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Heart Transplant at Seoul National University Hospital: Is It Reproducible in Sub-Saharan Africa?

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Abstract

Introduction: Heart transplantation is used to treat heart failure. The first human-to-human heart transplant took place in South Africa in 1967. However, this surgical technique is not practiced in sub-Saharan Africa, but heart failure is clearly increasing in the young and active African populations. We report the case of 03 heart transplants successfully performed in the pediatric cardiac surgery department at Seoul National University Hospital. **Objective**: To present heart transplantations for congenital heart disease in order to reproduce them technically in sub-Saharan Africa. **Cases series: Case 1**: Male, 3 years old. Background: main pulmonary artery (MPA) banding, Ventricular Septal defect (VSD) closure, Heart failure requiring left ventricular assist device (LVAD) implantation. Echocardiography: left ventricle dysfunction (EF 28%), Heart transplantation. The immediate postoperative follow-up was simple. **Case 2**: Male, 9 years old. Background: Dilated cardiomyopathy (DCMP), Left ventricular assist Device (LVAD) implantation. Echocardiography: Severe LV dysfunction, global akinesia, LV FS/EF 10.4/22.4% (PLAX). Heart transplantation. The immediate postoperative follow-up was simple. **Case 3**: Male, 20 years old. Background: dilated cardiomyopathy (DCMP), Duchenne Muscular Dystrophy (DMD), Left ventricular assisted device (L-VAD) (HeartMate 3) implantation. Echocardiography: Aggravated LV dysfunction (EF 26% - 29%). Heart transplantation. The immediate postoperative follow-up was simple. **Conclusion**: Heart transplantation according to the bi-caval procedure has made it possible to treat children with end-stage heart failure at Seoul National

University Hospital. End-stage heart failure in Africa is clearly increasing among the young working population. Although Africa faces a range of challenges, heart transplantation is reproducible in sub-Saharan Africa.

Keywords

Heart Transplantation, Heart Failure, Ventricular Assist Device

1. Introduction

Heart transplantation (HTx) is the final treatment for patients with advanced heart failure [1]. It is estimated that 26 million adults worldwide are living with heart failure (HF) [2], costing roughly 1% - 2% of healthcare expenditures in Europe and North America [3]. In Korea, heart failure prevalence was estimated to be 1.53% in 2013 [4]. Heart failure is a serious and frequent pathology in Africa. It affects young and active subjects [5]. According to PIO *et al.* [5] in Togo, the prevalence of HFs was 28.6%. PIO found left ventricular systolic dysfunction in 213 patients (56.6%) [5]. Thiam [6] in Senegal reported a prevalence of 37.7%. In Côte d'Ivoire, according to Gnaba *et al.*, HF accounted for 60 to 65% of hospitalized patients. The average left ventricular ejection fraction (LVEF) was 35.8 ± 13% [7]. The main identified causes of heart failure were ischemic heart disease (60%) and hypertensive heart disease (20%) [7]. Patients with end-stage heart failure and cardiomyopathies are candidates for heart transplantation. The first attempt was made 118 years ago, in 1905, by Alexis Carrel and Charles Guthrie at the University of Chicago. In 1967, Human-to-human heart transplantation, which is the replacement of a failing heart with one from a suitable donor, was first carried out by Dr Christian Barnard at the Groote Schuur Hospital in Cape Town, South Africa [8]. Since 1982, more than 14,000 heart transplants have been performed in pediatric patients worldwide [9], which corresponds to around 10% of all heart transplants [10]. About 50% of pediatric patients received heart transplants due to CHD [9], while this proportion is 2.2% in the adult comparison group [11] [12]. The indications (**Table 1**) and contraindications (**Table 2**) for heart transplantation according to the European Society of Cardiology (ESC) and American Heart Association (AHA) guidelines are varied. There are two surgical techniques used in cardiac transplantation: the right atrial (RA) technique and the bi-caval technique. The bi-caval anastomosis technique is currently used. This gesture is not practiced in Sub-Saharan Africa, due to the absence of laws in force and certain beliefs. Dilated cardiomyopathies with severe heart failure are on the rise in our countries.

