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DONOR HEART CORONARY ARTERY BYPASS GRAFTING

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Objective: to evaluate the initial experience of performing simultaneous heart transplant (HT) with coronary artery bypass grafting (CABG) at Almazov National Medical Research Centre in St. Petersburg. **Materials and methods.** Outcomes of 196 HT performed between January 1, 2016, and January 1, 2025, were analyzed. Patients were divided into two groups: 16 recipients who underwent combined HT + CABG (Group 1) and 180 recipients who underwent standard HT (Group 2). The groups were compared using the following parameters: duration of surgery, graft ischemic time, duration of cardiopulmonary bypass (CPB), duration of inotropic therapy, length of stay in the intensive care unit (ICU), 30-day mortality, and one-year survival. **Results.** The operative time was longer in Group 1, at 312 (286–415); 2020; 1130 min, compared with Group 2, at 268 (225–320); 150; 2150 min ($p = 0.007$). Group 1 also demonstrated a significant increase in graft ischemic time and CPB duration compared to group 2. Median graft ischemic time in Group 1 was 156 (146–180); 120, 240 min, versus 140 (120–160); 40, 240 min in Group 2 ($p = 0.021$). CPB duration was 159 (133–180); 101, 214 min in Group 1 and 128 (101–162); 71–350 min in Group 2 ($p = 0.015$). Despite the more complex nature of the intervention in Group 1, no statistically significant differences were observed between the groups in the duration of inotropic therapy or length of stay in the ICU. Although the 30-day mortality rate was higher in Group 1 than in Group 2 (18.7% *vs.* 7.8%), this difference did not reach statistical significance ($p = 0.136$). One-year survival rates were comparable between the two groups. **Conclusion.** Simultaneous HT and CABG procedures are associated with longer operative time, prolonged graft ischemia, and longer CPB duration compared with standard HT. However, no differences were observed in the duration of inotropic therapy or early postoperative period. Combined HT and CABG procedures are technically feasible, with 30-day mortality and one-year survival rates comparable to those of standard HT. The use of donor hearts with underlying coronary artery pathology may expand donor selection criteria and increase the number of HT procedures performed.

Keywords: simultaneous heart transplantation, coronary artery bypass grafting, expanded-criteria heart donors, coronary artery stenosis, transplant coronary artery disease, donor-transmitted coronary atherosclerosis.

INTRODUCTION

Despite significant progress over the past decade in the use of mechanical circulatory support (MCS) systems, heart transplantation (HT) remains the only definitive treatment for patients with end-stage chronic heart failure (CHF). The use of these systems as a bridge to HT is associated with high mortality. For example, a study by J.C. Cleveland Jr. et al. reported that approximately 35% of patients receiving MCS died before undergoing HT [1]. Similarly, data from Almazov National Medical Research Centre indicate persistently high mortality rates among patients on extracorporeal membrane oxygenation (ECMO) prior to transplantation, exceeding 40%.

The shortage of donor organs remains a main challenge in transplantation medicine. This issue was further exacerbated during the COVID-19 pandemic. A 2021 international analysis of transplant activity reported a substantial global decline in the number of procedures performed, primarily due to a reduction in deceased donors. In certain countries, the decrease was particularly pronounced, reaching up to 88% for heart transplantation, 85% for lung transplantation, and 69% for kidney transplantation [2]. COVID-19 outbreaks continue to occur periodically in various countries to this day.

Concurrently, the demographic profile of heart donors has shifted, with the average donor age now approaching 70 years. As a consequence, the prevalence of coronary artery disease (CAD) among donors has increased, being identified in up to 58% of evaluated individuals [3]. The presence of coronary artery stenoses is associated with a heightened risk of early postoperative complications, including acute myocardial infarction following HT.

In response, the European Directorate for the Quality of Medicines & HealthCare recommends routine coronary angiography (CAG) on all heart donors: men >55 years; women >55 years with one or more risk factor; and both men and women aged 45–55 years with two or more risk factors [4]. However, in most transplant centers, despite these recommendations, routine CAG is not consistently performed on potential heart donors.

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There are a few isolated reports in the literature addressing HT combined with simultaneous cardiac surgical procedures. Between 2006 and 2008, the Almazov National Medical Research Centre performed the first four cases of cardiac autotransplantation in the Russian Federation, which included simultaneous left atrial reduction and correction of valvular pathology [5].

In 2009, Saito et al. [6] reported a successful case of HT combined with aortic valve replacement. More recently, in 2021, Juneja et al. [7] demonstrated the feasibility of simultaneous liver transplantation and off-pump coronary artery bypass grafting (CABG). Earlier, in 1988, Thomson et al. [8] described the first case of HT combined with CABG performed on a donor heart.

Despite more than three decades since this initial report, there remains a paucity of data – particularly in the Russian literature – regarding the outcomes and feasibility of simultaneous HT and CABG. Expanding the donor pool by including hearts from donors with coronary artery disease may represent a promising strategy to mitigate the ongoing shortage of donor organs.

The aim of this study is to evaluate the initial experience with simultaneous HT and CABG at Almazov National Medical Research Centre.

