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Clinical Research

Surgical Results of the Superior Vena Cava Intimal Layer-Only Suture Technique in Heart Transplantation

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Background: Superior vena cava (SVC) stenosis during follow-up is a major concern after heart transplantation, and many technical modifications have been introduced. We analyzed the surgical results of the SVC intima layer-only suture technique in heart transplantation.
Methods: We performed SVC anastomosis with sutures placed only in the intima during heart transplantation. We measured the area of the SVC at 3 different points (above the anastomosis, at the anastomosis, and below the anastomosis) in an axial view by freely drawing regions of interest, and then evaluated the degree of stenosis. Patients who underwent cardiac computed tomography (CT) at 2 years postoperatively between June 2017 and May 2020 were included in this study.
Results: We performed heart transplantation in 41 patients. Among them, 24 patients (16 males and 8 females) underwent follow-up cardiac CT at 2 years postoperatively. The mean age at operation was 49.4±4.9 years. The diagnoses at time of operation were dilated cardiomyopathy (n=12), ischemic heart disease (n=8), valvular heart disease (n=2), hypertrophic cardiomyopathy (n=1), and congenital heart disease (n=1). No cases of postoperative bleeding requiring intervention occurred. The mean CT follow-up duration was 1.9±0.7 years. At follow-up, the mean areas at the 3 key points were 2.7±0.8 cm^2, 2.7±0.8 cm^2, and 2.7±1.0 cm^2 (p=0.996). There were no SVC stenosis-related symptoms during follow-up.
Conclusion: The suture technique using only the SVC intimal layer is a safe and effective method for use in heart transplantation.

Keywords: Superior vena cava, Heart transplantation, Stenosis

Introduction

Superior vena cava (SVC) stenosis during follow-up is one of the major concerns after heart transplantation. Symptoms include facial or upper extremity swelling and signs suggesting congestive heart failure, such as dyspnea or orthopnea [1]. As exemplified by these symptoms and signs, SVC stenosis can mimic congestive heart failure or pericardial disease. SVC stenosis results from various mechanisms, and the presentation may be acute or chronic depending on the upper venous pressures or collateral pathways [1,2]. Thus, several surgical modifications have been introduced to avoid SVC stenosis [3,4]. These surgical modifications showed excellent outcomes during follow-up. However, we often encounter SVC wall thickness differences between donor and recipient hearts due to prolonged indwelling catheter times. This makes it difficult to anastomose the vessels and may be a risk factor for SVC stenosis [5]. For these reasons, we performed intima-only sutures during SVC anastomosis to avoid SVC stenosis and simplify anastomosis. We analyzed the surgical results of the SVC intima-only suture technique in this study.

Methods

Ethical statement

This study protocol was approved by the Institutional

Review Board of the Keimyung University Dongsan Medical Center (Daegu, Korea) (DSMC 2022-02-060), and all procedures were performed in accordance with our institutional guidelines for the protection of patient confidentiality. The requirement for patient consent was waived due to the retrospective nature of this study.

Study population

Heart transplantation patients who underwent cardiac computed tomography (CT) scans immediately postoperatively and 2 years postoperatively between June 2017 and May 2020 were included in this study. We determined the measurement sites of the SVC in the areas above the anastomosis, at the anastomosis, and below the anastomosis with axial and coronal views simultaneously on a cardiac CT scan. We measured the cross-sectional areas of the SVC at these 3 different points in the axial view by drawing regions of interest and evaluating the degree of stenosis (Figs. 1, 2). In the axial view, the margin of the enhanced SVC lumen on contrast CT was drawn manually with the free drawing region-of-interest method in the INFINITT PACS M6 program (INFINITT Healthcare, Seoul, Korea), and the area inside the line was measured automatically. To reduce the chances of observer bias, each point was measured 3 times, and the mean value was selected as the approximate area of the SVC. As an additional datum, the diameter of the narrowest point of the SVC was measured on the CT coronal view. We defined SVC stenosis as patients having SVC-related symptoms, an SVC anastomosis area less than <50% compared to the other 2 sites, or meaningful collateral flow around the SVC.

Data collection

Data on demographics and clinical, echocardiographic, and CT parameters were obtained using data collection forms from electronic medical records. Demographic data included age, sex, body weight, height, blood type, and predefined comorbidities. Clinical data included preoperative heart transplantation status, waiting duration, and operative data. Echocardiographic data included ejection fraction and left ventricle volume data. CT data were used to obtain the area of the SVC.

