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Clinical Experience with Assisted Venous Drainage Cardiopulmonary Bypass in Elective Cardiac Reoperations

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ABSTRACT

Reoperative cardiac surgery is associated with substantial morbidity and mortality due to technical problems at sternal reentry, which can result in laceration of the right ventricle, innominate vein injury, or embolization from patent grafts. To minimize the risk associated with reentry, we adopted the method of assisted venous drainage in the cardiopulmonary bypass circuit with peripheral cannulation for cardiac reoperations. From March 1999 to May 2003, a series of 52 patients (38 males; mean age 48.7 years, range 4 months to 78 years) underwent cardiac reoperations performed with centrifugal pump venous-assisted cardiopulmonary bypass. EuroSCORE was 7.34 ± 3.9 (range, 4-19). The reoperations were coronary artery bypass graft (25 patients), valve replacement/repair (18 patients), and complex pediatric procedures (11 patients). The studied adverse events were structural damage at reentry, mortality, blood loss, stroke, and hemolysis. Complications at sternotomy were damage to the innominate vein (1 patient) and aorta (1 patient) with blood loss of 625 and 225 mL, respectively. Four patients required intraaortic balloon pump or extracorporeal membrane oxygenation (n = 1) for hemodynamic support on weaning off cardiopulmonary bypass. Three patients died in the postoperative period. Our experience with centrifugal pump–assisted venous drainage in cardiac reoperations has shown excellent results, with reduced risk of damage to vital structures on sternal reentry. In cases in which structural damage did occur, blood loss was minimal.

INTRODUCTION

The use of cardiac reoperations is increasing, reaching a prevalence of up to 15%-20% of all heart operations [Lytle 1993; Nakanishi 2001]. According to the Society of Thoracic Surgeons database, An average of 8% of all operative revascularizations are coronary artery bypass reoperation, 11% are redo aortic valve and 20% are redo mitral valve procedures 20% respectively [STS 1998]. In the pediatric population, the reoperation rate for congenital heart disease approaches 15%.

Sternal reentry is primarily a blind procedure, and the risks involved are well known [English 1978; Dobell 1984; Garrett 1989; Temeck 1990] and include injury of major cardiac structures in the presence of adhesions between the posterior sternal table and the innominate vein, right ventricle, and extracardiac conduits or grafts. The sequelae of such injuries include catastrophic hemorrhage. To minimize the risk associated with sternal reentry, our group and others have become convinced that femoral cannulation for cardiopulmonary bypass with centrifugal pump–assisted venous drainage offers distinct advantages, particularly in minimizing damage and blood loss.

Concerns have been expressed about the exacerbation of arterial air embolism owing to entrainment of air in the venous system [Davila 2001; Carrier 2002; Walther 2002], but other authors have not experienced this as a problem. Carrier et al [2002] showed that vacuum-assisted venous drainage does not significantly increase air microembolism and was not associated with increased neurological risk following surgery. A further concern is that vacuum-assisted venous drainage could potentially increase trauma to blood cells.

This report details our experience and results with this technique in both adult and pediatric cardiac reoperations.

MATERIALS AND METHODS

Patient Profiles

From January 1999 to August 2003 at a single cardiac surgical center 52 patients, age 1 month to 78 years (mean, 48.7 years), underwent repeat sternotomy for nontransplantation cardiac surgery. All reoperations were performed by a group of 6 surgeons at a single institution using the technique described below. Baseline clinical characteristics in both adults and children are outlined in Table 1. In all cases, resternotomy was performed a minimum of 4 months after the previous sternotomy. The indications for reoperation are outlined in Table 2 and were predominantly revascularization (40%). First-time redo sternotomy was done in 33 patients, second-time redo sternotomy in 16 patients, and third-time in 3 patients.