We report the cases of 3 children who underwent successful heart transplants in pediatric cardiac surgery at Seoul National University Hospital from July to October 2024.

Table 1. Main indications for heart transplantation.

Advanced heart failure
Cardiogenic shock with the need for circulatory support with devices or the need for continuous administration of inotropes
Use of long-term circulatory support devices
NYHA III-IV, despite optimally tolerated therapy and application of resynchronization therapies
Multiple episodes of fluid retention leading to pulmonary congestion or significant peripheral edema requiring high-dose diuretics or decreased cardiac output at res requiring inotropic and/or vasoconstrictor drugs leading to >1 unscheduled emergency department visit or hospitalization in a year
Severe cardiac dysfunction with LVEF < 30% or right ventricular dysfunction or inoperable valvular diseases or elevated NT-proBNP values and evidence of severe diastolic dysfunction (ultrasound, cardiac catheterization), or structural abnormalities according to the definitions for HFrEF, HfpEF.
Intolerance to mild exercise with peak VO2 < 10 Ml/kg/min
Recurrent life-threatening ventricular arrhythmias despite ICD use or ablation therapy
End-stage heart failure due to congenital defects without evidence of pulmonary hypertension
Resistant angina without further possibility of pharmaceutical or surgical treatment
Abbreviations: NYHA, New York Heart Association; LVEF, Left Ventricular Ejection Fraction; HFpEF, Heart Failure with preserved Ejection Fraction; ICD, Implantable Cardioverter Defibrillator

Table 2. Main contraindications for heart transplantation.

Active serious infection, except LVAD device infection, which is an indication
Severe peripheral vascular disease with reduced possibility of recovery and no possibility of revascularization
Medically irreversible pulmonry hypertension (PASP > 60 mmHg, PVR >5 WU, TPG > 15 mmHg)
Malignancies with a poor prognosis
Irreversible liver damage or kidney damage (eGFR < 30 Ml/min/1.73 m^2)
Systemic disease involving multiple organs
Abuse of alcohol or addictive substances
Poor social support with inability to care in the period after surgery
Serious neurological diseases
Active pulmonary embolism
Frailty (>10 Ibs weight loss, fatigue, muscle cachexia
BMI > 35 kg/m^2
Diabetes with HbA1c >7.5 % despite optimal meddication and target organ complications excluding retinopathy
Abbreviations: LVAD, Left Ventricular Assist Device; PASP, Pulmonary Artery Systolic Pressure; PVR, Pulmonary Vascular Resistance; TPG, Transpulmonary Pressure Gradient; eGFR, estimated Glomerular Filtration Rate; BMI, Body Mass Index; HbA1C, hemoglobin A1C

2. Case Series

2.1. Case 1

2.1.1. Clinical and Biological Data

Male patient, 3 years old, height = 91 cm and weight = 15.3 Kg. Background: pul-

monary hyper flow requiring a banding of the trunk of the pulmonary artery in July 2021. Veno-arterial extracorporeal membrane oxygenation (VA ECMO) insertion (2022/6/3). Finally, left ventricular assist device (LVAD) insertion was performed (2022/6/9). The patient was then transferred from his initial health center to Seoul National University Hospital (SNUH).

At Seoul National University Hospital, LVAD pump has been changed (2024/7/01). Ventricular Septal Defect has been closed (2022/10/24). Clinical examination had shown heart failure, Blood pressure = 109/73 mmHg, temperature = 36˚4 and saturation $wSpO_2$ = 96% - 99%. The patient had LVAD (Berlin heart, heart mate III) (CO 25 cc x 75 bpm = 1.875) in situ. The hemoglobin level was 10.7 g/dl, the platelet level was 138,000/mm^3. The INR was 2.88 on warfarin.

