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A single-center long-term experience with marginal donor utilization for heart transplantation

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Abstract

Background: To evaluate the early and late outcome of heart transplantation (HT) using marginal (MDs) and optimal donors (ODs).

Methods: Clinical records of recipients transplanted between July 2004 and December 2014 were retrospectively reviewed. MDs were defined as follows: age >55 years, high-dose inotropic support, left ventricular ejection fraction <45%, left ventricular hypertrophy, donor to recipient predicted heart mass ratio <0.86, ischemic time >4 hours.

Results: A total of 412 (55%) recipients received an organ from a MD; recipients who received an organ from an OD had less primary graft dysfunction (PGD) (25% vs 38%; $P < .001$), less acute renal failure (23% vs 34%; $P < .001$), and higher survival rates (90.2% vs 81.8% at 30 days, 79.5% vs 71.1% at 1 year, 51.8% vs 45.4% at 12 years; $P = .01$) than recipients who received an organ from a MD. There was no statistically significant difference in 30-day conditional survival between the two groups (survival rates 57.4% vs 55.5% at 12 years; $P = .43$). PGD, perioperative hemodialysis, and sepsis were independent risk factors of mortality at multivariate analysis.

Conclusions: Utilization of MDs for HT is associated with a higher incidence of PGD and acute renal failure, and a reduction of 30-day survival.

KEYWORDS
heart transplantation, marginal donor

1 | INTRODUCTION

Heart transplantation (HT) represents the gold standard treatment for patients with end-stage heart failure[1] as it is associated with improved survival and quality of life in these patients[2]; however, its wider application is limited by the scarce availability of suitable organ donors. The huge discrepancy existing between the growing number of patients suffering from heart failure and the limited number of donors has led to an increase in the use of left ventricular assist devices (LVAD) as a bridge to transplant therapy (BTT).[3] New strategies are required to implement the donor pool including the expansion of criteria for acceptance of organ donor, the use of non heart-beating donors, and the development of optimal preservation and perfusion techniques for the reconditioning of the heart after cardiac arrest.[4,5] While reluctance exists in accepting marginal donors in consideration of higher incidence of primary graft dysfunction (PGD) and worse survival, waiting for an optimal donor especially in higher risk patients is no longer ethically acceptable. The

purpose of the present study is to assess the influence of marginal donors on early and long-term results of HT.

2 | PATIENTS AND METHODS

The study protocol was approved by the Institutional Review Board. Clinical records of all adult patients transplanted between July 2004 and December 2014 were retrospectively reviewed. In July 2004, a national high urgency waiting list started in France to prioritize organs for critically ill patients requiring high-dose inotropic drugs or short-term mechanical cardio-circulatory support (High Urgency type 1, HU1) and for patients experiencing thrombotic or infective complications related to the implant of a long-term mechanical circulatory support (High Urgency type 2, HU2). Patients undergoing multi-organ and re-transplantation were excluded from the study. Data were collected until June 2017. Patients were divided into two groups according to the quality of the donor: patients receiving an organ from an optimal donor (OD) were assigned to the OD group, while patients receiving an organ from a marginal donor (MD) were assigned to the MD group. Marginal donor criteria were defined as follows: age >55 years, donor to recipient predicted heart mass (D/R-PHM) ratio < 0.86,[6] high-dose inotropic support (norepinephrine > 4 mg/h), left ventricular ejection fraction (LVEF) < 45%, left ventricular hypertrophy (LVH) (septum thickness ≥ 14 mm), ischemic time > 4 hours. The RADIAL score[7] could not be calculated because recipients' right atrial pressures were unavailable; a modified RADIAL score was calculated including all the other components (recipient age ≥60 years, diabetes mellitus, inotrope dependence, donor age ≥30 years, length of ischemic time ≥240 minutes).[8] Clinical records of donors were provided by the "Agence de la Biomedicine," the French Agency for organ transplantation that guarantees for the accurateness of the information. Further details about the operative technique, the immunosuppression, the PHM formula, the follow-up, and the statistical analysis are provided as Appendix S1.

