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The Limiting Factors for the Transxiphoid Approach in Congenital Cardiac Surgery

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ABSTRACT

Objective: Minimally invasive cardiac surgery is currently being performed for a wide variety of cardiothoracic procedures. Since August 1998, the transxiphoid approach using a direct cannulation to the ascending aorta has been selected for the closure of atrial septal defects (ASD) and ventricular septal defects (VSD) in our institution. However, this approach cannot be performed for all patients because of the small "xiphoid window." We analyzed the factors limiting this approach to determine the best factor predicting risk.

Methods: Of 26 patients who had an ASD or a VSD, 14 underwent complete repair using a transxiphoid approach. Preoperative data collected for all patients included the relationship between the right ventricular outflow tract and the lower sternum (the RVSA) in the cineangiograph. Multiple logistic regression analysis was used to investigate which of the factors best predicted whether the transxiphoid approach should be adopted.

Results: The factors best predicting this approach were the combination of RVSA and body surface area (BSA) (odds ratios of 2.982 [P = .018] and 0.925 [P = .046], respectively). With the logistic model used in a prospective study of 6 consecutive patients, we were completely successful in predicting whether the transxiphoid approach could be performed.

Conclusion: The combination of RVSA and BSA was the limiting factor for using the transxiphoid approach in congenital cardiac surgery.

INTRODUCTION

The patient's demand for less traumatic and more cosmetically appealing surgery has increased, particularly in congenital heart surgery. Several investigators have reported the usefulness of minimally invasive or less invasive procedures for repairing atrial septal defects (ASD) [Barbero-Marcial 1998] and ventricular septal defects (VSD). In particular, Barbero-Marcial et al reported in 1998 on the excellent results obtained for ASD closure with the transxiphoid approach without sternotomy [Barbero-Marcial 1998].

Since August 1998, the transxiphoid approach has been selected for ASD and VSD closure in our institution, including the repair of double chamber of the right ventricle. However, this approach cannot be performed in all patients with an ASD and/or VSD, because the "xiphoid window" in some patients is too small to carry out the aortic cannulation through the limited incision. For such patients, we have to convert this approach to a partial sternotomy or a conventional full sternotomy. The problem is that there are no reliable parameters for predicting preoperatively the possibility of a transxiphoid approach. In this study, we reviewed patients with an ASD or a VSD who underwent complete repair with the transxiphoid and partial- or full-sternotomy approaches and analyzed the risk factors that limited the transxiphoid approach to determine the best predicting factor.

MATERIALS AND METHODS

Patient Data

Twenty-six patients who had an ASD (central type, without a partial anomalous pulmonary venous connection) and/or a VSD (perimembranous type) underwent complete repair of their septal defects between August 1998 and December 1999. Of these 26 patients, 14 patients underwent a complete repair using a transxiphoid approach.

Risk Factors

We reviewed all of the medical records of these 26 patients and collected the preoperative data thought to affect the transxiphoid approach, such as sex, height, body weight, body surface area (BSA), age, preoperative ratio of the pulmonary blood flow to the systemic blood flow (Qp/Qs), cardiothoracic ratio (CTR) of the chest radiograph, diagnosis (ASD or VSD), malrotation, and surgeon (staff or resident). Video-assisted cardioscopy (VAC) is a novel method for providing clear visualization of small intracardiac structures and for achieving complete repair in minimally invasive surgery [Burke 1994, Miyaji 2000b, 2001]. Since July 1999, we have applied the VAC technique for all intracardiac repairs,

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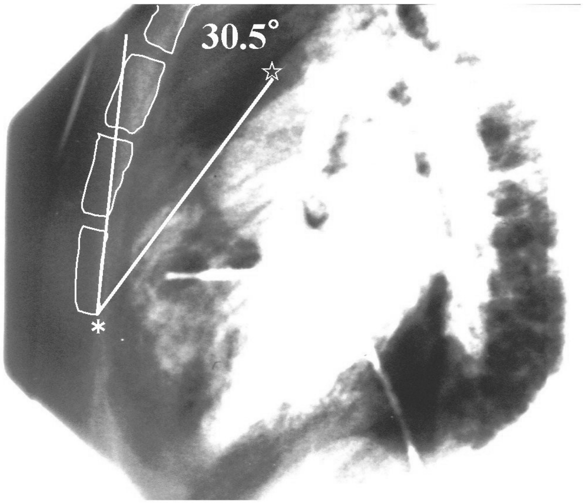

Figure 1. The angle formed in the lateral view of the preoperative cineangiograph between the line connecting the lowest point of sternum to the aortic cannulation site and the line of the inside face of the lowest part of the sternum. The star symbol represents the aortic cannulation site, and the asterisk represents the lowest point on the inside of the sternum.