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Table 1. Baseline Patient Characteristics

No. of patients	64
Age, y, mean (range)	48.69 (0.3-77)
No. of pediatric patients (age <16 y)	13 (25%)
Sex (male/female)	38/14
EuroSCORE, mean ± SD (range)	7.34 ± 3.9 (4-19)
Diabetes	8 (15%)
Hypertension	18 (35%)
Previous myocardial infarction	12 (23%)
Chronic obstructive pulmonary disease	6 (12%)

In the pediatric group, there were 9 boys (mean age, 8.2 ± 5.5 years; range, 1 month to 15 years) and 4 girls (mean age, 7.5 ± 3.1 years; range, 4 to 11 years).

Twenty-nine patients were identified as high risk for reentry because of second or third reentry (n = 19), patent mammary graft (n = 23), enlargement of right chambers (n = 3), the presence of a conduit (n = 2), or history of sternal infection with mediastinitis (n = 1). Routine blood tests were performed to evaluate hemolysis and hepatic and renal function.

Surgical Technique

After the induction of general anesthesia and full invasive monitoring, the femoral vessels were exposed. After adequate heparinization, venous cannulation was performed using a long 20-28 Fr cannula with the tip advanced to the level of the right atrium under the guidance of transesophageal echocardiography. A Sarns Delphin II® centrifugal pump system (3M, Ann Arbor, MI, USA) was attached to the venous line to augment venous drainage. The level of suction was regulated by means of a Medtronic DLP 60000 line pressure monitor set to a maximum pressure of –80 mmHg. Arterial cannulation was established by open exploration of the vessels, and then a Seldinge-type cannulation through a purse-string suture and sternal reentry were performed while the patient was on full bypass. With 20Fr and 28Fr venous cannulae, the flow rate achieved was 1.8-2.5 L/min and 3.5-4.5 L/min, respectively. Perfusion pressures were 50-80 mmHg, and arterial line pressures were 150-300 mmHg. Mean bypass times were 175 ± 100 min, and aortic cross-clamp times were 62.17 ± 55.97 min.

Statistical Analysis

Data are expressed as the mean ± SD. Statistical analysis was performed using the SPSS software. Fisher exact test was used to analyze differences in mortality rates according to the number of reoperations (first vs second or third) and to assess the predictive impact of the high-risk category on the occurrence of injury during sternotomy.

Table 2. Indications for Surgery

Coronary artery disease	23
Paravalvular leak	3
Prosthetic valve degeneration/failure	9
Infective endocarditis	2
Congenital heart disease	15

RESULTS

Cardiopulmonary bypass time and aortic cross-clamp times were as indicated in Table 3. Complications of surgery are outlined in Table 4. One injury in an adult patient and 1 in a pediatric patient were attributed to the use of the sternal saw during reentry. In the adult case, a 73-year-old man undergoing redo coronary artery bypass graft sustained structural damage to the ascending aorta and innominate vein. These injuries were repaired easily without significant loss of blood. In the pediatric case, a 13-year-old boy undergoing redo mitral valve repair sustained a tear of the innominate vein during reentry. This injury also was repaired easily, and only 225 mL blood loss occurred. There was no statistical difference between the first, second, and third redo operations in regard to the occurrence of structural injury.

The overall mortality rate was 5.8% (3 of 52). Two of the deaths may have been directly related to sternal reentry from femoral cannulation. One patient, a 29-year-old man, underwent redo aortic root replacement for prosthetic valve endocarditis. He developed a perioperative cerebrovasvular accident and subsequently died of multiorgan failure. The second death occurred in a 57-year-old man who underwent redo double valve replacement. He was in atrial fibrillation and died of mesenteric ischemia. The third death was in a 32-year-old man who underwent redo pulmonary valve replacement and died of pulmonary hemorrhage. In 1 patient, peripheral cannulation was complicated by a tear of the femoral artery. This injury was easily repaired with a vein patch. Data on patient morbidity unrelated to venous assist are presented in Table 4.

Renal function as measured by mean creatinine was 100.1 ± 30.1 µmol/L preoperatively and 118 ± 56.2 µmol/L on postoperative day 1.

DISCUSSION

The number of cardiac reoperations is steadily increasing. The ability to decompress the heart during penetration of the posterior sternal table reduces the risk of tearing vital structures, especially in cases in which the heart, and the right ventricle in particular, are dilated and vulnerable. A tear in the right ventricle may be impossible to repair without decompression.