3 | RESULTS

From July 2004 to December 2014, a total of 803 HTs were performed at our institution; 39 patients underwent multi-organ transplantation and 16 patients underwent re-transplantation and were excluded from the study. The remaining 748 patients were divided into two groups according to the quality of the donor: 336 (45%) recipients received an organ from an optimal donor (OD group) and 412 (55%) recipients received an organ from a donor with at least one marginal donor (MD group) criteria. The most frequent MD criteria were age >55 year (38%) and ischemic time >4 hours (24%) (Table S1); 312 (76%) recipients had a donor with 1 MD criteria, 86 (21%) had a donor with 2 criteria, and 14 (3%) had a donor with 3 criteria. Donors' and recipients' pre- and postoperative characteristics are illustrated in Table 1; ODs were significantly younger and were more often male, they had higher PHM, more history of cardiac arrest and drug abuse, more anoxia as cause of death. Recipients who received an organ from an OD had a significantly lower modified RADIAL score and had less sex mismatch and less female donor for a male recipient; they also had significantly less PGD requiring a postoperative ECMO, acute renal failure requiring CRRT, perioperative plasmapheresis sessions for immune sensitization and MOF than recipients who received an organ from a MD. Recipients who needed a postoperative ECMO for PGD were older, were transplanted more frequently in HU1, had more preoperative ECMO, had longer ischemic and CPB time, were more frequently transplanted with pfDSA requiring perioperative plasmapheresis, underwent more frequently a redo surgery, and had higher modified RADIAL score and their corresponding donors needed more frequently a high-dose inotropic support (Table 2). Acute renal failure requiring early postoperative CRRT was recorded in 218 (29%) recipients; patients who required early postoperative CRRT had longer only ischemic and CPB time compared to patients who did not (Table S2). There was no difference in end-stage renal disease (ESRD) requiring hemodialysis or need for kidney transplantation between recipients who needed early postoperative CRRT and recipients who did not (Table S2). We additionally evaluated if there was a change over time in the acceptance of MDs; we divided the study period into two sub-periods: from July 2004 to December 2009 (period 1) and from January 2010 to December 2014 (period 2) (Table S3); 376 HTs were performed during the period 1 and 197 (52%) recipients received an organ from a MD, while 372 HTs were performed during the period 2 and 215 (58%) recipients received an organ from a MD ($P = .15$). No difference was observed in donors' age between the two periods; however, donors in period 1 had significantly less cardiac arrest, LVH, and drug abuse than donors of period 2. We also evaluated if there was a change of the recipient's profile over time; during period 1, recipients had less preoperative ECMO and LVAD and were less frequently transplanted in HU1 and HU2, than recipients belonging to period 2 (Table S3). Recipients of the period 1 had less postoperative ECMO for PGD and more CRRT and MOF than recipients of period 2 (Table S3).

3.1 | Recipient survival

At the end of the follow-up, a total of 304 events were recorded, including 300 deaths and 4 re-transplantations; we recorded 123 events in the OD group including 121 deaths and 2 re-transplantation (1 for chronic allograft rejection and 1 for PGD) and 181 events in the MD group, including 179 deaths and 2 re-transplantation for chronic allograft rejection. Kaplan-Meier analysis showed a mean survival time of 8.6 ± 0.3 years in the OD group and 7.5 ± 0.3 years in the MD group. Survival rates were significantly higher in recipients receiving an organ from an OD donor (90.2% vs 81.8% at 30 days, 79.5% vs 71.1% at 1 year, 51.8% vs 45.4% at 12 years; $P = .01$) (Figure 1A). There was no statistically significant difference in 30-day conditional survival between the two groups (survival rates 57.4% vs 55.5% at 12 years; $P = .43$) (Figure 1B). The

TABLE 1 Donors' and recipients' preoperative and early postoperative characteristics according to the quality of the donor

	OD group (n = 336)	MD group (n = 412)	*P*
Donors' characteristics			
Age (y)	45 (35-50)	55 (43-60)	<.001
Male sex	247 (74%)	235 (57%)	<.001
Sex mismatch	84 (25%)	159 (39%)	<.001
Donor F/recipient M	44 (13%)	129 (31%)	<.001
BMI	25	25 (22-28)	.46
PHM	178 (153-195)	167 (138-187)	<.001
Main cause of death			
Cerebrovascular accident	149 (44%)	227 (55%)	.004
Trauma	106 (32%)	107 (26%)	.11
Anoxia	58 (17%)	48 (13%)	.03
Gunshot wound	11 (3%)	16 (4%)	.8
Other	13 (4%)	14 (3%)	.88
Cardiac arrest	94 (28%)	76 (18%)	.003
Drug abuse	23 (7%)	14 (3%)	.04
LVEF (%)	60 (59-66)	62 (60-70)	.15
Troponine T peak level (ng/mL)	0.16 (0.05-1.1)	0.15 (0.04-0.59)	.13
Norepinephrine dose (mg/h)	1 (0.4-1.9)	1 (0.3-2)	.13
Brain injury time (d)	2 (1-6)	2 (1-5)	.94
Recipients' preoperative characteristics			
Age (y)	51 (42-58)	53 (41-60)	.18
Male sex	251 (75%)	334 (81%)	.04
BMI	24 (21- 27)	24 (21-27)	.17
PMH	168 (144-184)	172 (152-189)	.02
Dilated cardiomyopathy	137 (41%)	188 (46%)	.2
Ischemic cardiomyopathy	113 (34%)	143 (35%)	.81
Valvular cardiomyopathy	20 (6%)	25 (6%)	.93
Hypertrophic cardiomyopathy	15 (4%)	11 (3%)	.25
Restrictive cardiomyopathy	13 (4%)	13 (3%)	.74
Arrhythmogenic right ventricular dysplasia	11 (3%)	7 (2%)	.24
Toxic cardiomyopathy	11 (3%)	6 (2%)	.15
Congenital cardiomyopathy	5 (1%)	13 (3%)	.21
Postpartum cardiomyopathy	5 (1%)	3 (1%)	.51
Other cardiomyopathy	6 (2%)	3 (1%)	.32
National high emergency waiting list			
HU1	132 (39%)	154 (37%)	.52
HU2	20 (6%)	35 (8%)	.23
Preoperative ECMO	60 (18%)	78 (19%)	.77
Time on ECMO (d)	9 (3-17)	7 (3-15)	.33
LVAD	21 (6%)	29 (7%)	.77
Time on LVAD (d)	400 (254-549)	303 (225-430)	.34
BIVAD or TAH	9 (3%)	23 (6%)	.07
Time on BIVAD or TAH (d)	163 (41-206)	92 (57-290)	.66
Redo surgery	109 (32%)	150 (36%)	.29