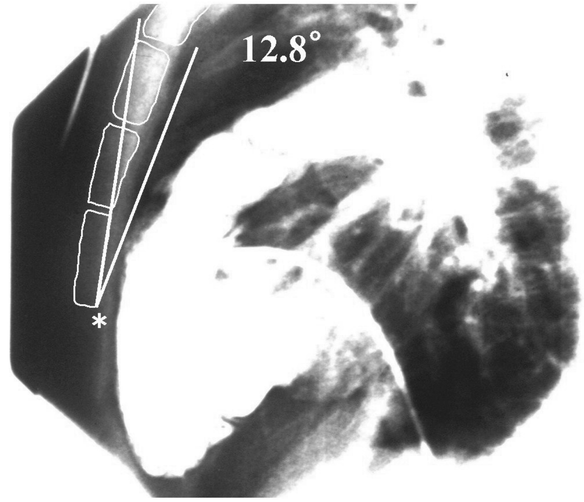

Figure 2. The angle formed in the lateral view of the cineangiograph between a tangential line drawn from the lowest point of the sternum to the right ventricular outflow tract at the end-diastolic phase and the line of the inside face of the lowest part of the sternum. The asterisk represents the lowest point of the inside face of the sternum.

including those for ASD and VSD. Then, we reviewed all of the patients' medical records to determine whether VAC affected the transxiphoid approach. We made measurements for the following variables: (1) the angle formed in the lateral view of the preoperative cineangiograph between the line connecting the lower edge (the lowest point) of the sternum to the aortic cannulation site and the line of the inside face of the lowest portion of the sternum (ASA) (Figure 1), and (2) the angle formed in the lateral view of the preoperative cineangiograph between a tangential line drawn from the lowest edge of the sternum to the right ventricular outflow tract at the end-diastolic phase and the line of the inside face of the lowest portion of the sternum (RVSA) (Figure 2).

Transxiphoid Approach

The transxiphoid approach was begun [Barbero-Marcial 1998, Murakami 2000] by making a longitudinal skin incision approximately 1 cm above the base of the xiphoid process and extending it to 1 cm below the tip of the xiphoid process. A resection of the xiphoid process and a 1-cm opening of the cartilaginous base of the supraxiphoid portion of the sternum were performed with an electrocautery. To place the "xiphoid process window" in front of the right atrium, we used a deep-profile retractor and positioned a Kent retractor (Takasago Medical Industry Co, Tokyo, Japan) at the upper edge of the xiphoid process to provide superior and anterior traction. The pericardium was opened and suspended. Purse-string sutures were placed in the ascending aorta, the right atrial appendage, and the inferior vena cava–atrium junction. After the patient underwent heparinization, an 8F to 12F straight aortic cannula (Medtronic Biomedicus, Eden Prairie, MN, USA) was inserted by means of the Seldinger technique [Murakami 2000]. Venous cannulation was performed through the right atrial appendage and the inferior vena cava–atrium junction. We began cardiopulmonary bypass, and the superior vena cava and the inferior vena cava were controlled with tapes. For ASD closure, fibrillation was used to induce ventricular fibrillation, and the right atrium was opened under ventricular fibrillation. The ASD was closed with running sutures or a 0.4-mm patch of polytetrafluoroethylene. For VSD closure, the aorta was cross-clamped, and antegrade blood cardioplegia was administered with a good arrest achieved. The left atrium vent was inserted from the right upper pulmonary vein. The right atrium was opened, and the VSD was closed with a 0.4-mm polytetrafluoroethylene patch and mattress or running sutures.

Since July 1999, we have applied VAC routinely for intracardiac repairs [Burke 1994, Miyaji 2000a], and the combined procedure with the transxiphoid approach and VAC has been performed for 8 patients (VSD, 5; ASD, 3) [Rao 1999, Miyaji 2001].

Statistical Analysis

Differences in patient characteristics between the transxiphoid-approach group and the nontransxiphoid-approach group were examined by Student *t* tests for continuous variables and by chi-square tests (and by the Fisher exact tests when applicable) for dichotomous variables. Then, the bivariate relationships among these variables were examined by calculating the Spearman correlation coefficients for continuous variables, by *t* tests for the combination of dichotomous and continuous variables, and by Fisher exact tests for dichotomous variables. Multiple logistic regression analysis was used to investigate which of the factors best predicted the adoption of the transxiphoid approach. All of the factors were entered and removed at a significance level of $P < .05$ by either the forward or the backward stepwise method. Sex, diagnosis, malrotation of the heart, and surgeon were modeled with binary dummy variables, and height, body weight, BSA, age, Qp/Qs ratio, CTR, ASA, and RVSA were examined as continuous variables. In all of the analyses, a *P* level <.05 was considered statistically significant.

