Research Square

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Timing of intra-aortic balloon pump support and early mortality after isolated coronary artery bypass grafting in patients with preserved ejection fraction: a single-centre retrospective cohort study

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Abstract

Background.

An intra-aortic balloon pump (IABP) is sometimes needed after coronary artery bypass grafting (CABG), but it is unclear what the timing of that need says about the patient with preserved left ventricular function. Most published series mix different open-heart operations, and the chance of needing support depends partly on the operation. We studied IABP use and timing in one homogeneous group, comparing support already running when the patient left the operating room with rescue support started in the intensive care unit (ICU).

Methods.

We reviewed consecutive adults who had elective or urgent isolated on-pump CABG with cross-clamping between July 2024 and December 2025, all with a preoperative ejection fraction (EF) of at least 50%. The primary outcome was operative mortality: death during the index stay, or within 30 days. Patients given an IABP were grouped by when it went in and by where support was running: OR-IABP if the balloon was working as the patient came off bypass, ICU-IABP if it started later in the ICU.

Results.

Of 1224 patients, 57 (4.7%) received an IABP. Operative mortality was 49.1% with IABP and 2.3% without ($p < 0.001$), and rose across the preoperative, intraoperative and postoperative groups (18.8%, 38.5% and 71.4%; $p = 0.002$). It was 32.0% for OR-IABP ($n = 25$) and 71.4% for ICU-IABP ($n = 28$; $p = 0.004$); 30-day mortality was 24.0% and 67.9% ($p = 0.001$). Urgent surgery was more common in the OR-IABP group (76.0% versus 50.0%; $p = 0.051$). Crude odds of death were higher with ICU-IABP (odds ratio 5.31, 95% CI 1.64–17.19; $p = 0.005$); after adjustment for age, sex, renal function and urgency the estimate was 4.54 (0.84–24.46; $p = 0.078$).

Conclusions.

Needing an IABP after elective or urgent isolated CABG with preserved EF marks a very high early risk. Rescue support started in the ICU carried much higher crude mortality than support established before the patient left the operating room, even though the former group was less acutely ill. These findings raise a hypothesis; they do not show that earlier support saves lives.

Background

The intra-aortic balloon pump (IABP) is the most widely used form of temporary mechanical circulatory support in cardiac surgery [1]. Counterpulsation raises diastolic coronary perfusion and lowers left

ventricular afterload, so the heart gets more oxygen and needs less. The problem it treats is common. In a secondary analysis of the LEVO-CTS trial, low cardiac output syndrome occurred in 22% of patients after cardiac surgery and was followed by a sharp rise in 90-day mortality [2].

Prophylactic preoperative IABP in high-risk CABG has been tested in randomised trials and pooled in meta-analyses. These report lower hospital mortality, and the effect is largest in isolated on-pump CABG [3–5]. The evidence is not all one way. A Cochrane review found the data too weak to support routine prophylactic use in genuinely elective high-risk patients [6]. In stable patients with left main disease having off-pump surgery, a prophylactic balloon gave no benefit and was followed by more prolonged ventilation [7].

Far less is known about what the timing of an unplanned balloon means. Observational series agree that outcomes are worst when the balloon goes in after the operation [8–10]. Most of those cohorts, though, mix coronary, valve and combined procedures, and the baseline chance of needing support differs between them; the largest of these series warns against reading too much into its own subgroups [8]. In a patient with preserved ejection fraction (EF), an unexpected need for a balloon may point to perioperative ischaemia, difficult or incomplete revascularisation, trouble coming off cardiopulmonary bypass (CPB), or low-output physiology that preoperative EF never predicted. A balloon already running as the patient leaves the operating room is also a different clinical situation from one started after the patient deteriorates in the intensive care unit (ICU).

We therefore studied IABP use and timing in a cohort limited to elective and urgent isolated on-pump CABG with preserved EF. We asked three questions. How do patients who need a balloon differ from those who do not? Do outcomes differ by preoperative, intraoperative or postoperative insertion? And do patients who come off bypass on balloon support fare differently from those who leave the operating room without one and need rescue support in the ICU?

Methods

Study design and setting

This is a single-centre retrospective cohort study from the Department of Cardiovascular Surgery at Koşuyolu High Specialization Training and Research Hospital, Istanbul, Türkiye. It covers operations performed between 1 July 2024 and 31 December 2025. Data were obtained from the Koşuyolu Adult Cardiac Surgery Quality Improvement Program database [11].

Participants

We included adults aged 18 or older who had isolated CABG on CPB with aortic cross-clamping, a preoperative EF of 50% or more, and an elective or urgent operative status. Patients having a valve, aortic, congenital or other major cardiac procedure at the same time were excluded, because the

operative burden and the baseline chance of needing support are different. We also excluded off-pump cases and cases without cross-clamping or a recorded cross-clamp time, so that ischaemic time and technique stayed comparable. Emergent and salvage cases were excluded because there the balloon follows haemodynamic collapse and the question of timing loses its meaning.