(Continues)

TABLE 1 (Continued)

	OD group (n = 336)	MD group (n = 412)	*P*
Modified RADIAL score	1 (1-2)	2 (1-2)	<.001
Recipients' early postoperative characteristics			
Ischemic time (min)	182 (129-210)	205 (139-246)	<.001
CPB time (min)	101 (81-129)	113 (88-147)	<.001
Postoperative ECMO	84 (25%)	156 (38%)	<.001
Plasmapheresis	56 (17%)	109 (26%)	.002
Mechanical ventilation > 48 h	151 (45%)	217 (53%)	.04
Postoperative CRRT	76 (23%)	142 (34%)	<.001
Multiple organ failure	47 (14%)	88 (21%)	.01
Sepsis	59 (18%)	93 (23%)	.1
Cerebrovascular accident	20 (6%)	25 (6%)	.93
Re-exploration for bleeding	34 (10%)	39 (9%)	.86

Abbreviations: MD, marginal donor; OD, optimal donor.

TABLE 2 Donors' and recipients' variables according with PGD requiring early postoperative ECMO after HT

	Primary graft dysfunction		
Variable	No (n = 508)	Yes (n = 240)	*P*
Donors's variables			
Age >55 y	132 (26%)	72 (30%)	.28
History of cardiac arrest	109 (21%)	61 (25%)	.26
Ischemic time > 4 h	72 (14%)	56 (23%)	.002
Norepinephrine > 4 mg/h	21 (4%)	21 (9%)	.01
IV Septum ≥ 14 mm	25 (5%)	17 (7%)	.3
IV Drug abuse	22 (4%)	15 (6%)	.34
D/R-PHM ratio < 0.86	72 (14%)	44 (18%)	.17
LVEF < 45%	5 (1%)	3 (1%)	.95
Recipients' variables			
Age (y)	51 (42-58)	54 (43-61)	.05
High urgency 1	180 (35%)	106 (44%)	.02
High urgency 2	34 (7%)	21 (9%)	.32
Preoperative ECMO	64 (13%)	74 (31%)	<.001
LVAD	31 (6%)	19 (8%)	.42
BIVAD or TAH	17 (3%)	15 (6%)	.1
Ischemic time (min)	184 (125-220)	207 (169-240)	<.001
CPB (min)	99 (79-125)	127 (102-174)	<.001
Perioperative plasmapheresis	95 (19%)	70 (29%)	.002
Redo surgery	153 (30%)	106 (44%)	<.001
Modified radial score	2 (1-2)	2 (1-2)	<.001

main cause of 30-day mortality was PGD and the main cause of late mortality was sepsis in both groups (Table S4). We found no difference in long-term survival of recipients who received an organ from a MD with regard to the number of MD criteria; in particular survival rates at 12 years were 45.5% in recipients who received an organ from a donor with 1 MD criteria and 47.7% in recipients who received an organ from a donor with 2 or 3 MD criteria (*P* = .65) (Figure S1). Univariate analysis was performed with several donors' and recipients' variables; significant variables on univariate analysis were entered in the Cox multivariate regression. Multivariate analysis showed that donor age > 55 years, postoperative ECMO, early postoperative CRRT, and sepsis were independent risk factors of mortality after HT, while donor's history of cardiac arrest and LVH had a protective effect (Table 3).