MATERIALS AND METHODS

This study analyzed the outcomes of 196 heart transplantations performed at Almazov National Medical Research Centre in St. Petersburg, Russia, between January 1, 2016, and January 1, 2025. Among these, 16 procedures involved the use of donor hearts that underwent CABG prior to implantation.

Patients were divided into two groups. Group 1 included 16 recipients (14 men and 2 women) who underwent simultaneous HT with CABG. Group 2 comprised 180 recipients (138 men and 42 women) who underwent standard HT without additional surgical procedures.

The median age of the overall cohort was 52 years (interquartile range [IQR]: 37–58). In Group 1, the median age was 53 years (IQR: 35–58), whereas in Group 2 it was 51 years (IQR: 37–58). There were no statistically significant differences between the groups in terms of age (p = 0.916) or sex distribution.

Prior to HT, all recipients had chronic heart failure classified as functional class III–IV according to the New York Heart Association (NYHA).

In Group 1, the predominant underlying etiology of end-stage heart failure was ischemic heart disease (IHD), accounting for 60% of cases, whereas dilated cardiomyopathy (DCM) was observed in only 10% of patients. In contrast, in Group 2, DCM was the leading cause (45%), followed by IHD (43%).

According to the United Network for Organ Sharing (UNOS) urgency classification, the distribution of patients was as follows: Class IA included 6.25% of patients in Group 1 and 16.67% in Group 2; Class IB comprised 31.25% and 27.22%, respectively; and Class II included 62.50% and 56.11%, respectively (p = 0.549) (Fig. 1).

No statistically significant differences were observed between the groups in terms of waiting list duration. The median waiting time in Group 1 was 122 days (IQR: 76–284), compared with 100 days (IQR: 54–177) in Group 2 (p = 0.547).

A comparative assessment of pre-transplant functional status showed no significant differences between the groups. According to echocardiography data, left ventricular ejection fraction (LVEF) was comparable: 23% (IQR: 19–28) in Group 1 and 23% (IQR: 18–29) in Group 2 (p = 0.898).

The mean pulmonary artery pressure was 44 mmHg (IQR: 35–56) in Group 1 and 47 mmHg (IQR: 38–60) in Group 2 (p = 0.493). Pulmonary vascular resistance also did not differ significantly between the groups, measuring 2.93 Wood units (IQR: 2.16–4.75) in Group 1 and 2.74 Wood units (IQR: 2.08–3.88) in Group 2 (p = 0.585).

The primary criteria for patient selection for HT included: advanced chronic heart failure (NYHA class III–IV) refractory to optimal medical therapy; reduced

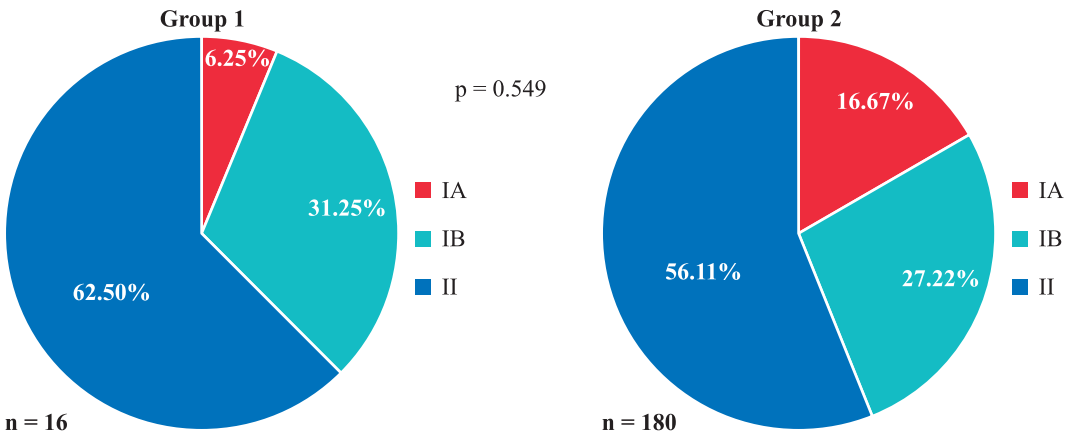

Fig. 1. Urgency of HT according to the UNOS system in patients with simultaneous HT and CABG (Group 1) and standard HT (Group 2)

functional capacity defined by peak oxygen consumption (VO_2) <14 mL/kg/min or <50% of the predicted value; severe CAD with persistent angina not amenable to revascularization; and malignant ventricular arrhythmias resistant to medical management [9].

A comparative analysis of postmortem heart donors revealed no statistically significant differences between the groups with respect to sex distribution, with male donors predominating in both cohorts – 75% in Group 1 and 67.97% in Group 2 (p = 0.926). The mean donor age was 49.40 ± 4.94 years in Group 1 and 45.20 ± 9.86 years in Group 2 (p = 0.122). The leading cause of donor death in both groups was stroke, accounting for 75% of cases in Group 1 and 81.25% in Group 2.