RESULTS

Surgical Results

There were no operative or hospital deaths in either the transxiphoid-approach group or the nontransxiphoid-approach group. The mean (± SD) procedure time was 187 ± 66 minutes in the transxiphoid-approach group. The mean cardiopulmonary bypass time was 73 ± 49 minutes, and the mean size of the skin incision was 4.9 ± 0.6 cm. The postoperative courses of all patients in the transxiphoid-approach group were uneventful without any complications. The mean duration of the postoperative hospital stay was 7.6 ± 4.4 days.

The mean procedure time in the nontransxiphoid-approach group was 209 ± 52 minutes. The mean cardiopulmonary bypass time was 73 ± 38 minutes. There were no statistical differences between the transxiphoid-approach and nontransxiphoid-approach groups in procedure times and cardiopulmonary bypass times (*P* = .37, and *P* = .98, respectively). There was 1 patient (8.3%) with mediastinitis postoperatively in the nontransxiphoid-approach group. The mean duration of the postoperative hospital stay was 12.7 ± 10.0 days in the nontransxiphoid-approach group, and there was no significant difference (*P* = .13) between the groups in this respect, although there was a tendency toward longer hospital stays in the nontransxiphoid-approach group.

Analyses for Limiting Factors

The results of univariate analyses are given in Table 1. Height, body weight, BSA, age, ASA, and RVSA were significantly different between the 2 groups. Spearman correlation coefficients among variables demonstrated that height, body weight, BSA, and age were highly correlated each other. We also found that ASA was correlated both with BSA and with RVSA (*P* < .01). None of the dichotomous-continuous or dichotomous-dichotomous combinations of variables were significantly associated. The results of stepwise logistic regression analysis are shown in Table 2. The relative risk of the selection of the transxiphoid approach is 2.982 for a 1° increase in RVSA (*P* = .018) and 0.925 for a 100-cm^2 increase in BSA (*P* = .046). Because the preliminary examination disclosed that ASA was correlated both with BSA and with RVS, another model was built by using ASA. In this model with RVSA and BSA dropped from the analysis, only ASA was selected as an explanatory variable, and the relative risk of the selection of the transxiphoid approach is 1.840 for a 1° increase in ASA (*P* = .021; Table 2).

In the logistic model using RVSA and BSA, the possibility of this approach for each patient was obtained from the following equation:

$$P = \exp[(\text{RVSA} \cdot 1.09) - (\text{BSA} \cdot 7.8) - 5.06]/\{\exp[(\text{RVSA} \cdot 1.09) - (\text{BSA} \cdot 7.8) - 5.06)] + 1\}.$$

Table 1. Results of Univariate Analyses for Limiting Factors*

Variables	Transxiphoid (+)	Transxiphoid (−)	P
M/F sex, n	9/5	6/6	.462
Diagnosis (ASD/VSD), n	8/6	5/7	.431
Height, cm	86.6 ± 15.5	114.6 ± 32.1	.008
Body weight, kg	11.7 ± 3.6	23.0 ± 12.3	.003
BSA, 100 cm^2	52.4 ± 13.1	84.5 ± 35.5	.004
Age, y	2.63 ± 1.57	6.97 ± 4.65	.003
Qp/Qs ratio	2.18 ± 0.67	1.86 ± 0.67	.235
Cardiothoracic ratio, %	55.7 ± 3.5	52.4 ± 5.6	.079
ASA, °	31.9 ± 2.6	23.8 ± 5.1	.00015
RVSA, °	11.7 ± 2.4	7.9 ± 2.1	.0003
VAC (yes/no), n	9/5	9/3	.683
Malrotation (yes/no), n	0/14	2/10	.112
Surgeon (staff/resident), n	10/4	7/5	.484

*Data are presented as the mean ± SD where appropriate. ASD indicates atrial septal defect; VSD, ventricular septal defect; BSA, body surface area; Qp/Qs, ratio of pulmonary blood flow to systemic blood flow; ASA, the angle formed in the lateral view of the preoperative cineangiograph between the line connecting the lowest point of sternum to the aortic cannulation site and the line of the inside face of the lowest part of the sternum; RVSA, the angle formed in the lateral view of the cineangiograph between a tangential line drawn from the lowest point of the sternum to the right ventricular outflow tract at the end-diastolic phase and the line of the inside face of the lowest part of the sternum; VAC, video-assisted cardioscopy.