3.2 | Allograft rejection

The cross-matching was positive in 13 (4%) recipients of the OD group and in 26 (6%) recipients of the MD group (*P* = .18). Three hundred and eight (92%) recipients of the OD group and 353 (86%) of the MD group had a least one EMB during the follow-up. Acute cellular allograft rejection grade ≥ 2R was histologically recorded in 50 (16%) recipients of the OD group and in 54 (15%) recipients of the MD group. Long-term survival free from acute allograft rejection grade ≥ 2R was 80.7% in the OD group and 81.5% in the MD group (*P* = .9) (Figure 2A).

3.3 | Cardiac allograft vasculopathy

Two hundred and fifty-three (75%) recipients in the OD group and 273 (66%) in the MD group received at least one coronary angiography during the follow-up. CAV grade 2 was diagnosed in 31 (9%) patients of the OD group and in 25 (6%) patients of the MD group and CAV grade 3 was diagnosed in 17 (5%) patients of the OD group and in 23 (6%) patients of the MD group. Forty-one (12%)

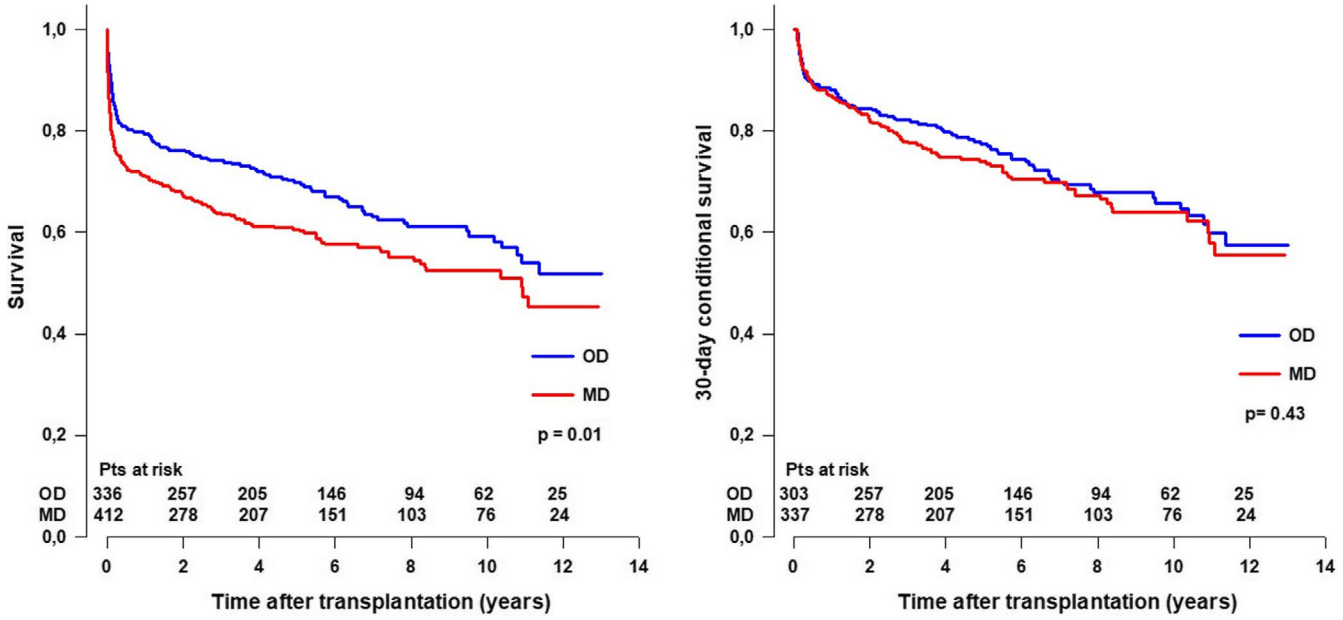

FIGURE 1 Kaplan-Meier curves for long-term overall survival (left) and 30-d conditional survival (right) in recipients according to the quality of donors; OD, optimal donor; MD, marginal donor

TABLE 3 Donors' and recipients' risk factors for long-term mortality at univariate and multivariate analysis