2.1.2. Electrocardiogram

Normal Sinus Rythm, Left Atrial Dilatation, Left Ventricular Hypertrophy, prolonged QT (QTc 478 ms).

2.1.3. Echocardiography

1) LV dysfunction, septal thinning, paradoxal septal wall motion (+)

LV EF (auto) 28% (A4C) 42% (Bip), (biplane simpson s) 43% (4CV simpson) 34.9%.

(m mode PLAX) 32.6%, probably inaccurately measured d/t PSWM.

2) LVAD inflow cannula in situ, peak vel 4.2 m/s at late systole

In LV and LA cavity, no visible thrombus.

Aortic valve opening (+) trivial AR.

3) moderate-severe MR (type III large eccentric zet), MV annulus = 21.6 mm

Careful preparation and perfect cooperation between the collection and transplantation teams. A complete preoperative check-up, Compatibility tests, The start of immunosuppressive treatment.

2.1.4. Surgical Procedure

GEA, full median sternotomy, pericardium -tenting, arterial cannulation-Distal ascending aorta, venous cannulation-SVC direct, IVC direct, Vent-RUPV, CPB 327 mn, ACC 191 mn, Donor ischemic time 163 mn; approach-LA, Aorta, RA, PA.

Redo-sternotomy, Adhesiolysis, cannulation (distal ascending aorta, SVC, IVC, RUPV for vent); CBP on; L-VAD (Berline Heart Excor) weaning and clamping; additional dissectin and mobilization around SVC and RA and pulmonary vein; ACC. Cardiecomy.

ICD explantation, LVAD cannlae retrieval; donor heart CPS; LA anastomosis (5-0, double-layer continuous sutures, x4) (**Figure 1**); aorta anstomosis (5-0 prolene; double -layer continuous sutures, x2); ACC release; IVC-RA anastomosis (6-0 prolene, single-layer continuous sutures, x1); SVC anastomosis (6-0 prolene, single-layer continuous sutures, x1). Rewarming, root vent, CPB weaning; modi-

fied ultrafiltration; decannulation; meticulous bleeding control; chest tube insertion; pericardial coverage with seprafilm; wound closure layer-by-layer.

Transfer to intensive care unit.

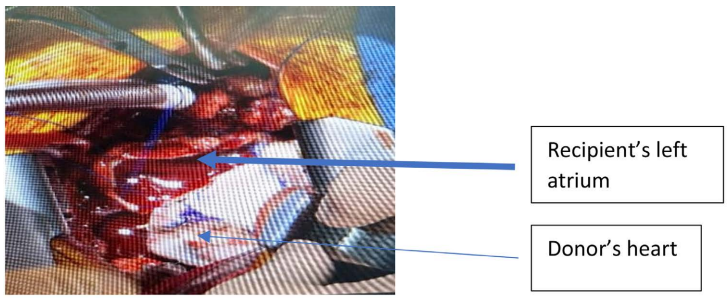


Figure 1. Intraoperative view of heart transplantation, time of left atrium suture.

2.2. Case 2

2.2.1. Clinical and Biological Data

Male patient, 9 years old, height = 125 cm and weight = 23 Kg. Background: dilated cardiomyopathy (D-CMP); Biventricular dysfunction and dilatation.

Maintenance treatment: ASA, Plavix, Dilatrend hold, Warfarin hold → heparinization, Lasilix, spironolactone, digoxin, Viagra