All donors received inotropic and vasopressor support prior to organ procurement. The duration of such therapy did not differ significantly between the groups, with a median of 4 days (IQR: 3–4; range 1–10) in Group 1 and 3 days (IQR: 2–4; range 1–9) in Group 2 (p = 0.213). Similarly, the length of stay in the intensive care unit (ICU) was comparable between groups, at 4 days (IQR: 3–4; range 1–10) in Group 1 and 3 days (IQR: 2–4; range 1–9) in Group 2 (p = 0.213).

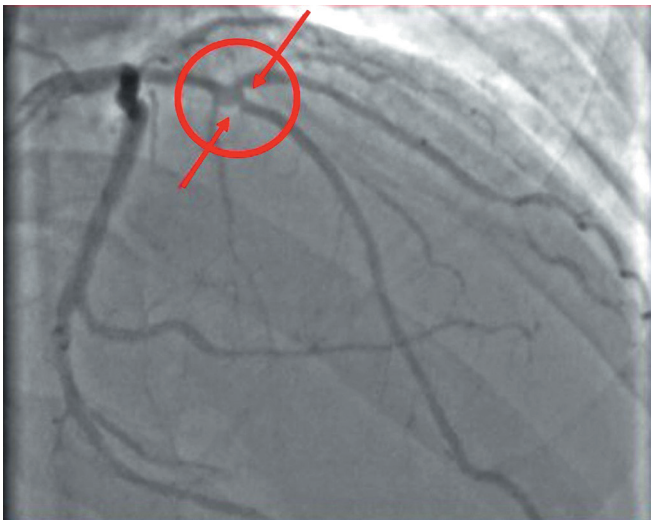

Fig. 2. Donor single-vessel coronary artery disease: stenosis in the proximal segment of the left anterior descending artery

Donor–recipient matching was performed in accordance with established criteria from the specialized literature [10]. Specifically, donor body weight was required not to differ from recipient weight by more than 20%. In cases involving female donors and male recipients, differences in both height and weight were limited to 10%. These criteria were met in all transplant procedures across both groups.

CAG was performed in all donors in Group 1, whereas in Group 2 it was carried out in only 35% of cases. In Group 1, CAG revealed two cases of two-vessel CAD with stenoses of up to 75%, as well as eight cases of single-vessel disease with stenoses also reaching up to 75%. In contrast, no hemodynamically significant coronary stenoses were identified in any of the donors evaluated in Group 2.

An example of single-vessel CAD in a donor heart is presented in Fig. 2, demonstrating a hemodynamically significant stenosis in the proximal anterior interventricular artery (AIV).

The algorithm for deciding whether to perform simultaneous HT and CABG was based on an assessment of donor and recipient parameters (Fig. 3). The primary selection criterion was the UNOS HT urgency classification. Preference was given to patients with more urgent indications for surgery. Another important selection criterion was the patient's prolonged stay on the heart-lung machine compared to other recipients. Since potential heart donors with CAD were in the older age group, efforts were made to select a recipient of a similar age. We also took into account the height and weight of donors and recipients, as well as the number and location of coronary artery stenoses in donors.

The technical feasibility of performing CABG on a donor heart was determined based on the number and anatomical location of coronary artery stenoses. The

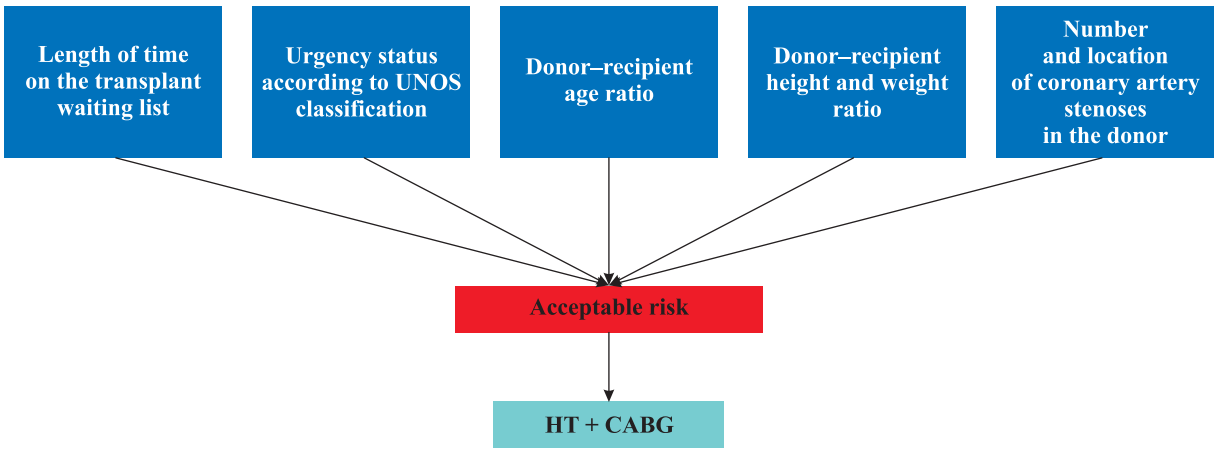

Fig. 3. Algorithm for deciding on the possibility of performing simultaneous HT and CABG

final intraoperative decision regarding the possibility of simultaneous HT and CABG was made by the operating surgeon.

In Group 1, the distribution of procedures was as follows: 14 patients underwent HT with CABG using a single autovenous graft, while 2 patients received HT with a combination of one autovenous graft and one internal mammary artery–coronary graft.