Surgical techniques

We applied the intimal layer-only technique in all patients who underwent heart transplantation. An arterial cannula was inserted into the ascending aorta after median sternotomy, and standard bicaval cannulation was applied. We performed SVC anastomosis after removal of the aortic cross-clamps. SVC anastomosis was applied in all patients with 6-0 Prolene (Ethicon, Raritan, NJ, USA) monofilament polypropylene continuous suture. The nadir of the SVC in the donor and recipient hearts was identified using the azygos vein for guidance. SVC anastomosis was performed after careful examination of the respective intimal layers of the SVC in both the donor and recipient (Fig. 3),

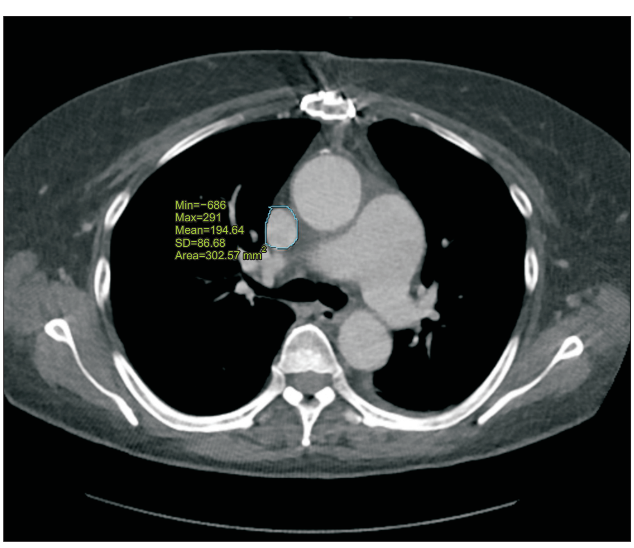

Fig. 1. The areas of the superior vena cava that were measured by the region-of-interest method. SD, standard deviation.

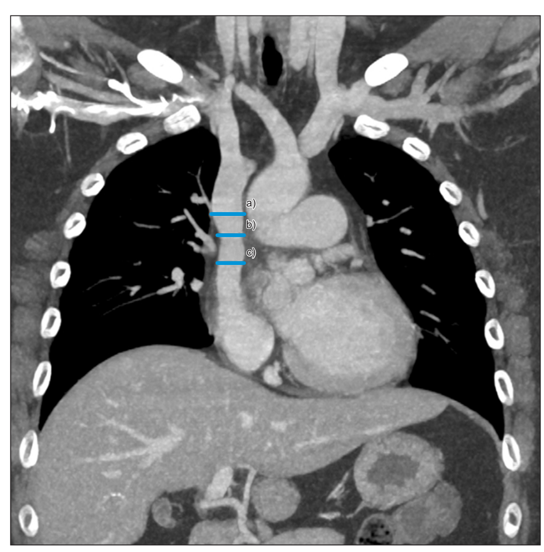

Fig. 2. The measurement sites of 3 key points: [a]above the anastomosis site, [b]at the anastomosis site, and [c]below the anastomosis site.

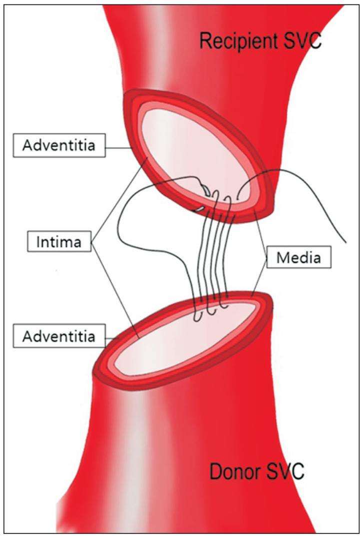

Fig. 3. Illustration of the superior vena cava (SVC) intima-only suture technique.

and only the tunica intima was engaged to avoid anastomotic tension.

Patient follow-up

Patients were monitored using CT immediately postoperatively and at the 2-year follow-up. We compared the degree and progression of stenosis.