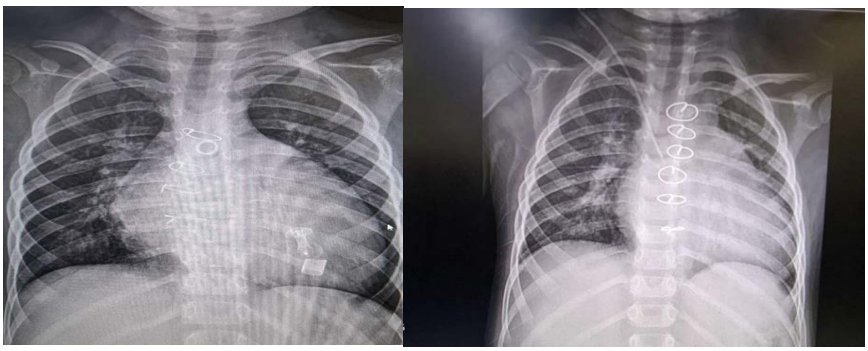
Heart Failure, PHT d/t D-CMP s/p L-VAD (24. 01. 25)

- Berlin heart CO support: 25 cc x 94 = 2.350: filling VAD rate 88

Clinical examination has shown heart failure, Blood pressure = 89/51 mmHg, heart rate = 90 - 95 per minute on Dobutamine 3 mcg/kg/min. Peripheral partial oxygen saturation wSpO2 (RA) 97% - 99%. The body temperature was 36.3˚C. Biological assessment: The haemoglobin level was 8.4, the platelet count was 222,000/mm^3, the INR was 1.58.

2.2.2. Chest X-Ray

Chest X-rays were taken before and after transplantation **(Figure 2).**



(A) (B)

Figure 2. X-ray of the chest from the front. (A) Preoperative; (B) Postoperative.

2.2.3. Electrocardiogram

The electrocardiogram showed junctional rhythm.

2.2.4. Echocardiography

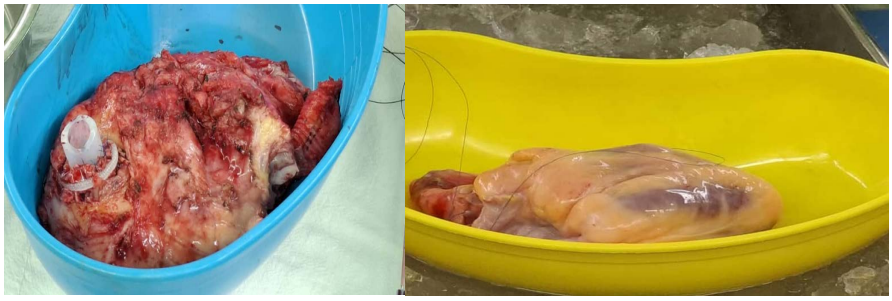
Severe Left Ventricle dysfunction, global akinesia, LV FS/EF 10.4/22.4% (PLAX). LV apex inflow cannula and AAo outflow cannula *in situ* no visible thrombus below aortic valve. Mild MR. Severe RAE, RAA 19.8 cm^2 (Z 4.87), moderate TR, coaptation gap 13 mm, RV dilatation.

Careful preparation and perfect cooperation between the collection and transplantation teams. A complete preoperative check-up, Compatibility tests. The start of immunosuppressive treatment.

2.2.5. Surgical Procedure

GEA, full median sternotomy, pericardium-tenting, arterial cannulation-Distal ascending aorta, venous cannulation-SVC direct, IVC direct, Vent-RUPV, CPB 259 mn, ACC 157 mn, Donor ischemic time 153 mn; approach-LA, Aorta, RA, PA

Redo-sternotomy, Adhesiolysis, cannulation (distal ascending aorta, SVC, IVC, RUPV for vent); CBP on; L-VAD (Berline Heart Excor) outflow graft clamping, LVAD (Berlin Heart Excor) weaning; additional dissection and mobilization around SVC and RA and pulmonary vein; ACC. Cardiecomy (**Figure 3**).



(A) (B)

Figure 3. View of the heart outside the body. (A) Pathological heart removed; (B) Donor heart ready for transplant.