The surgical technique involved a median sternotomy and pericardiotomy, followed by harvesting of the conduit for CABG (saphenous vein). Cardiopulmonary bypass (CPB) was initiated, and the aorta was cross-clamped. After induction of cardiac arrest, the recipient's native heart was excised. The donor heart was then inspected, and a distal anastomosis was created between the autovenous graft and the affected coronary artery of the donor heart (Fig. 4).

Subsequently, the donor heart was implanted using the bicaval technique, and cardiac activity was restored. Coronary perfusion was established either through the internal mammary artery graft or by constructing a proximal off-pump anastomosis between the autovenous graft and the aorta, after which flow was initiated.

In the final stage, hemodynamic stability was achieved through titration of inotropic and vasopressor support, and the CPB system was disconnected.

A comparative assessment of treatment outcomes between the groups was performed using the following criteria: operative time, duration of graft ischemia, CPB time, duration of inotropic support, length of stay in the ICU, 30-day mortality, and one-year survival. Survival analysis was conducted using the Kaplan–Meier method, and differences between groups were assessed using the log-rank test.

Fig. 4. Formation of a distal anastomosis between recipient's autologous vein graft and the affected coronary artery of the donor heart

Statistical analysis included assessment of normality for continuous variables using the Kolmogorov–Smirnov test. Depending on data distribution, group comparisons were performed using either the Mann–Whitney U test or the independent samples t-test. Continuous variables with non-normal distribution are presented as median (Me) with interquartile range (Q1–Q3) and minimum–maximum values, while normally distributed variables are expressed as mean ± standard deviation (M ± SD). Categorical variables were compared using Pearson's chi-squared test, and are presented as percentages.

The study was conducted in accordance with the principles of the Declaration of Helsinki, and all patients provided written informed consent for postoperative follow-up by a cardiologist.

RESULTS

A comparison of operative time between the groups (Fig. 5) showed longer procedures in Group 1. The mean operative time in Group 1 was 312 minutes (IQR: 286–415; range 220–1130), compared with 268 minutes (IQR: 225–320; range 150–2150) in Group 2 ($p = 0.007$). This difference is primarily attributable to the additional time required for conduit harvesting and the performance of CABG in Group 1.

A similar pattern was observed for graft ischemia time (Fig. 6) and CPB duration (Fig. 7), both of which were significantly higher in Group 1. Graft ischemia time was 156 minutes (IQR: 146–180; range 120–240) in Group 1 versus 140 minutes (IQR: 120–160; range 40–240) in Group 2 ($p = 0.021$). CPB duration was also prolonged in Group 1, at 159 minutes (IQR: 133–180; range 101–214), compared with 128 minutes (IQR: 101–162; range 71–350) in Group 2 ($p = 0.015$).

No statistically significant difference was found between the groups in the duration of inotropic therapy (Fig. 8). In Group 1, median duration was 7 days (IQR: 5–19; range 1–24), compared with 6 days (IQR: 5–11; range 1–52) in Group 2 ($p = 0.485$).

Despite the greater technical complexity of the surgical procedure in Group 1, no difference was found in the length of stay in the ICU (Fig. 9). ICU stay was 8 days (IQR: 6–19; range 4–31) in Group 1 and 9 days (IQR: 6–13; range 3–119) in Group 2 ($p = 0.974$).

Although 30-day mortality was higher in Group 1 compared with Group 2 (18.7% vs. 7.8%, respectively), this difference did not reach statistical significance ($p = 0.136$) (Fig. 10). The leading cause of death in Group 1 was bilateral polysegmental pneumonia, whereas in Group 2 it was acute right ventricular failure.

One-year survival did not differ significantly between the two study groups (Fig. 11), with survival rates of 81.3% in Group 1 and 87.8% in Group 2 ($p = 0.477$). The maximum follow-up duration was 12 months.

