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Transplant & Mechanical Support: Short Report

Outcomes of Full and Partial Cardiac Autotransplantation for Complex Left-Sided Heart Tumors

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ABSTRACT

BACKGROUND Complex or malignant left-sided heart tumors present a challenge for resection and reconstruction. Cardiac autotransplantation was developed to address this but is a complex technique. Partial autotransplantation was developed to simplify the procedure. This study evaluates the outcomes of partial cardiac autotransplantation compared with those of full cardiac autotransplantation.

METHODS We analyzed our prospectively collected cardiac tumor database for cases between 1998 and 2022 requiring full or partial cardiac autotransplantation. The primary end points for the study were morbidities including bleeding, total blood transfusions, renal failure, prolonged ventilation (>48 hours), arrhythmias, total cardiopulmonary bypass time, total aortic clamp time, hospital length of stay, and intensive care unit length of stay. The secondary end point was operative 30-day mortality.

RESULTS We identified 57 consecutive cases of partial or full cardiac autotransplantation. Full autotransplantation was performed in 47 of 57 (82.5%) patients, and partial autotransplantation was performed in 10 of 57 (17.5%) patients. For full vs partial techniques, mean cardiopulmonary bypass time was 191.0 vs 147.5 minutes ($P = .01$), and median number of blood transfusions was 5.0 vs 2.0 units ($P = .04$). Mean aortic clamp time was 120.5 vs 103.0 minutes ($P = .12$), median length of hospital stay was 12.0 vs 8.5 days ($P = .23$), and intensive care unit stay was 5.0 vs 2.0 days ($P = .14$); renal failure (9/47 [19%] vs 0) did not differ ($P = .34$). There was no 30-day mortality in the partial group.

CONCLUSIONS Partial cardiac autotransplantation represents a simplification of the full autotransplantation technique and can be performed with a reasonable operative risk.

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Malignant or complex cardiac tumors involving the left atrium or left ventricle can present the surgeon with significant challenges based on anatomic accessibility and proximity to vital structures that cannot be safely resected and reconstructed. Cardiac autotransplantation to address these issues for a left heart tumor was done in 1985 by Denton Cooley.[1] To provide better anatomic

IN SHORT

- Malignant and complex left-sided heart tumors may require complex techniques.
- Cardiac autotransplantation has been used to treat these complex tumors successfully.
- Partial cardiac transplantation may simplify this approach with acceptable outcomes.

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exposure in these cases, we began the use of cardiac explantation, ex vivo tumor resection and reconstruction, and cardiac reimplantation in 1998. We subsequently updated our experience with cardiac autotransplantation to 35 cases in 2014.[2] The 30-day mortality for these complex tumors was 15%, and morbidity was common. The most difficult anastomosis to complete was the inferior vena cava (IVC)-to-right atrial (RA) junction. We hypothesized that if we left the IVC intact, it would simplify the procedure, leading to potentially better outcomes. This study examines the outcomes for 47 complete and 10 partial cardiac autotransplantations.

PATIENTS AND METHODS

We analyzed our prospectively collected cardiac tumor database from 1998 to March 2022 and identified 57 patients undergoing full or partial cardiac autotransplantation for complex left-sided heart tumors. Tumors requiring extensive resections that did not include complete or partial autotransplantation or patients who refused consent into the study were excluded. Treatment planning was done through a multidisciplinary cardiac tumor board at Houston Methodist Hospital and MD Anderson Cancer Center, where all cases were reviewed before treatment. The senior author (M.J.R.) was involved in all surgical resections. Institutional review board approval and consent into our prospective cardiac tumor database were obtained for all patients undergoing the operative resection. Baseline, operative, and follow-up data were collected using all available medical records and direct patient contact from the time of referral through March 2022.

The primary end points for the study were morbidities including bleeding, total blood transfusions, renal failure, prolonged ventilation (>48 hours), arrhythmias, total cardiopulmonary bypass time, total aortic clamp time, hospital length of stay, and intensive care unit (ICU) length of stay. The secondary end point was operative 30-day mortality.

Patients' characteristics and outcomes were reported as frequencies and proportions for categorical variables and as median and interquartile range for continuous variables. Differences between the groups (full vs partial autotransplantation) were determined by Fisher exact test for categorical variables and Wilcoxon rank sum test for continuous variables. Kaplan-Meier curves were used to depict patient survival from surgery at 1 year. Difference in 1-year survival between the groups was compared by the log-rank test. Box plots were used to present the distribution of blood transfusion volume and intraoperative cardiopulmonary bypass time. All the analyses were performed on Stata version 17.0 software (StataCorp LLC). A P value of $<.05$ was considered statistically significant.

We have previously presented our technique for complete cardiac autotransplantation in detail.[3] With the technique of complete cardiac autotransplantation, we saw excellent exposure for resection and reconstruction but found that the IVC-RA anastomosis was often challenging, as was proper orientation of the heart after extensive left atrial reconstruction with loss of normal landmarks. Partial autotransplantation maintains all the steps previously described for full autotransplantation and eliminates only the IVC-RA junction division to remove this anastomosis and to maintain cardiac orientation.