Statistical analysis

All continuous variables are expressed as means±standard deviations. Categorical variables are expressed as frequencies and percentages. Comparisons between continuous variables were performed using the Student t-test, and categorical variables were analyzed using the Fisher exact test. A p-value of less than 0.05 was considered to indicate a statistically significant difference. All analyses were performed using IBM SPSS ver. 26.0 (IBM Corp., Armonk, NY, USA).

Results

Baseline outcomes

We performed heart transplantation in 41 patients between June 2017 and May 2020. Among them, 10 patients died before the 2-year follow-up. Non enhanced CT scan was performed in 5 patients due to renal failure and severe contrast allergy. Follow-up CT was not performed in 2 patients. Patients whose follow-up information lacked contrast CT examinations were excluded from the study to facilitate a precise comparison of the SVC area. Therefore, 24 patients (16 males and 8 females) who underwent follow-up cardiac CT at 2 years postoperatively were included in the study population. The mean age at operation was 49.4±4.9 years. We performed heart transplantation as a repeat operation in 7 patients (29.2%). The heart transplantation status at operation was 0 in 10 patients (41.7%) and 1 in 12 patients (50.0%). The diagnoses at time of operation were dilated cardiomyopathy (n=12), ischemic heart disease (n=8), valvular heart disease (n=2), hypertrophic cardiomyopathy (n=1), and congenital heart disease (n=1) (Table 1). The mean ejection fraction at operation was 19.8%±11.0%. The mean left ventricle end-diastolic and left ventricle end-systolic dimensions were 65.3±9.8 mm and 58.9±10.6 mm, respectively.

We applied a peripherally inserted central catheter (PICC) in all patients, and the mean PICC indwelling time was 2.0±1.8 months. The mean waiting time from admission to transplantation was 2.1±2.0 months. The donor-recipient weight ratio was 1.0±0.2. The mean warm ischemic time was 59.4±16.5 minutes, while the mean cold ischemic time

Table 1. Patient characteristics

Characteristic	Value
Age (yr)	49.4±4.9
Sex	
Male	16
Female	8
Hypertension	8 (33.3)
Diabetes mellitus	10 (41.7)
Body surface area (m^2)	1.8±0.2
Blood type	
A+	8 (33.3)
B+	7 (29.2)
AB+	6 (25.0)
O+	3 (12.5)
Redo operation	7 (29.2)
Status	
0	10 (41.7)
1	12 (50.0)
2	1 (4.2)
3	1 (4.2)
Diagnosis	
Dilated cardiomyopathy	12 (50.0)
Ischemic heart disease	8 (33.3)
Valvular heart disease	2 (8.3)
Hypertrophic cardiomyopathy	1 (4.2)
Congenital heart disease	1 (4.2)

Values are presented as mean±standard deviation or number (%).

was 119.3±53.5 minutes. The mean cardiopulmonary bypass time was 166.3±49.5 minutes, and the mean aorta cross-clamp time was 72.4±18.8 minutes. No cases of postoperative bleeding requiring intervention occurred.

The heart rhythm during follow-up showed a normal sinus rhythm in all patients. There were no SVC stenosis-related symptoms, including upper extremity swelling, during follow-up.

Cardiac computed tomography measurement

On the immediately postoperative CT scans, the mean areas at 3 key points were 2.8±0.5 cm^2 (above anastomosis), 2.8±0.5 cm^2 (at anastomosis), and 2.7±0.5 cm^2 (below anastomosis) (p=0.915). The mean CT follow-up duration was 1.9±0.7 years. At follow-up, the mean areas at the same 3 points were 2.7±0.8 cm^2 (above anastomosis), 2.7±0.8 cm^2 (at anastomosis), and 2.7±1.0 cm^2 (below anastomosis) (p= 0.996) (Fig. 4). The difference in area between the postoperative and 2-year follow-up scans was not statistically significant (p=0.649 for the above-anastomosis area, p=0.677 for the anastomosis area, and p=0.878 for the below-anastomosis area). To adjust and compare the SVC area, body surface area (BSA) was measured. The adjusted SVC area was calculated using the following formula: adjusted SVC area=SVC area (cm^2)/BSA (m^2). The mean immediate postoperative adjusted SVC area at the anastomosis site was 1.5±0.4 cm^2, and the 2-year follow-up adjusted SVC area was 1.6±0.5 cm^2 (Fig. 5). The difference was not statistically significant (p=0.133). Collateral vessels were not detected in any patient on follow-up CT. Thus, no patient was defined as having SVC stenosis during the follow-up period.