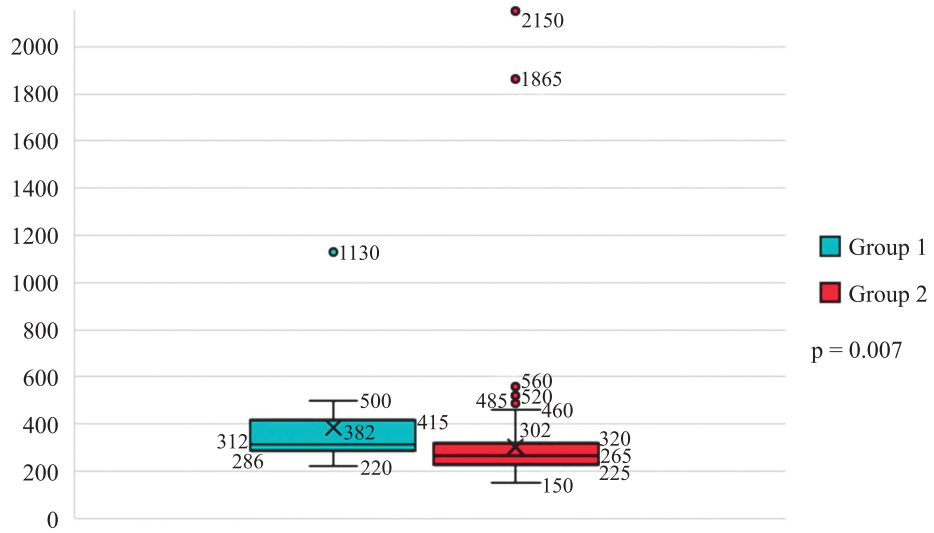

Fig. 5. Duration of the surgical procedure

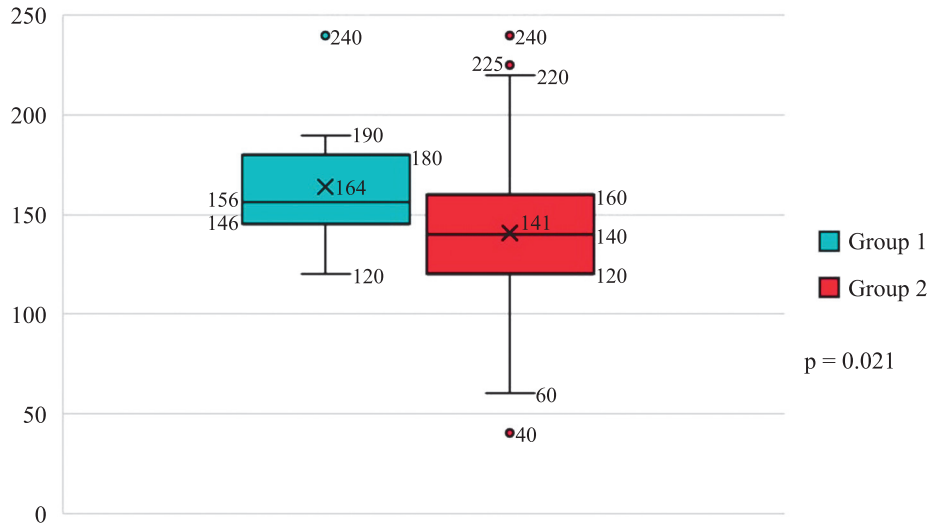

Fig. 6. Graft ischemia time

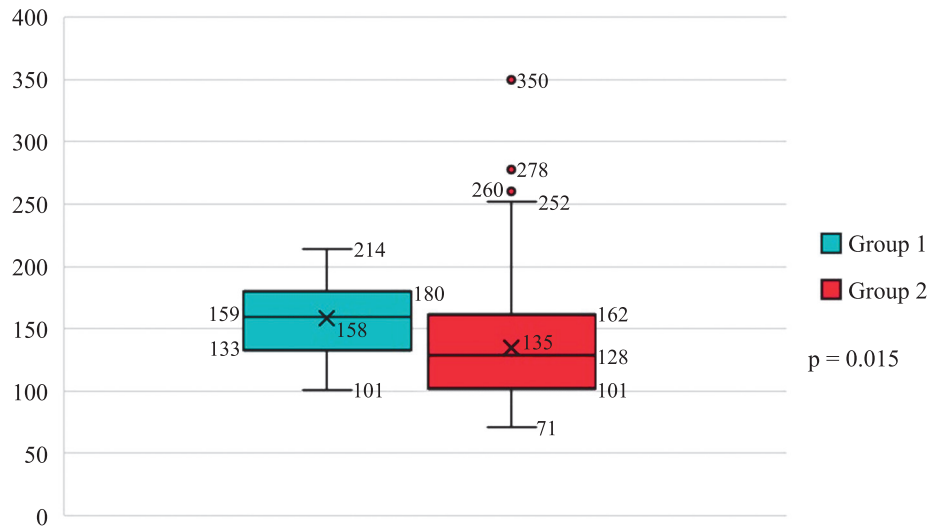

Fig. 7. Duration of CPB

All patients were enrolled in the structured post-transplant follow-up program at Almazov National Medical Research Centre and were monitored throughout the postoperative period at the center's dedicated transplant cardiology clinic. Patients were not followed up at external institutions or at their place of residence, nor were