In short, the technique requires cannulation of the superior vena cava far enough from the right atrium to allow division and easy reconstruction. The division should allow at least 1 cm of space on the superior vena caval side as this tissue will contract once divided. We also bevel the division toward the right atrium as it goes posterior to leave a longer back wall on the superior vena caval side for starting this anastomosis. The IVC-RA junction is mobilized to expose the vena cava itself, and cannulation is done at this junction. We begin by opening the left atrium in the groove in a standard fashion to expose the tumor and decide whether a standard left atrial approach can be used. If this is not feasible, we divide the superior vena cava as described before, the aorta about 2 cm above the sinotubular junction, and the main pulmonary artery just proximal to its bifurcation. The left atrium is divided just anterior to the pulmonary veins, with the left atrial appendage and mitral valve remaining on the cardiac side of the division. The heart can then be elevated on the attached IVC for extensive exposure.

RESULTS

We identified and enrolled 57 consecutive cases of partial or full cardiac autotransplantation for complex left-sided heart tumors; 47 (82.5%) cases were of primary cardiac sarcoma, 9 (15.8%) cases were paragangliomas, and 1 case was of an intracavitary left ventricular metastatic melanoma. Of the partial autotransplantation cases, 9 involved the left atrium and 1 was a large paraganglioma causing extensive extrinsic compression of the left atrium. Undifferentiated sarcoma was the most common sarcoma type (18/47 [38%]). Full autotransplantation was performed in 47 of 57 (82.5%) patients and partial autotransplantation in 10 of 57 (17.5%). Overall, 30 of 57 (52.6%) patients were male, and most were White (39/57 [68.4%]). The most common presenting symptoms for all cardiac tumors were shortness of breath and chest pain. Partial cardiac autotransplantation was predominantly performed in the more recent time period. Supplemental Table 1 shows the demographics and tumor characteristics.

The mean age at the time of surgery was 45.1 (35.8-56.3) years for full autotransplantation patients and 43.6

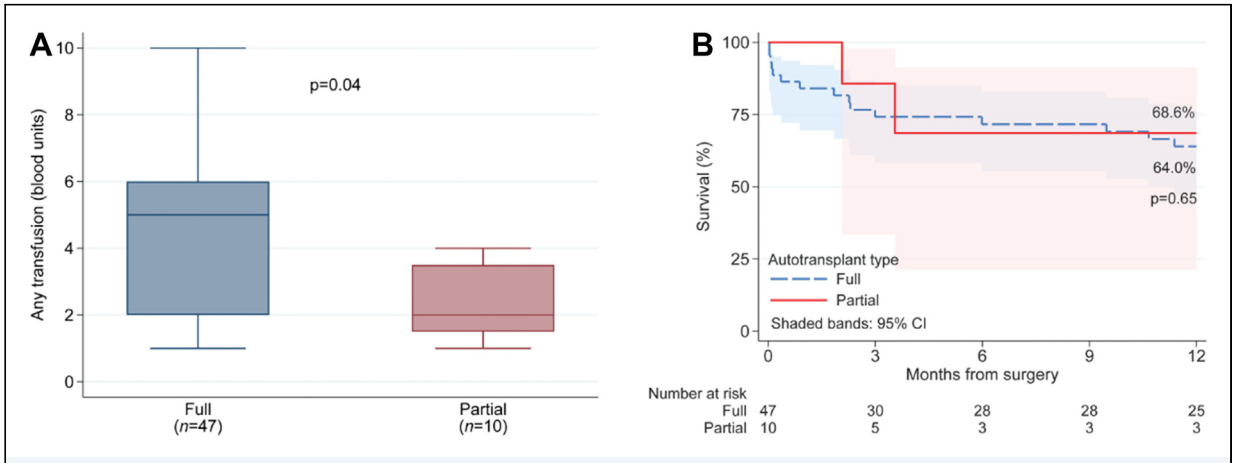

FIGURE (A) Transfusion by full vs partial autotransplantation technique. (B) Kaplan-Meier 1-year survival by partial vs full autotransplantation technique.

(37.3-59.4) years for partial autotransplantation patients ($P = .97$). Supplemental Table 2 shows the operative details and the recurrence status. Recurrent tumor at the time of operation was present in 31 of 47 (66%) of the full autotransplantation cases and in 8 of 10 (80.0%) of the partial autotransplantation cases. A total of 33 of 47 (70%) of the full autotransplantation cases and 9 of 10 (90%) of the partial autotransplantation cases were redo sternotomy procedures ($P = .20$). For the partial autotransplantation group, left atrial reconstruction was needed in all but the paraganglioma case, and 7 of 10 (70%) had R0 resections.