	Univariate analysis		Multivariate analysis	
	Hazard ratio (95% CI)	*P*	Hazard ratio (95% CI)	*P*
Donors's variables				
Donor age >55 y	1.39 (1.09-1.76)	.009	1.26 (0.99-1.61)	.02
History of cardiac arrest	0.7 (0.52-0.94)	.01	0.74 (0.55-1.01)	.05
Ischemic time >4 h	1.14 (0.85-1.59)	.35		
Norepinephrine >4 mg/h	1.7 (1.11-2.6)	.02	1.33 (0.86-2.05)	.18
LVH	0.5 (0.26-0.98)	.02	0.34 (0.17-0.67)	.002
Drug abuse	0.64 (0.34-1.21)	.17		
D/R-PHM ratio < 0.86	1.11 (0.82-1.51)	.48		
LVEF < 45%	0.89 (0.28-2.78)	.84		
Recipients' variables				
Age > 50 y	1.45 (1.15-1.83)	.001	1.16 (0.92-1.47)	.2
High urgency 1	0.79 (0.62-1)	.05		
High urgency 2	0.92 (0.58-1.47)	.75		
Preoperative ECMO	1.03 (0.76-1.38)	.83		
LVAD	0.72 (0.42-1.25)	.21		
Plasmapheresis	0.94 (0.71-1.26)	.71		
Postoperative ECMO	2.51 (2-3.16)	<.001	1.65 (1.29-2.11)	<.001
CRRT	4.2 (3.34-5.27)	<.001	2.59 (1.97-3.4)	<.001
Postoperative sepsis	3.78 (2.98-4.79)	<.001	2.11 (1.6-2.77)	<.001

patients of the OD group and 41 (10%) patients of the MD group underwent one or more percutaneous transluminal coronary angioplasty (PTCA) with stenting; no patient underwent coronary artery bypass grafting. At the end of the follow-up, survival free from PTCA was 75.7% in the OD group and 76.1% in the MD group ($P = .96$) (Figure 2B).

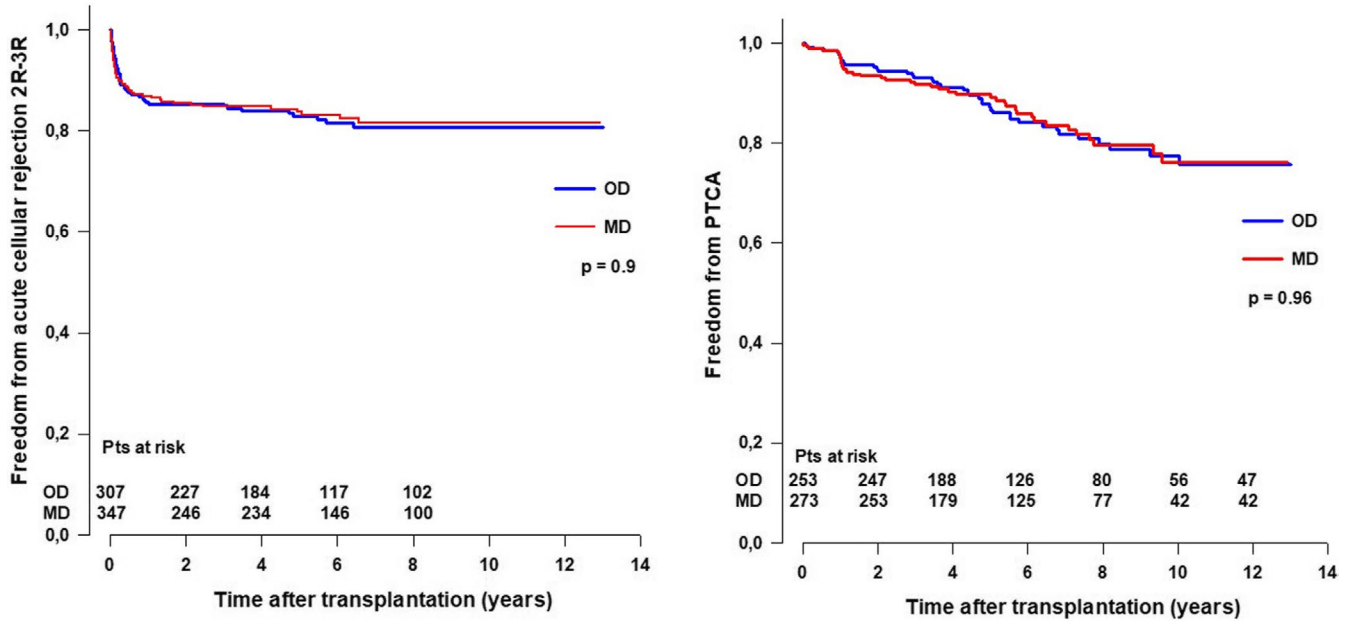

FIGURE 2 Kaplan-Meier curves for long-term survival free from acute cellular rejection grade ≥ 2R (left) and PTCA for cardiac allograft vasculopathy (right) according to the quality of donors; OD, optimal donor; MD, marginal donor