In the logistic model using ASA, the possibility of this approach for each patient was obtained from the following equation:

$$P = \exp[(\text{ASA} \cdot 0.61) - 17.4]/\{\exp[(\text{ASA} \cdot 0.61) - 17.4] + 1]\}.$$

Prospective Study

Using these equations, we performed the prospective study to confirm that these factors (RVSA plus BSA, ASA) predicted whether the transxiphoid approach could be performed. In the 6 consecutive cases (3 ASD, 2 VSD, and 1 partial atrioventricular septal defect), we calculated the probability of the transxiphoid approach for each patient and did not show the results of the calculation to the surgical team, including the surgeons, fellows, residents, anesthesiologists, perfusionists, and nurses, before surgery. The results of the prospective study are shown in Table 3. Five patients whose probabilities of the transxiphoid approach were greater than

Table 2. Results of the Stepwise Logistic Regression Analysis*

	Odds Ratio	Standard Error	P	95% CI
RVSA, °	2.982	1.382	.018	1.203-7.396
BSA, 100 cm^2	0.925	0.036	.046	0.858-0.998
ASA, °	1.84	0.486	.021	1.096-3.088

*CI indicates confidence interval; other abbreviations are expanded in the footnote to Table 1.

Table 3. Results of the Prospective Study*

Patient No.	Procedure Performed	BSA, m^2	RVSA, °	ASA, °	Probability of RVS + BSA Model	Probability of ASA Model	Transxiphoid Approach?
1	ASD closure	0.71	11	31	.801	.817	Yes
2	ASD closure	0.78	12.4	35.7	.915	.987	Yes
3	VSD closure	0.33	12	35	.996	.981	Yes
4	Partial AVSD repair	0.39	14.8	33.8	.999	.961	Yes
5	VSD closure	0.46	6.1	23.1	.119	.035	No
6	ASD closure	0.45	10.3	33.8	.934	.961	Yes

*AVSD indicates atrioventricular septal defect; other abbreviations are expanded in the footnote to Table 1.

.8 (ranges, .801-.999 in the RVS-plus-BSA model and .817-.987 in the ASA model) underwent surgical repair using a transxiphoid approach that was combined with VAC [Miyaji 2001]. For the remaining patient, whose probabilities of the transxiphoid approach were .119 in the RVS-plus-BSA model and .035 in the ASA model, we converted the patient to the partial-sternotomy approach because the xiphoid window was too small to do the aortic cannulation. In the prospective study, these factors were completely successful in predicting whether the transxiphoid approach could be performed in the 6 consecutive patients.

DISCUSSION

We started a transxiphoid approach for all patients with ASD and/or perimembranous VSD in August 1998. In this approach, the most important and critical procedure is the aortic cannulation. Barbero-Marcial et al [1998] selected the left common femoral artery as an arterial cannulation site in their series with the transxiphoid approach. Because patient demand for less traumatic and more cosmetically appealing surgery has increased, an incision in the groin is contradictory to the demand for a cosmetically appealing surgery. We cannulated the ascending aorta directly by using the Seldinger technique, resulting in a transxiphoid approach with 1 small lower-midline incision. This technique is a safe and effective method for a limited operative field such as a xiphoid window [Murakami 2000]. However, carrying out the transxiphoid approach is extremely difficult in some patients, and conversion to a partial sternotomy or sometimes to a conventional full sternotomy is needed. In this study, we analyzed what limiting factors are the best predictors for the transxiphoid approach. The results of the stepwise logistic regression analysis showed that the best predicting factors were the combination of BSA and RVSA. For patients with a larger BSA or a greater height, a transxiphoid approach using direct aortic cannulation might be difficult to do in general, because the cannulation site would be far away from the xiphoid window. In patients with a left-to-right shunt such as with an ASD or a VSD, the excessive pulmonary blood flow can cause a dilated right ventricle and atrium, resulting in obstruction in access to the aorta. The results of our study were reasonable and acceptable. On the other hand, the relationship between the ascending aorta and the sternum (the ASA) is also a potential predicting factor. The ASA represents the access route to the aortic cannulation site through the xiphoid window. These results reveal that access to the aorta for cannulation and cross-clamping was the factor that was most limiting for the transxiphoid approach.

In 1994, Burke et al reported that VAC is feasible for imaging small, inaccessible structures during the repair of complex congenital heart defects [Burke 1994]. Actually, for intracardiac repairs with limited space, VAC allows atraumatic visualization and magnification of inaccessible structures while avoiding vigorous cardiac manipulation and extended incisions [Miyaji 2000a, 2000b]. Since July 1999, we have applied VAC routinely for intracardiac repairs. The technical feasibility and the acceptable surgical results of the transxiphoid approach using VAC have been reported [Rao 1999, Miyaji 2001]. The current study has shown that the VAC technique did not affect the results of the transxiphoid approach, and this approach accompanied with the VAC technique can be a sophisticated and useful procedure in complex congenital cardiac surgery.

In conclusion, the ASA and the combination of RVSA and BSA were the potentially limiting factors for the transxiphoid approach. Using these variables, we can predict preoperatively the probability of success of the transxiphoid approach for each patient.

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