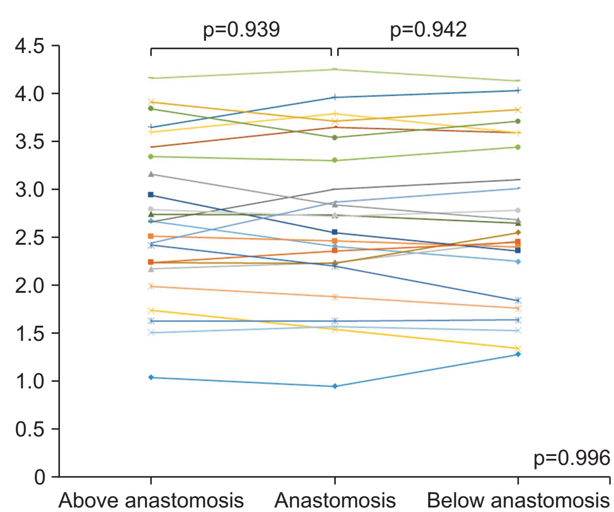

Fig. 4. The mean areas at 3 key points. There was no significant difference among the 3 points.

The median diameter of the narrowest point of the SVC on the 2-year follow-up CTs was 1.34 cm (interquartile range, 1.46–1.23 cm).

Discussion

The bicaval technique replaced the biatrial technique for heart transplantation and became the standard option because it resulted in a reduced rate of atrial arrhythmia, lower right atrial pressure, improved right atrial contractility, decreased tricuspid valve incompetence, and decreased permanent pacemaker placement incidence [6-8]. However, the bicaval technique also has some postoperative complications, including risks of SVC stenosis, hemodynamic instability, and atrioventricular valve regurgitation due to excessive anastomosis site tension, anatomical disorientation, or the potential for twisting or kinking [6].

Among those complications in the bicaval technique, several risk factors for SVC stenosis were introduced, including younger age at transplantation, donor-recipient size mismatch, and previous SVC anastomosis history [5,9-11]. Younger patients showed an SVC stenosis incidence of approximately 3.1% [12]. Treatment methods for SVC stenosis include chemical thrombolysis, mechanical thrombolysis, balloon angioplasty, and stent placement [9,11,13].

Thus, several surgical modifications were introduced to compensate for deficiencies in the bicaval anastomosis technique. Kitamura et al. [14] reported their modified bicaval anastomosis technique, which showed better hemodynamic and echocardiographic results without SVC stenosis. Kakuta et al. [15] also described a surgically modified bicaval anastomosis technique to maintain anastomotic orientation without traction, kinking, or distortion of the

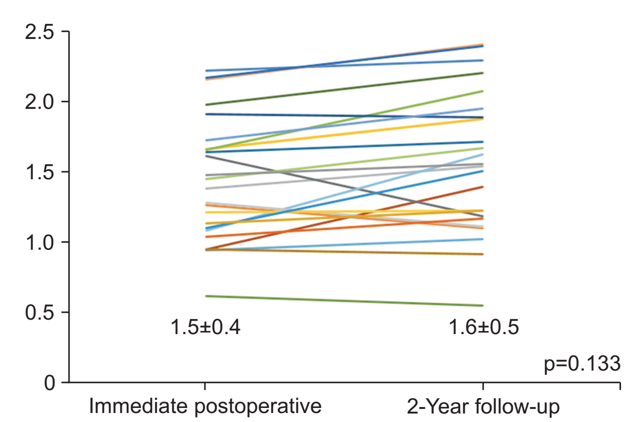

Fig. 5. Graph of the superior vena cava areas adjusted for body surface area of the anastomosis sites on immediate postoperative computed tomography (CT) and 2-year follow-up CT.

vena cava. Furthermore, Doring and Marcsek [3] presented their atrial flap technique for connecting the SVC with the donor right atrium and showed the maintenance of atrioventricular valve competence and atrial conduction function. The authors showed favorable surgical results for SVC stenosis with good hemodynamic conditions after heart transplantation during follow-up.