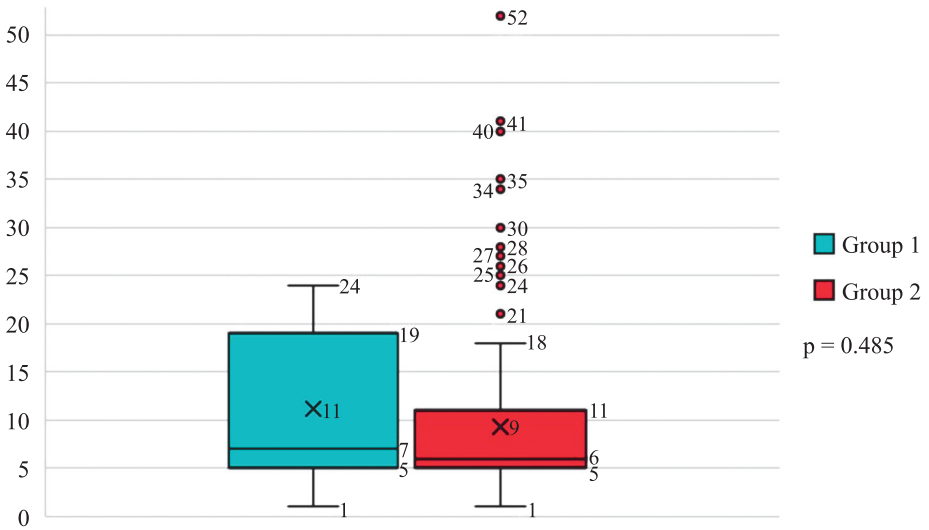

Fig. 8. Duration of inotropic therapy

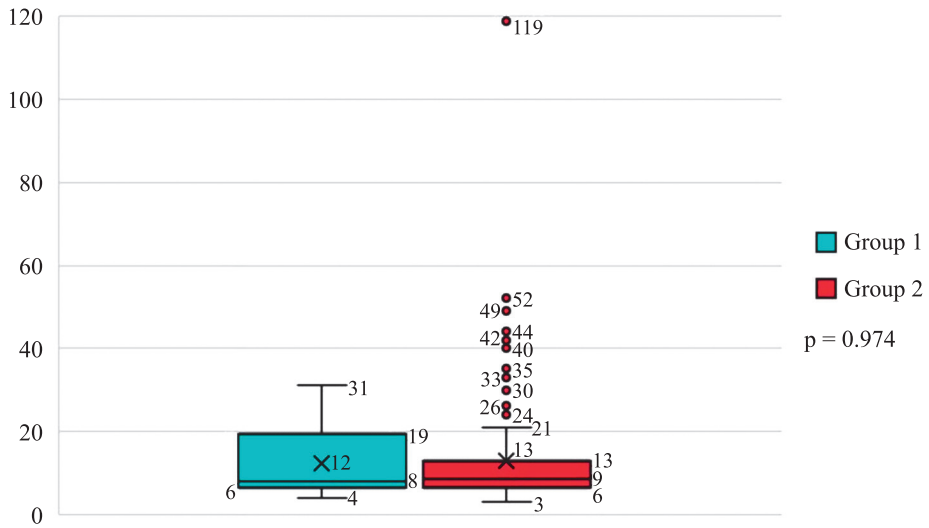

Fig. 9. Length of stay in the ICU

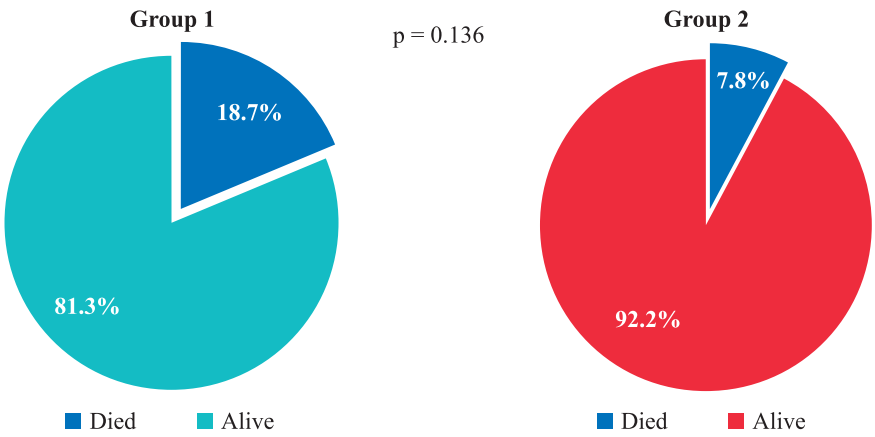

Fig. 10. Post-HT 30-day mortality in the study groups

they transferred to other heart transplant centers within the Russian Federation during the observation period.

Of particular interest in our study is the first clinical case of simultaneous HT and CABG. Patient F., a 64-year-old male with a diagnosis of CAD, coronary atherosclerosis, post-infarction cardiosclerosis with chamber dilation, Lown grade 4A ventricular extrasystoles, paroxysmal atrial tachycardia, severe mitral regurgitation (grade 3), severe tricuspid regurgitation (grade 3), and chronic heart failure (stage IIB, NYHA class II–III), underwent combined HT and CABG.

The donor was a 45-year-old female who died from a ruptured cerebral aneurysm. In the ICu, the donor required 2 days of mechanical ventilation and vasopressor therapy with norepinephrine at 0.45 μg/kg/h. Multiorgan procurement was performed, including the heart and both kidneys. As noted above, coronary angiography of the donor heart revealed a hemodynamically significant stenosis in the proximal AIV.

Orthotopic HT was performed using the bicaval technique, combined with mammary artery bypass grafting to the AIV and autovenous grafting to the diagonal branch under extracorporeal circulation (ECC) and pharmacologic cold crystalloid cardioplegia (Custodiol). The total operative time was 355 minutes. Donor heart ischemia time was 160 minutes, and ECC duration was 178 minutes.

The recipient was extubated on postoperative day 2. Inotropic therapy was required for 3 days, and on postoperative day 6, the patient was transferred to the cardiology ward for further rehabilitation.