4 | DISCUSSION

We reported our long-term experience of marginal heart donor utilization in a large series of recipients and showed that acceptance of MD for patients waiting for HT is associated with a higher incidence of PGD and acute renal failure, and a reduction of 30-day survival. We found no statistically significant difference in 30-day conditional survival as well as in long-term complication as CAV and allograft rejection between recipients transplanted with an optimal heart donor and recipients transplanted with a marginal heart donor. Previous studies focused on the utilization of MDs for recipients in alternate list and showed controversial results; some authors reported that the alternate list patients had comparable survival with standard list patients,[9] while others demonstrated a lower survival in these patients.[10] One of the main concerns when using MDs is higher the risk of PGD which represents the most common cause of death within 30 days of HT,[11] accounting for about 40.5% of deaths.[12] The reported incidence of PGD after HT varies widely between studies with estimates ranging between 2% and 26% and most of the variability can be attributed to the different definitions of PGD used by various authors[13]; in the most recent series, the reported incidence of PGD is as high as 30%.[14,15] In our series, PGD was defined as the need of a temporary mechanical circulatory support and its incidence may appear elevated but this is probably due to a lower threshold at our institution for aggressive use of temporary circulatory mechanical support in HT patients. Our policy is to rest the transplanted heart on ECMO for 24-48 hours rather than attempt immediate weaning from cardiopulmonary bypass in the operating room. The rationale is to allow the heart more time to recover from the perioperative stress that it has been subjected to before imposing further stress of supporting the recipient circulation; moreover, in recipients preoperatively implanted with ECMO, our policy is to maintain ECMO postoperatively to avoid complications of repeated vessel cannulation. Consequently, we found a higher incidence of PGD in recipients receiving an organ from a MD, which is in contrast with previous reports showing similar incidence of PGD between alternate and standard list patients.[16] In our series, recipients transplanted with a MD had also more acute renal failure requiring early postoperative CRRT, which was an independent risk factor of mortality at multivariate analysis; however, there was no difference in ESRD requiring hemodialysis or need for kidney transplantation between recipients who needed early postoperative CRRT and recipients who did not. These results are consistent with a recent report showing that the need for acute postoperative renal replacement therapy was associated with impaired survival but did not predict ESRD among survivors.[17]

In our series, acceptance of MDs remained stable over time; however, the acceptance of donors with a history of cardiac arrest increased over time. We previously reported that acceptance of donors with a history of cardiac arrest is safe to expand the donors pool[18]; additionally we showed a significantly better long-term survival in recipients receiving an organ from a cardiac arrest resuscitated donor, probably due to the younger age of these donors as well as to the ischemic preconditioning effect of cardiac arrest.[19] Also, the number of donors with history of drug abuse increased over time; results of heart transplantation using donors with a history of drug abuse are controversial. Some authors described a case of acute right ventricular failure due to cocaine cardiomyopathy,[20] while other studies showed that use of donors with a history of past and current cocaine use does not result in worse outcomes.[21,22]

Recipients' profile also changed over time: recent recipients were at higher risk and were more frequently transplanted in high priority,

they had more preoperative ECMO and LVAD and were more immune-sensitized. As at the time of this study high priority allocation was available only for 4 consecutive days in France, this may explain why a considerable number of MDs were accepted for transplantation in the study period. The discrepancy between the limited availability of donor hearts and the increasing number of patients with heart failure whose condition deteriorates while on the heart transplant waiting list or who have advanced heart failure with end-organ dysfunction at listing has also led to an increase in the use of LVADs as BTT[3]; moreover, survival after HT in patients supported with continuous-flow devices is equivalent to that with conventional transplantation.[23,24] Waiting list mortality has significantly improved in the recent era due to the increase in the use of long-term mechanical circulatory support[24]; nevertheless, HT still represents the gold standard for patients with end-stage heart failure. Previous reports showed no difference between waiting list survival of patients with LVAD support as BTT and post-transplant survival of recipients with marginal donor hearts at 30-day, 1-year and 2-year.[25] Using LVAD support as BTT may theoretically allow time for better allocation of optimal donor hearts as opposed to transplantation with a MD. However, patients implanted with LVAD have a progressive decline of survival due to hemorrhagic, thrombotic, and infective complications compared with survival of recipients that remains relatively stable after HT, and they undergo transplantation mainly in case of emerging complications.[26] When LVAD implantation is contraindicated and heart transplantation is the only option, patients should be involved in the decision and be informed about the risk of higher mortality when using marginal donors.[27]