In a previous study, Salavitabar et al. [16] reported that 12 out of 349 patients (3.4%) were diagnosed with SVC obstruction after orthotopic heart transplantation. The study was performed on pediatric patients (median age 2.5 years in the SVC obstruction group), and the median time from heart transplantation to SVC obstruction was 1.8 months. Ten patients with SVC obstruction underwent bicaval anastomosis. Sachdeva et al. [11] studied 138 pediatric heart transplantation patients, and among them, 7 patients (5.1%) developed SVC obstruction and needed SVC stenting. Six patients underwent bicaval anastomosis, and 1 patient underwent biatrial anastomosis. In another study, Aldoss et al. [12] reported 28 patients (3.1%) with SVC obstruction out of 894 pediatric heart transplantation patients during a median follow-up of 1.0 years. Although the findings of this study cannot be directly compared with the results of the previous studies presented above, because those studies dealt with pediatric patients, no patients in our study experienced SVC stenosis or obstruction.

Heart transplantation candidates often face a prolonged waiting time due to donor shortages. Thus, we applied a PICC for inotropic or nutritional support while patients were on the waitlist. Nonetheless, we observed thickening of the recipient's SVC wall during the wait for heart transplantation. Keeping the PICC in other central veins, including the inferior vena cava, through a saphenous vein puncture might prevent thickening of the SVC wall. We have also attempted saphenous vein PICC insertion. However, the major problem with saphenous vein PICCs is difficulty in managing the catheter and ambulation. Because the catheter is located on the thigh or calf, in many cases it may become contaminated with urine or feces. The dressing on the catheter may peel off easily during leg movement. These conditions increase the risk of catheter contamination and catheter-related bloodstream infection. Furthermore, most hospitalized heart transplantation candidates need ambulation and physical therapy for cardiac rehabilitation. Due to the location of the catheter, the catheter itself and intravenous extension lines made it difficult for patients to walk and exercise. To keep both the catheter and the patient more aseptic before transplantation and to encourage patients to exercise, our center decided to keep the PICC in the SVC through the basilic vein. In addition, other indwelling catheters, including implantable cardioverter defibrillators or pacemakers, may accelerate thickening of the recipient's SVC wall. A difference in wall thickness in the SVC between the donor and recipient can make anastomosis difficult. Thus, we invented the SVC intima layer-only anastomosis technique to make it easy to perform anastomosis, and we expected this surgical technique to prevent SVC stenosis during follow-up. Although several surgical modifications have been introduced to avoid stenosis, these techniques are somewhat complex [3,4]. In addition, if donor patients wait a long time for heart transplantation, SVC wall thickening is inevitable. However, these modified surgical techniques have potential SVC stenosis problems because a thickened SVC wall is still included during SVC anastomosis. The thickened SVC walls may function as a cause of SVC stenosis, especially in cases of donor-recipient size discrepancies or with younger recipients [5,9-12]. However, the intimal layer-only technique has an advantage in cases of size discrepancy or younger age due to the lack of involvement of the medial and adventitial layers. In addition, this intima-only suture technique is easy to apply and does not increase postoperative bleeding. In this study, there was no case of postoperative bleeding after heart transplantation, and if there was a bleeding focus after SVC anastomosis, controlling nearby bleeding was straightforward because we could easily inspect the SVC anastomosis site at approximately 360°.

Our study has several limitations. First, the follow-up duration was approximately 2 years after heart transplantation, which is likely to be too short to detect permanent SVC stenosis. Second, the sample size was relatively small. Third, the loci of SVC anastomosis site measurements could vary by observer. On postoperative CT, the aorta anastomosis site can be easily identified based on the Teflon felt or Pledget suture around the anastomosis. However, the SVC anastomosis sites had no definite landmarks. In our study, the dimension of the SVC anastomosis site was measured on the left pulmonary artery level because donor and recipient SVC anastomosis was usually performed just below that level. This assumption may have caused observer variation or bias. Thus, we analyzed the diameter of the narrowest point of the SVC on CT.

In conclusion, this study provides evidence that the SVC intima layer-only suture technique is a safe and effective surgical method in heart transplantation.

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Conceptualization: WSJ, NHP. Data curation: WSJ, SP. Formal analysis: WSJ, KS. Methodology: KS, SP. Project administration: NHP, ICK, JK. Visualization: WSJ, SP. Writing–original draft: WSJ, KS, SP. Writing–review and editing: all authors.

Conflict of interest

No potential conflict of interest relevant to this article was reported.

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