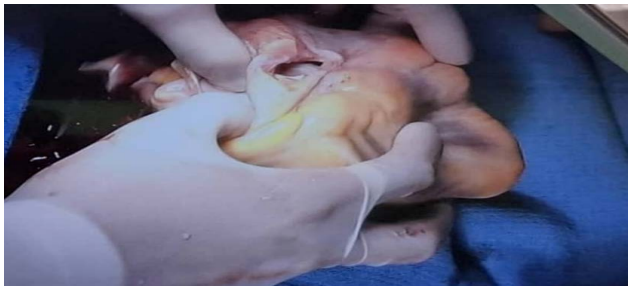


Figure 4. Examination of the heart ready before transplantation.

ICD explantation, LVAD cannlae retrieval; donor heart examination (**Figure 4**); LA anastomosis (5-0, double-layer continuous sutures, x4); aorta anstomosis (5-0 prolene; double -layer continuous sutures, x2); ACC release; IVC-RA anastomosis (6-0 prolene, single-layer continuous sutures, x1); SVC anastomosis (6-0

prolene, single-layer continuous sutures, x1). Rewarming, root vent, CPB weaning; modified ultrafiltration; decannulation; meticulous bleeding control; chest tube insertion; pericardial coverage with seprafilm; wound closure layer-by-layer.

Transfer to the intensive care unit.

2.3. Case 3

2.3.1. Clinical Data

Male patient, 20 years old, rhesus blood type AB+, height = 156 cm, weight = 54.9 Kg. Background: DMD (Duchenne Muscular Dystrophy); Hypercalciuria; dilated cardiomyopathy (DCMP); L-VAD (HeartMate 3) insertion (2022/12/13); anticoagulation: aspirin + warfarin, Heart failure medication: carvedilol 6.25 mg bid, ivabradine 5 mg bid. Clinical examination: heart failure.

2.3.2. Echocardiography

Aggravated LV dysfunction: EF 26% - 29%, No visible intracardiac thrombus. LV dimension: no significant interval change.

- LVIDd (PLAX) 72.9 mm, (PSAX) 72.6 mm.
- LA/Ao ratio 1.7.

IVS flattening –; AV opening –; Mild to moderate AR; Mild to moderate MR; Trivial TR; Trivial PR; No pericardial effusion.

2.3.3. Electrocardiogram

Electrocardiogram showed normal sinus rhythm.

2.3.4. Chest X-Ray

The preoperative chest X-ray was normal and showed the left ventricular assist device (Figure 5).

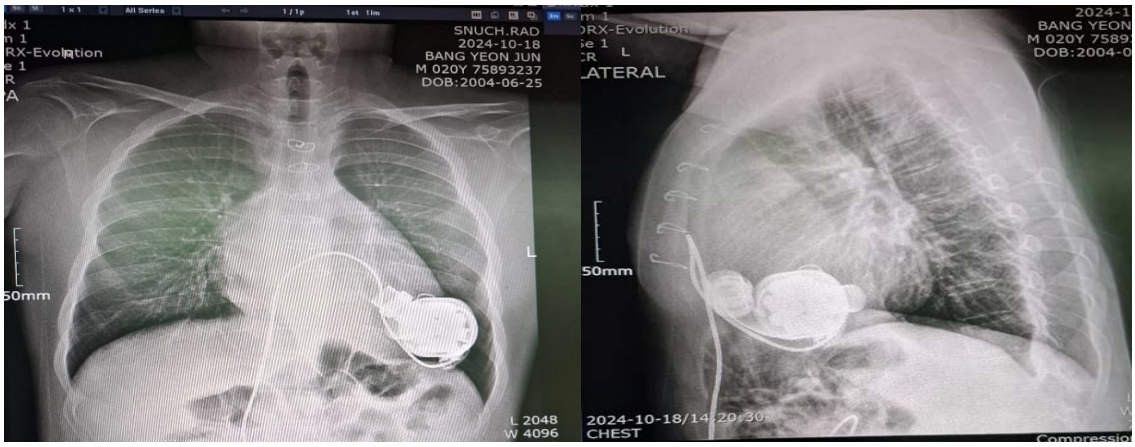


Figure 5. Chest x-ray from the front and side.