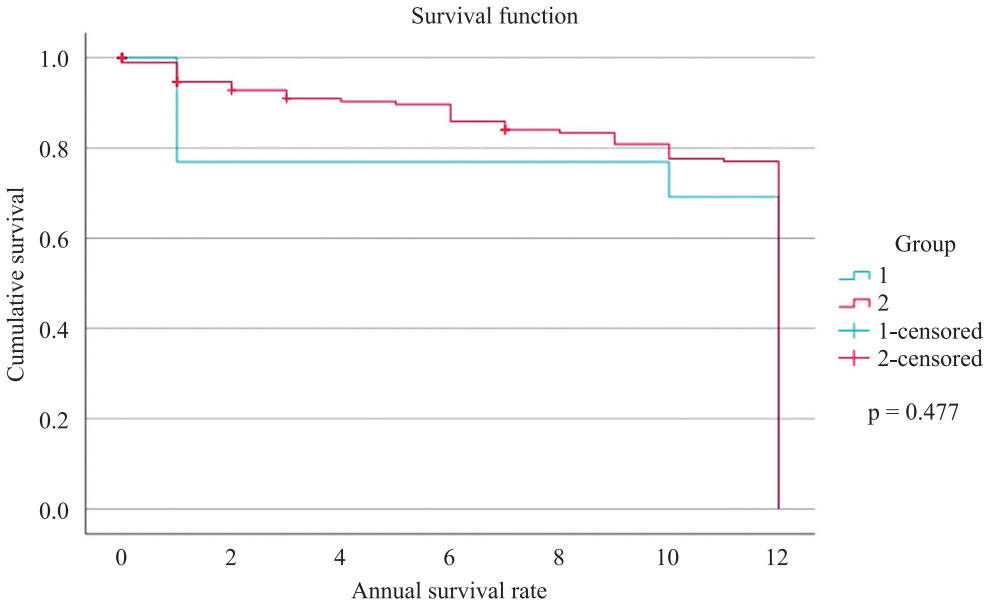

Fig. 11. 12-month survival analysis based on the Kaplan–Meier method

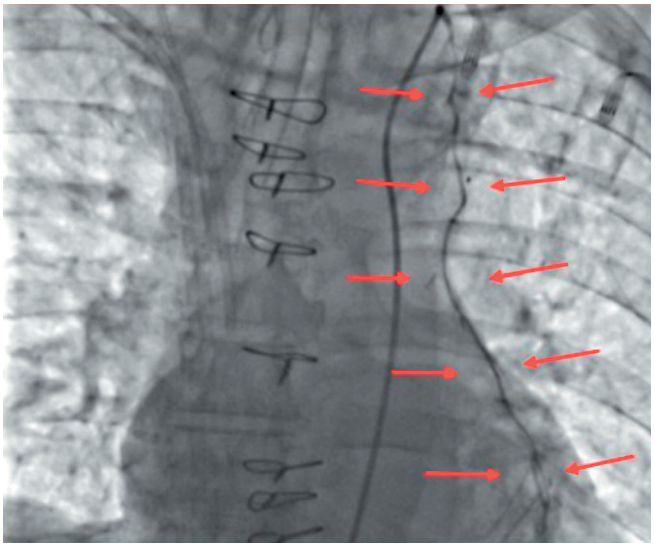

Fig. 12. Recipient's coronary angiography one year after HT

At 1-year follow-up, CAG (Fig. 12) revealed satisfactory graft function. The left main coronary artery showed no hemodynamically significant stenosis. AIV exhibited moderate diffuse proximal changes with 50–60% stenosis distally. The first diagonal branch was free of significant stenosis, while the second diagonal branch had ostial stenosis of 70–80% but was adequately perfused antegradely and via a functioning bypass graft. The circumflex artery, represented by a dominant marginal branch, showed no significant stenosis. The right coronary artery was free of hemodynamically significant lesions. The aortocoronary bypass graft to the second diagonal branch remained patent without significant stenosis.

DISCUSSION

Aortic atherosclerosis is one of the most common conditions in elderly potential heart donors evaluated by

cardiac surgeons. This donor population is of particular clinical interest, as the presence of coronary artery stenosis has traditionally been considered a contraindication to HT.

Although more than 35 years have elapsed since the first report describing simultaneous HT and CABG [8], such procedures remain exceedingly rare.

The largest published series to date was reported by Yang et al. [11] from the Heart Center in Taiwan and included only 11 cases of combined HT and CABG. The early postoperative outcomes were favorable, with no mortality observed within 3 months following surgery. This study thus provided initial evidence that simultaneous HT and CABG is technically feasible and does not appear to increase early postoperative mortality in transplant recipients. Nevertheless, simultaneous HT and CABG procedures continue to be reported only in isolated cases worldwide.

The initial experience of simultaneous HT and CABG at our center demonstrated, on one hand, the technical feasibility of this combined approach and, on the other, its comparable effectiveness relative to standard HT, as shown for the first time in our study.

Despite a more than 100-fold increase in the number of heart transplants performed in our country between 2008 and 2024 as a result of substantial reorganization of donor and transplant services, mortality among patients on the heart transplant waiting list (HTWL) remains high and has not significantly improved, both in the Russian Federation and internationally. The primary limiting factor continues to be the persistent shortage of donor organs, with waiting list mortality rates reported to reach 5–15% [13].