The mean cardiopulmonary bypass time was significantly higher for the full autotransplantations compared with the partial autotransplantations, 191.0 vs 147.5 minutes, respectively ($P = .04$). There was no difference in the aortic cross-clamp times between the groups, 120.5 vs 103.0 minutes ($P = .12$). The median blood transfusion requirement was also significantly higher in the full autotransplantation patients, 5.0 vs 2.0 units (full vs partial; $P = .04$; Figure A). The median length of hospital stay was 12.0 vs 8.5 days ($P = .23$), and the ICU stay was 5.0 vs 2.0 days ($P = .14$) for full autotransplantation compared with partial autotransplantation. Renal failure occurred in 9 of 47 (19%) full autotransplants vs none in partial autotransplants ($P = .34$). The 30-day operative mortality was 9 of 47 (19%) for complete autotransplantation and none for partial autotransplantation ($P = .34$; Supplemental Table 3). There was no difference in 1-year survival between the groups ($P = .65$; Figure B). Supplemental Table 4 shows differences stratified by mortality from surgery.

COMMENT

Our 57 cardiac autotransplantation cases represent the largest series reported in the medical literature to date. The major findings of this study were that partial cardiac autotransplantation can be done safely and results in fewer blood transfusions and less cardiopulmonary bypass time compared with full autotransplantation. The hospital and ICU length of stay and renal failure were not statistically different. The 30-day mortality for partial autotransplantation was 0 of 10 (0%) vs 9 of 47 (19%) for full cardiac autotransplantation, with no difference in survival at 1 year.

Complete radical surgical resection is the optimal treatment for most benign and malignant left-sided heart tumors. Whereas most left-sided benign heart tumors can be completely resected without incident, complete resection of malignant and complex left-sided heart tumors can be technically challenging and complicated by anatomic inaccessibility and proximity to vital cardiac structures. To address the multiple recurrences of malignant tumors in patients with incomplete resection, our institution developed the technique of cardiac autotransplantation in early 1998, a protocol entailing cardiac explantation, ex vivo resection and reconstruction, and cardiac reimplantation. Such a technique allows optimal anatomic exposure for complete resection and accurate cardiac reconstruction. We have subsequently used this technique on complex left-sided heart tumors, such as large left atrial paraganglioma.[2,4-7] The operative times were extensive, and morbidity was common. We found the IVC-RA anastomosis as well as proper orientation of the heart after extensive left atrial reconstruction and loss of normal landmarks to be challenging. In an attempt to simplify the approach to these tumors, our surgical team has recently moved toward a partial autotransplantation approach in which the IVC is left intact as our primary method. We have found that primary cardiac sarcoma that extends to the origin of the left pulmonary veins or involves the anterior left atrium benefits from the exposure provided

by this technique. In addition, large left atrial paragangliomas are highly vascular and often involve the mediastinum behind and superior to the left atrium and need extensive exposure for successful resection.

We have previously reported surgical resection techniques for cardiac paraganglioma as well as our technique for cardiac autotransplantation.[3,5,8,9] In general, pulmonary root replacement is done with pulmonary allograft, aortic root replacement with valve conduit, and atrial wall replacement with bovine pericardium. Cardiac autotransplantation involves complete excision of the heart, dividing the superior vena cava, IVC, aorta, pulmonary trunk, and left atrium just anterior to the pulmonary veins, allowing explantation of the heart and complete exposure of the left atrium and mediastinum behind the heart for resection.

Partial cardiac autotransplantation involves division of the superior vena cava, aorta, pulmonary root, and left atrium while leaving the IVC attached.[10] Partial autotransplantation provides adequate visualization and exposure in most cases and avoids transection of the IVC; it allows the operator to keep orientation and to suture 1 less anastomosis.

Primary cardiac sarcoma is a rare disease with improved survival associated with surgical resection.[10] Almost half of primary cardiac sarcomas in our experience occur in the left atrium or ventricle, and most of these require full or partial cardiac autotransplantation for adequate anatomic exposure for full excision.[5] These are by their nature complex and lengthy procedures. We have found that using the partial technique shortens and simplifies the surgical procedure while maintaining exposure for resection and safety.

LIMITATIONS. This is a retrospective nonrandomized study, and selection bias may have occurred. Partial cardiac autotransplantation is a relatively newer technique, and these procedures have been performed in a more recent time frame. A learning curve bias for complex cardiac sarcomas has likely occurred before establishing this recent surgical approach.

CONCLUSIONS. Partial autotransplantation for complex or malignant left-sided heart tumors can be safely performed, requiring less pump time and the need for blood transfusions. No operative or 30-day mortality was seen with the partial autotransplantation group, and the survival at 1 year was similar between the techniques.

The Supplemental Tables can be viewed in the online version of this article [https://doi.org/10.1016/j.athoracsur.2022.09.012] on http://www.annalsthoracicsurgery.org.

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PATIENT CONSENT

The authors attest they are in compliance with human studies committees and animal welfare regulations of the authors' institutions and Food and Drug Administration guidelines, including patient consent where appropriate.

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