.72–13.9)	0.002
none	50	18		
Yes	27	51		
Pleura		0.38 (0.13–1.06)	0.061	
opened	36	19		
closed	41	39		
Social reason			–	0.006
Yes	4	5		
No	73	95		

ASD, Atrial septal defect; *VSD,* ventricular septal defect; *OR,* operating room; *ICU,* intensive care unit.

tially, such minimally invasive methods were applied to the repair of ASD and other simple intracardiac anomalies. Several approaches other than midline skin incision have been used, including a submammary skin incision[11,12] and right thoracotomy.[13,14] In our view, the point of issue of the minimal access surgery for the congenital heart disease is to secure an improved cosmetic result without compromising the safety or accuracy of the repair. We, therefore, prefer using the term of "minimal access" to "minimally invasive or less invasive". This view led us to introduce a lower midline skin incision approach, because most patients desire that the wound is invisible when wearing an ordinary shirt. Additionally this approach can be easily converted to a conventional median approach when necessary.

Komai and associates[7] maintained that the wound should not be higher than the level of the nipple and should not be seen even when the patient wears an open-necked shirt or swimwear. In addition to the

Table III. *Univariate relations between continuous variables and failure of critical pass*

Continuous variables	*Critical pass*		*p value*
	Failure	*Success*	
Age (yr)	13.9±16.1	10.9±7.9	0.903
Height (cm)	127±26	131±27	0.494
Body weight (kg)	31.2±16.4	32.0±16.0	0.889
Skin incision/Height (cm/m)	5.7±0.8	5.8±1.1	0.605
Operation time (min)	221±61	235±141	0.742
CPB time (min)	89±32	79±41	0.166
AXC time (min)	42±24	34±27	0.086
Intubation time (min)	28±48	37±53	0.486
Postope. Hb (g/dl)	10.1±1.2	10.5±28	0.135

CPB, Cardiopulmonary bypass; *AXC*, aortic cross clamp; *Hb*, hemoglobin.

Table IV. *Multivariate analysis of factor determining prolonged hospital stay*

	Odds ratio (95%CI)	*p value*
Pericardial effusion (+)	5.70 (1.61–19.8)	0.007
Pleural opening (+)	0.27 (0.05–1.39)	0.118
AXC time	0.99 (0.96–1.01)	0.447
Median approach	–	0.987
Social reason	–	0.988

AXC, Aortic cross clamp.

Table V. *Univariate and multivariate analysis of factors affecting pericardial effusion. Significant (*) and marginally significant (†) factors detected by univariate analysis are entered into multivariate analysis.*

	Univariate p value	*Multivariate*	
		Odds ratio (95%CI)	*p value*
Opened pleura	0.061†	0.20 (0.47–0.89)	0.035
AXC time	0.027*	1.01 (0.98–1.03)	0.300
CPB time	0.008*	1.05 (0.97–1.09)	0.343
VSD	0.054†	1.23 (0.24–6.23)	0.788
Operation time	0.067†	0.90 (0.91–1.03)	0.610
Median approach	0.023*	–	0.997

AXC, Aortic cross clamp; *CPB*, cardiopulmonary bypass; *VSD*, ventricular septal defect.

reports of partial sternotomy,[1,9,15,16] recent studies introduced trans-xiphoid approach[2,4,17] as a promising technique in terms of meeting the obligatory demand. After increasing experience of the partial sternotomy approach to ASD repair, this approach has been applied to the repair of subarterial VSD, and we[9] confirmed that the lower partial sternotomy for the closure of subarterial VSD was technically feasible with a comparable cosmetic result and safety as that of ASD (Figs. 1 and 2). Recently, the cosmetic result of the patients with ASD, wherein the size of the wound was equal to the those with the partial sternotomy approach (4–10 cm), was excellent without deformity of the sternum or agonizing pain (Fig. 3). In both the lower partial sternotomy and right thoracotomy approaches, the only specific instrument that we required was a flexible thin-walled reinforced arterial cannula with a lumen-occluding stylet inserted, because major technical modifications or the use of particular instrumentation did not conform with our intent. In fact, earlier authors[3] suggested that an easy approach to minimally invasive operation should allow a practicing surgeon to continue to use familiar tools and approaches for the conventional cardiac operations. Khan and associates[18] endorsed our view and described a simple and effective method to repair ASD using standard equipment and cannulation techniques, with exposure through a limited skin incision.

In addition to excellent cosmetic results, no hospital or late death, no need for the perioperative blood transfusion, no hospital re-admission justified the use of this approach. Another goal of minimal access surgery is to improve postoperative recovery, including early tracheal extubation and a shorter hospital stay. In 62% of patients in this study, the tracheal tube was extubated in the operating room and 81% of them were transferred to the ward without any complication related to early extubation, although whether the patient was transferred to the ICU or ward depended on the availability of beds. It has been demonstrated that early extubation after cardiac operations or congenital heart disease has a minimal risk in carefully selected patients with or without minimal access surgery, allowing reduced postoperative stays in the ICU and hospital, as well as decreased cost of hospitalization.[19–21]

In regard to the shorter hospital stay, we developed the clinical practice guideline protocol, the so-called critical pass, for patients with minimal access surgery. Because, in our institute, half of the patients come from areas far from our hospital, we were conservative in our discharge policy and the final decision as to whether a patient can be discharged from the hospital or not was made by pediatric cardiologists. Thus, the protocol of discharge from hospital was 14 days after operation in the early period, and was reduced to 10 days in the late period. In our earlier experience, the high prevalence of postoperative pericardial effusion was noted during from postoperative days 6 to 10. This experience prompted us to create a pericardio-pleural fenestration so as to drain the fluid into the pleural space. Since this modification was adopted, protocol of postoperative hospital stay was reduced to 10 days. In this study we statistically confirmed that postoperative pericardial effusion was an independent factor determining postoperative hospital stay, and that the creation of a peicardial window or pleural opening could decrease the incidence of postoperative pericardial effusion. These findings were also pointed out by others[4] who reported that 3% of ASD patients with mini-sternotomy needed to be re-admitted for pericardial effusion requiring pericardiocentesis, and that routine formation of a pericardial window could reduce this to 1.5% for pericardiocentesis, which is similar to the incidence of patients with full sternotomy. In our series, early diagnosis and appropriate use of the diuretics and aspirin precluded the need for the pericardiocentesis or readmission. Although the protocol of hospital stay at our institute is relatively long compared to those reported by others overseas, we believe that the postoperative hospital stay can be reduced to 3–5 days if the patients undergo 2-week follow-up by pediatric cardiologists after operation.

Conclusions

Our study demonstrates that minimal access surgery for the simple congenital heart defects is feasible to provide excellent cosmetic results. The retention of pericardial effusion, possibly due to pericarditis, is likely a major risk factor of prolonged hospital stay. The pericardio-pleural fenestration could reduce the risk of retention of effusion, thereby reducing hospital stay.

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