The level of neurological care, particularly for stroke, is improving annually. Therefore, in our view, the continued use of standard donor selection criteria alone is unlikely to significantly increase the number of available donor hearts in the near future.

Over the past decade, the average age of heart donors has increased from 45 to 70 years, while the prevalence of CAD among potential donors now ranges from 42% to 58% [3]. In this regard, it appears reasonable to consider the expansion of donor selection criteria, particularly through inclusion of donors with CAD for HT.

In addition, efforts to address the persistent shortage of donor organs through surgical modification of transplant procedures have been ongoing for decades and continue worldwide. In this context, the experience of four cases of cardiac autotransplantation performed between 2006 and 2008 at Almazov National Medical Research Centre, involving simultaneous reduction of the left atrial cavity and correction of valvular pathology, demonstrated the feasibility of such approaches and, in our opinion, may be considered an early step toward the development of complex simultaneous cardiac transplant procedures [5].

In 2009, Saito et al. [6] successfully performed HT combined with simultaneous aortic valve replacement. In 2021, Juneja et al. [7] reported a series of successful combined liver transplantation and off-pump CABG. In 2017, Patel et al. [13] described HT with simultaneous back-table aortic valve replacement, with the patient discharged in satisfactory condition on postoperative day 11.

However, no publications were identified in the available literature describing similar procedures within the Russian Federation. Accordingly, the results of simultaneous HT and CABG presented in our study may be considered the first reported experience of this approach both at our center and, to our knowledge, in Russian transplant surgery as a whole.

Our study included 196 HT cases, of which 16 patients underwent simultaneous HT and CABG. Comparison of preoperative characteristics between the groups demonstrated that most variables were comparable. The slightly lower baseline LVEF observed in Group 2, despite the absence of statistical significance, may be attributed to the larger sample size in the control group.

The difference in the primary etiology of chronic heart failure – predominantly ischemic heart disease in Group 1 (60%) versus dilated cardiomyopathy in Group 2 (45%) – in our opinion, reflects the significant difference in the patient sample across the groups.

The limited national and global experience with simultaneous HT and CABG raises important questions regarding appropriate patient selection criteria. In the present study, we proposed a decision-making algorithm for assessing the feasibility of combined procedures (Fig. 3). We suggest that potential candidates for simultaneous HT and CABG include patients with prolonged waiting list time, high UNOS urgency status, older recipient age comparable to that of the donor population, and an optimal donor–recipient size match with respect to height and weight parameters.

An important determinant of the technical feasibility of simultaneous HT and CABG is the operating surgeon's intraoperative assessment of the number and anatomical location of coronary stenoses in the donor heart. Integration of these parameters at the final stage of decision-making allows for a balanced evaluation of perioperative risk and, consequently, for determining the appropriateness of performing the combined procedure.

At present, in the Russian Federation, standardized evaluation protocols for potential heart donors older than 40 years do not mandate routine CAG. In our opinion, this issue warrants further discussion. The use of CABG in donor hearts may, on one hand, facilitate more accurate risk stratification and reduce the likelihood of early graft dysfunction. On the other hand, in-depth additional screening of donors could help identify a subset of suboptimal heart donors whose CAD may still be compatible with successful HT.

In the present study, involvement of more than two coronary arteries was considered significant and was regarded as a contraindication to simultaneous HT and CABG. It can be assumed that simultaneous HT and CABG could also be feasible even with more extensive coronary artery lesions in potential donors.

The first experience in simultaneous HT and CABG at our center demonstrated the key technical characteristics of this combined procedure. Comparative analysis of perioperative parameters revealed a statistically significant difference in total operative time between the groups. The additional time required for conduit harvesting and performance of CABG accounted for this difference, although it remained relatively modest (p = 0.007).

Graft ischemia time and CPB duration also differed significantly between the groups. In Group 1, mean ischemia time was 156 minutes (IQR: 146–180; range 120–240), compared with 140 minutes (IQR: 120–160; range 40–240) in Group 2 (p = 0.021). CPB duration was 159 minutes (IQR: 133–180; range 101–214) in Group 1 versus 128 minutes (IQR: 101–162; range 71–350) in Group 2 (p = 0.015). No statistically significant differences were observed in the duration of postoperative inotropic therapy or length of ICU stay between the groups.

Although one-year survival rates were comparable between the groups, 30-day mortality was higher in the HT + CABG group; however, this difference did not reach statistical significance (p = 0.136), likely due to the limited number of cases in Group 1.

CONCLUSION

Thus, the initial experience of our center with simultaneous HT and CABG using donor hearts with CAD allows us to draw the following conclusions:

1. Simultaneous HT and CABG is associated with increased operative duration, longer graft ischemia time, and prolonged CPB time compared with standard HT. However, no differences were observed in the duration of inotropic therapy or the early postoperative course.
2. Simultaneous HT and CABG is technically feasible, with 30-day mortality and one-year survival rates comparable to those of standard HT.
3. The use of donor hearts with pre-existing CAD may contribute to an expansion of donor selection criteria and, consequently, an increase in the number of HT procedures performed.

The authors declare no conflict of interest.

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