2.3.5. CT Scan (Figure 6)

Careful preparation and perfect cooperation between the collection and transplantation teams. A complete preoperative check-up, Compatibility tests, The start of immunosuppressive treatment.

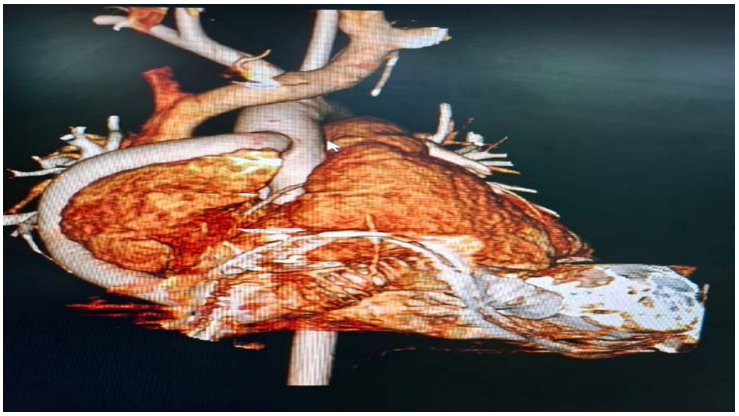
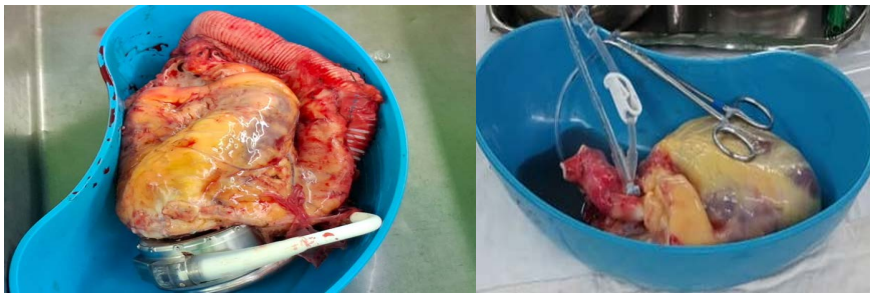


Figure 6. CT angiography showing heart and L-VAD.

2.3.6. Surgical Procedure

GEA, full median sternotomy, pericardium-tenting, arterial cannulation-Distal ascending aorta, venous cannulation-SVC direct, IVC direct, Vent-RUPV, CPB 289 mn, ACC 189 mn, Donor ischemic time 157 mn; approach-LA, Aorta, RA, PA.

Redo-sternotomy, Adhesiolysis, cannulation (distal ascending aorta, SVC, IVC, RUPV for vent); CBP on; L-VAD (Berline Heart Excor) weaning and clamping; additional dissectin and mobilization around SVC and RA and pulmonary vein; ACC. Cardiecomy (**Figure 7**).



(A) (B)

Figure 7. View of a heart outside the organism, (A) Recipient's heart; (B) Donor's heart.

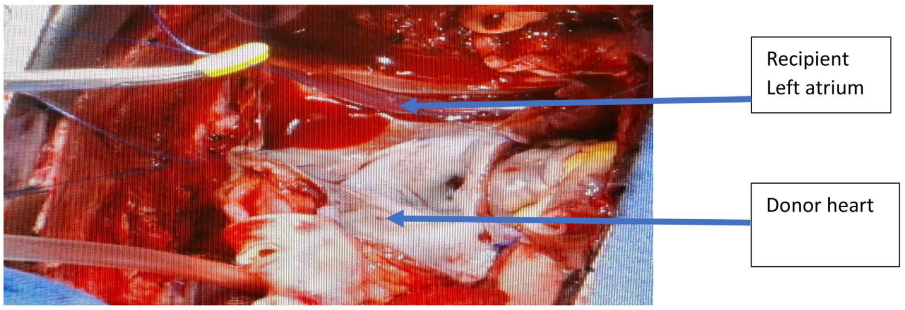


Figure 8. Intraoperative view of a heart transplant: beginning of anastomosis of LA.