Univariate and multivariate analysis highlighted that marginal donor criteria do not affect recipient outcome in the same way; some criteria are strictly related to the quality of the heart, while others as D/R-PHM ratio or ischemic time > 4 hours does not necessarily mean that the heart itself is unsuitable for transplantation. HT can be safely performed using low D/R-WR donors between sex-matched and male to female transplants; however, in female to male transplants, using of low D/R-WR donors is associated with decreased survival.[28] We calculated the PHM of donors and recipients and we considered D/R-PHM ratio < 0.86 instead of weight mismatch as a marginal donor criteria, because PHM represents the optimal donor-recipient size match metric for prediction of mortality after heart transplant as highlighted by a recent study.[6] The effect of ischemic time on survival after heart transplantation is dependent on donor age, with greater tolerance for prolonged ischemic times among grafts from younger donors.[29] In our series, low D/R-PHM ratio and ischemic time >4 hours were not predictive of mortality, while high-dose inotropic support was an independent risk factor of mortality after HT only at univariate analysis. Previous reports showed association between donor norepinephrine use and PGD,[30] conversely a recent paper showed that in the presence of favorable recipient-donor sex combinations and short ischemic times, donor norepinephrine dose is not associated with mortality and PGD.[31] Donor age is a well-known risk factor of mortality after HT[32] especially when it is associated with a prolonged ischemic time[33] and our results confirmed that donor age >55 years is an independent risk factor of mortality at multivariate analysis. Surprisingly in our series, the use of MD with LVH was not a risk factor of mortality at multivariate analysis which is consistent with a previous report[34]; however, the authors also showed an increased risk of death in recipients of allografts with LVH and donor age >55 years, and in recipients of allografts with LVH and ischemic time ≥4 hours. In our series, acceptance of marginal heart donor slightly increased over time as well as the number of recipients and their fragility; more than 50% of all recipients received an organ from a MD which may seem excessively high; however, most of MDs had only one marginal donor criteria, mainly represented by donor age >55 years. In an era of donor shortage, consensus criteria need to be revisited to liberalize the pool of acceptable donors; however, the decision making should be based on recipient' clinical circumstances and careful evaluation of concurrent donor risk factors. Recipients should be involved in the decision and informed that use of MDs is associated with a higher incidence of PGD and a reduction of early survival; a lower threshold for ECMO use in transplanted patients may improve cardiac recovery and recipient's survival.

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CONFLICT OF INTEREST

None.

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REFERENCES

1. Yancy CW, Jessup M, Bozkurt B, et al. 2013 ACCF/AHA guideline for the management of heart failure: executive summary: a report of the American College of Cardiology Foundation/American Heart Association Task Force on practice guidelines. *Circulation*. 2013;128:1810-1852.
2. Galeone A, Kirsch M, Barreda E, et al. Clinical outcome and quality of life of patients surviving 20 years or longer after heart transplantation. *Transpl Int*. 2014;27(6):576-582.
3. Miller LW, Pagani FD, Russell SD, et al. Use of a continuous-flow device in patients awaiting heart transplantation. *N Engl J Med*. 2007;357:885-896.
4. Dhital KK, Chew HC, Macdonald PS. Donation after circulatory death heart transplantation. *Curr Opin Organ Transplant*. 2017;22(3):189-197.
5. Monteagudo Vela M, García Sáez D, Simon AR. Current approaches in retrieval and heart preservation. *Ann Cardiothorac Surg*. 2018;7(1):67-74.
6. Kransdorf EP, Kittleson MM, Benck LR, et al. Predicted heart mass is the optimal metric for size match in heart transplantation. *J Heart Lung Transplant*. 2019;38(2):156-165.
7. Segovia J, Cosío MD, Barceló JM, et al. RADIAL: a novel primary graft failure risk score in heart transplantation. *J Heart Lung Transplant*. 2011;30(6):644-651.
8. Givens RC, Farr MJ, Mancini DM, Christian Schulze P. The RADIAL score predicts primary graft failure and total mortality after heart transplantation. *J Card Fail*. 2014;20(8):S104.