Table 3. Operative Details

Coronary artery bypass graft	23
Aortic valve replacement (AVR)	7
Mitral valve replacement (MVR)	5
AVR and MVR	2
Tricuspid valve repair	1
Aortic root replacement	2
Mitral valve repair	1
Pulmonary valve/Pulmonary artery conduit replacement	2
Completion of total cavo-pulmonary connection	5
Other	4
Cross-clamp time, min	62.2 ± 55.9
Cardiopulmonay bypass, min	175.1 ± 100.1

Table 4. Complications

Mechanical injury at sternotomy	2 (3.8%)
Femoral vessel injury	1 (1.9%)
Prolonged hospitalization (>14 days)	16 (30.7%)
Resternotomy	4 (7.6%)
Neurological injury	
Transient	2 (3.8%)
Permanent	2 (3.8%)
Postoperative renal failure	7 (13.5%)
Wound infection	2 (3.8%)
Chest infection	10 (19.2%)
In-hospital death	4 (7.7%)

Catastrophic hemorrhage leading to death as a consequence of structural injury has been reported [Mueller 2001]. Dobell and Jain [1984] surveyed 224 surgeons and reported a 37% mortality rate. The mortality rate in our study was 5%. Two of the deaths may have been related to complications of cardiopulmonary bypass using femoral cannulation. Neurological complications in femoral cannulation are often related to the reversed flow in the abdominal aorta, where aortic calcification also starts. The use of femoral cannulation leads to neurological sequelae, and cannulation of the subclavian rather than the femoral artery may reduce these sequelae. Other maneuvers used to avoid entering underlying cardiac structures have been described. Temeck and colleagues [1990] reported no deaths related to sternotomy in a series of 113 reoperations. Garrett and Matthews [1989] described a simple technique used without adverse incidents in 50 consecutive patients. Previously placed sternal wires were cut and untwisted but not removed. An oscillating saw was used to divide the sternum while upward traction was applied to the wires. The wires provided a barrier to the saw while the posterior table was divided.

During a 4-year period, the use of venous assist in our institution was associated with 2 injuries and no deaths. In the 2 patients in whom structural damage occurred during reentry, blood loss was 625 mL and 225 mL. Our study confirmed our initial hypothesis that use of venous assist in redo surgery significantly reduces the incidence of catastrophic hemorrhage.

The venous-assisted cardiopulmonary bypass circuit has the added benefit of reducing prime volume, which is particularly advantageous in pediatric patients. Follis et al [1999] demonstrated a reduced incidence (0.65%) of injury with the use of a sagittal micro-oscillating saw compared with reciprocating, sagittal, or Stryker saws. Given the low incidence of catastrophic hemorrhage, it is difficult to prove the superiority of a single technique with a small series. The relative distribution of injured anatomic structures reflects their most common location in relationship with the midline.

Venoarterial air embolism has been described in case reports [Cosgrove 1989; Carrier 2002]. Other authors [Jones 2002] assert that vacuum assisted venous drainage does not statistically reduce the ability of the cardiopulmonary bypass circuit to remove gaseous microemboli. In our study, 2 patients (3.8%) suffered stroke, a rate that was no higher than in normal practice. One of these patients was 29 years old and had aortic root replacement for prosthetic valve endocarditis, with prolonged bypass time of 305 min. The other patient was 70 years old, a previous heavy smoker, and had a high EuroSCORE of 19. These 2 deaths may have been related to retrograde flow through the femoral artery, which inevitably detaches atheromatous plaques. The increasing use of subclavian cannulation may reduce the incidence of neurological sequelae.

The present study has several weaknesses. It is a retrospective study, and a comparison of this technique with others in a randomized prospective study would be useful.

In conclusion, the use of the centrifugal pump to assist venous drainage has proved to be a safe and useful adjuvant to femoral cardiopulmonary bypass in 52 repeat sternotomies. This series, the largest reported in the literature to date, demonstrates that the technique can be easily reproduced, with minimal morbidity.

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