ICD explantation, LVAD cannlae retrieval; donor heart CPS; Donor heart in-

spection: PFO primary closure (6-0 prolene, simple sure,x1); LA anastomosis (5-0, double-layer continuous sutures, x4) (**Figure 8**); aorta anstomosis (5-0 prolene; double -layer continuous sutures, x2); ACC release; IVC-RA anastomosis (6-0 prolene, single-layer continuous sutures, x1); SVC anastomosis (6-0 prolene, single-layer continuous sutures, x1). Rewarming, root vent, CPB weaning; modified ultrafiltration; decannulation; meticulous bleeding control; chest tube insertion; pericardial coverage with seprafilm; wound closure layer-by-layer.

Transfer to the pediatric intensive care unit.

3. Discussion

Heart transplantation (HTx) remains the last therapeutic resort for patients with advanced heart failure. The first clinical heart transplant was accomplished in an adult by Barnard in Cape Town, South Africa, in 1967 [13]. Thus, this first heart transplant in Africa has raised hope in the African population. But heart transplantation remains absent in sub-Saharan Africa. However, heart failure in the African working population is clearly on the rise. According to the Global Observatory of Donation and Transplantation 2017 database, Africa recorded only 14 heart transplants out of 7881 globally, representing 0.2% of the global total in 2016 [14]. Similarly, in 2022, the International Report on Organ Donation and Transplantation Activities recorded heart transplantations in only one country in Africa, Tunisia [15].

During our internship in the Department of Pediatric Cardiac Surgery at Seoul National University Hospital, 3 males children whose ages were 3, 9 and 20 years old were operated on. The majority of pediatric transplant patients are those with pre- and postoperative complex CHDs and those with cardiomyopathies. In our study, One patient had ventricular septal disease operated on and two patients had cardiomyopathy. In the pediatric population, congenital heart disease accounts for about half of the indications; these are either non-repairable malformations or malformations operated on but resulting in terminal heart failure. The 3 patients had left ventricular dysfunction with an ejection function of 28% for case 1, 22.4% for case 2 and 26% - 29% for case 3. The alteration of left ventricular function required the implementation of left ventricular support for the 3 patients. This essential ventricular support allows patients to wait until they have a donor for a heart transplant. All 3 patients had left ventricular assist device (L-VAD). These LVADs increase the difficulties and operating time during the preparation of the recipients. Recipients with congenital heart disease pose specific technical problems related to initial malformations and/or various palliative interventions. Heart transplantation in CHD patients is usually complicated by multiple previous operations, cardiac defects, abnormal situs, and collateral circulation, which should be precisely recorded before the heart transplantation. Case No. 1 had a VSD, *i.e.* a congenital heart disease. Case 2 had dilated cardiomyopathy of unidentified etiology. Case No. 3 had dilated cardiomyopathy, whose etiology was Duchenne Muscle Dystrophy. Though VAD has been widely used for end-stage

heart failure and bridge-to-transplantation or destination therapy, VAD application in CHD patients is not extensively used [16]. VADs in pediatric and adult CHD populations are increasing due to the shortage of donor's hearts and an increasing number of patients with heart failure [17] [18]. Previous studies found that VAD therapy can prolong survival in high-risk CHD patients who would either die or be delisted due to clinical deterioration [19].

Total heart transplantation requires careful preparation and perfect cooperation between the collection and transplantation teams. Particular attention should be paid to the condition of the pulmonary arterial bed. Accurate assessment of pulmonary vascular resistance. Several factors determine the outcome of HTx, such as ABO and HLA compatibility, graft size, ischemic time, and age. Active infection, peripheral vascular disease, malignancies, and increased BMI are frequent contraindications. The major complications of HTx include graft rejection, graft angiopathy, primary graft failure, infection, neoplasms, and retransplantation. Advances in the field of HTx encompass novel monitoring for acute cellular rejection and antibody-mediated rejection (Nikolaos) [20].