9. Chen JM, Russo MJ, Hammond KM, et al. Alternate waiting list strategies for heart transplantation maximize donor organ utilization. *Ann Thorac Surg*. 2005;80:224-228.
10. Felker GM, Milano CA, Yager JE, et al. Outcomes with an alternate list strategy for heart transplantation. *J Heart Lung Transplant*. 2005;24(2):S163.
11. Isaac D. Primary cardiac graft failure: defining, predicting, preventing. *J Heart Lung Transplant*. 2013;32:1168-1169.
12. Lund LH, Khush KK, Cherikh WS, et al. The registry of the international society for heart and lung transplantation: thirty-fourth adult heart transplantation report—2017; focus theme: allograft ischemic time. *J Heart Lung Transplant*. 2017;36(10):1037-1046.
13. Chew HC, Kumarasinghe G, Iyer A, et al. Primary graft dysfunction after heart transplantation. *Curr Transplant Rep*. 2014;1:257-265.
14. Nicoara A, Ruffin D, Cooter M, et al. Primary graft dysfunction after heart transplantation: Incidence, trends, and associated risk factors. *Am J Transplant*. 2017;18(6):1461-1470.
15. Squiers JJ, Saracino G, Chamogeorgakis T, et al. Application of the International Society for Heart and Lung Transplantation (ISHLT) criteria for primary graft dysfunction after cardiac transplantation: outcomes from a high-volume centre. *Eur J Cardiothorac Surg*. 2017;51(2):263-270.
16. Lima B. Marginal cardiac allografts do not have increased primary graft dysfunction in alternate list transplantation. *Circulation*. 2006;114(1_suppl):I-27-I-32.
17. Kolsrud O, Karason K, Holmberg E, et al. Renal function and outcome after heart transplantation. *JTCVS*. 2018;155:1593-1604.
18. Galeone A, Varnous S, Lebreton G, et al. Impact of cardiac arrest resuscitated donors on heart transplant recipients. *J Thorac Cardiovasc Surg*. 2017;153:622-630.
19. John R, Pagani FD, Naka Y, et al. Post-cardiac transplant survival after support with a continuous flow left ventricular assist device: impact of duration of left ventricular assist device support and other variables. *J Thorac Cardiovasc Surg*. 2010;140:174-181.
20. Houser SL, MacGillivray T, Aretz HT. The impact of cocaine on the donor heart: a case report. *J Heart Lung Transplant*. 2000;19(6):609-611.
21. Brieke A, Krishnamani R, Rocha MJ, et al. Influence of donor cocaine use on outcome after cardiac transplantation: analysis of the United Network for Organ Sharing Thoracic Registry. *J Heart Lung Transplant*. 2008;27(12):1350-1352.
22. Jayarajan S, Taghavi S, Komaroff E, et al. Long-term outcomes in heart transplantation using donors with a history of past and present cocaine use. *Eur J Cardiothorac Surg*. 2015;47:e146-e150.
23. Kamdar F, John R, Eckman P, Colvin-Adams M, Shumway SJ, Liao K. Postcardiac transplant survival in the current era in patients receiving continuous-flow left ventricular assist devices. *J Thorac Cardiovasc Surg*. 2013;145:575-581.
24. Trivedi JR, Cheng A, Singh R, Williams ML, Slaughter MS. Survival on the heart transplant waiting list: impact of continuous flow left ventricular assist device as bridge to transplant. *Ann Thorac Surg*. 2014;98(3):830-834.
25. Schumer EM, Ising MS, Trivedi JR, Slaughter MS, Cheng A. Early outcomes with marginal donor hearts compared with left ventricular assist device support in patients with advanced heart failure. *Ann Thorac Surg*. 2015;100(2):522-527.
26. Takeda K, Takayama H, Kalesan B, et al. Long-term outcome of patients on continuous-flow left ventricular assist device support. *J Thorac Cardiovasc Surg*. 2014;148(4):1606-1614.
27. Kamran S, Conti F, Pomey MP, Baron G, Calmus Y, Vidal-Trecan G. Patients' preferences in transplantation from marginal donors: results of a discrete choice experiment. *Transpl Int*. 2017;30(6):589-602.
28. Jayarajan SN, Taghavi S, Komaroff E, Mangi AA. Impact of low donor to recipient weight ratios on cardiac transplantation. *J Thorac Cardiovasc Surg*. 2013;146:1538-1543.
29. Russo MJ, Chen JM, Sorabella RA, et al. The effect of ischemic time on survival after heart transplantation varies by donor age: an analysis of the United Network for Organ Sharing database. *J Thorac Cardiovasc Surg*. 2007;133(2):554-559.
30. D'Ancona G, Santise G, Falletta C, et al. Primary graft failure after heart transplantation: the importance of donor pharmacological management. *Transplant Proc*. 2010;42:710-712.
31. Angleitner P, Kaider A, Gökler J, et al. High-dose catecholamine donor support and outcomes after heart transplantation. *J Heart Lung Transplant*. 2018;37:596-603.
32. Lund LH, Edwards LB, Kucheryavaya AY, et al. The registry of the international society for heart and lung transplantation: thirtieth official adult heart transplant report–2013; focus theme: age. *J Heart Lung Transplant*. 2013;32(10):951-964.
33. Reich HJ, Kobashigawa JA, Aintablian T, Ramzy D, Kittleson MM, Esmailian F. Effects of older donor age and cold ischemic time on long-term outcomes of heart transplantation. *Tex Heart Inst J*. 2018;45(1):17-22.
34. Pinzon OW, Stoddard G, Drakos SG, et al. Impact of donor left ventricular hypertrophy on survival after heart transplant. *Am J Transplant*. 2011;11(12):2755-2761.

SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section.

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