The 3 patients were operated on under general anesthesia and extracorporeal circulation, with moderate hypothermia. The heart transplant technique was the bicaval technique for the 3 patients. There are currently two surgical techniques used in cardiac transplantation: the right atrial (RA) technique and the bi-caval technique. The latter is a more recent technique and has become more popular than the former. In RA cardiac transplantation, when the native heart is explanted, the posterior walls of both atria of the recipient heart are left in place (**Figure 9**) and are anastomosed to the donor heart [21].

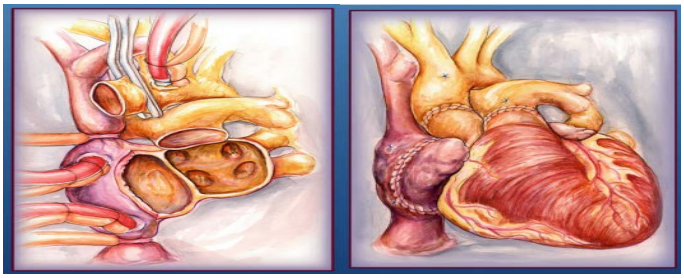


Figure 9. Right atrial technique (Backer, transplantation 2015) [22].

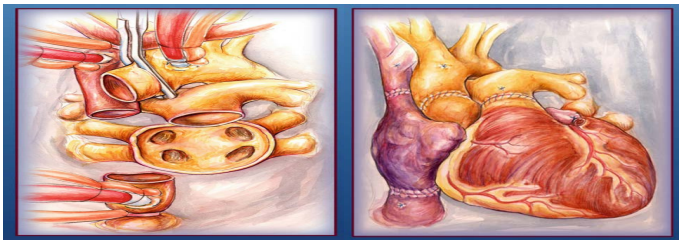


Figure 10. Bicaval technique (Backer, transplantation, 2015).

In the bi-caval technique (**Figure 10**), the RA is also explanted from the recipi-

ent, leaving only the posterior wall of the left atrium (LA) with four pulmonary veins attached [21]. Anastomoses are made between the LA, aorta, IVC, SVC, PA.

Studies have shown that bicaval anastomosis is less likely to require a pacemaker, and patients need less time in the hospital [23]. The bicaval technique preserves normal atrial morphology, sinus node function, and valvular function [24]. As a result, it has consistently been associated with a decreased incidence of atrial arrhythmias and the need for pacemaker implantation. However, potential disadvantages include an increased ischemic time and the possibility of narrowing of the caval anastomosis.

The immediate postoperative follow-up was simple for the 3 patients.

Heart transplantation is considered one of the most effective treatments for end-stage heart failure, giving patients another chance for survival and an improved quality of life. However, this practice faces impediments in Africa due to various barriers, including inadequate infrastructure, a lack of personnel for such procedures, a shortage of organ donors, negative beliefs regarding organ donation, and economic constraints. In 2021, it was reported in Uganda that one of the major barriers to performing a heart transplant was the financial challenge it poses on the part of the patient and the medical facility due to it being an expensive procedure [25]. The infrastructure required to support heart transplantation is often unavailable in many African countries. This includes specialized cardiac centers with dedicated intensive care units, sophisticated diagnostic materials, surgical equipment, tissue typing, cross-matching, and some viral studies [26]. Although there are difficulties, heart transplantation will give patients a second chance. They will then be able to contribute to the development of Africa.

4. Conclusion

Heart transplantation according to the bi-caval procedure has made it possible to treat children with end-stage heart failure in Seoul National University Hospital. End-stage heart failure in Africa is clearly increasing among the young working population. Although Africa faces a range of challenges, heart transplantation is reproducible in sub-Saharan Africa. Also, given the scarcity of donors and the morbidity and mortality of transplants, emphasis could be placed on other means of acquiring grafts, in particular xenotransplantation and cardiac tissue bioengineering.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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