A total of 1706 isolated CABG procedures were screened, of which 1224 entered the final cohort (Fig. 1). All consecutive eligible patients operated on during the period were included.

IABP practice and exposure definitions

The surgical and anaesthesia teams decided on the balloon case by case, from the patient's haemodynamic and clinical state. Patients admitted for planned CABG are classified as elective. Patients operated on during the same hospitalisation after an acute coronary syndrome are classified as urgent. Patients needing surgery within 24 hours of an acute coronary syndrome are classified as emergent. Patients who enter the operating room under cardiopulmonary resuscitation are classified as salvage. A preoperative balloon was generally used in urgent patients with ongoing angina or haemodynamic concern, to unload the heart and bridge them to surgery. An intraoperative balloon went in when the patient could not be weaned from CPB with acceptable haemodynamics. A postoperative balloon went in when the patient deteriorated in the ICU after leaving the operating room without one.

We looked at three exposures. First, any IABP versus none. Second, the insertion period: preoperative, intraoperative or postoperative. Third, a comparison based on where support was running. In our practice a preoperative balloon is usually switched off during the operation and switched back on to come off bypass, then weaned as the patient recovers. What matters clinically is therefore not the calendar moment of insertion but whether the patient left the operating room on support. We defined OR-IABP as balloon support active during separation from CPB: intraoperative insertions, plus preoperative insertions that were continued or restarted for the wean. We defined ICU-IABP as rescue support started after the patient left the operating room without a balloon.

Four patients with a preoperative balloon did not need it to come off bypass, and it was removed in the operating room. They fit neither definition, so they are outside the OR-IABP versus ICU-IABP comparison. They remain in the analyses of overall IABP use and insertion period.

Outcomes and covariates

The primary outcome was operative mortality, as defined by the Society of Thoracic Surgeons: any death during the hospital stay in which the operation was performed, however long that stay, plus any death within 30 days of surgery, including deaths after discharge [12]. We also report in-hospital and 30-day mortality separately. Secondary outcomes were hospital stay, re-exploration, tracheostomy and transfusion requirement. Early death shortens the recorded stay, so we report hospital stay among survivors as well.

Preserved EF meant an EF of 50% or more on preoperative transthoracic echocardiography. Demographics and comorbidities came from admission records; laboratory values, height and weight from routine preoperative testing; CPB and cross-clamp times and IABP use and timing from operative and perfusion records; and postoperative events from ICU and ward records. Everything was extracted from the institutional electronic medical record, and measurement did not differ between groups.

Bias and missing data

Several design choices were made to keep the groups comparable. Excluding emergent and salvage cases limits the timing question to patients in whom support could be started on clinical judgement rather than during collapse. Studying only isolated on-pump CABG with cross-clamping standardises technique and ischaemic time. Patients who fit neither support-location definition were reported separately instead of being pushed into one group. Even so, the decision to insert a balloon was made by clinicians, so confounding by indication and residual confounding remain possible. We did not impute missing values; analyses use available cases, and the tables give the denominators.

Study size

There was no a priori sample-size calculation. We included every eligible patient treated during a fixed 18-month period, the longest stretch with consistent and reasonably complete data. Because balloon use is uncommon, the subgroups are small and we have read them accordingly.

Statistical analysis

We checked the distribution of continuous variables with the Shapiro–Wilk test. Normally distributed variables are given as mean ± standard deviation and compared with the independent-samples t test or one-way analysis of variance. The rest are given as median [interquartile range] and compared with the Mann–Whitney U test or the Kruskal–Wallis test. Categorical variables are given as n (%) and compared with Pearson's chi-square test. Where any expected cell count fell below five we used Fisher's exact test for two groups and the Fisher–Freeman–Halton exact test for larger tables. Transfusion was recorded on an ordinal scale and was compared across its four categories in a single test.

We used binary logistic regression to look at what was associated with in-hospital mortality among the patients who received a balloon. Crude odds ratios came first, one variable at a time. We then fitted a multivariable model with support location, age, sex, preoperative eGFR and operative urgency entered together. The covariates were chosen in advance on clinical grounds, not by their univariable p values. We assessed the model with the likelihood-ratio test, the Nagelkerke pseudo-R^2, the Hosmer–Lemeshow goodness-of-fit test, the area under the receiver operating characteristic curve (95% confidence interval by the DeLong method) and variance inflation factors. Because the deaths were few relative to the number of terms, we added Firth penalised logistic regression with profile penalised-likelihood confidence intervals as a sensitivity analysis. Results are odds ratios with 95% confidence intervals.

All tests were two-sided and $p < 0.05$ was taken as significant. We used R version 4.6.1 (R Foundation for Statistical Computing, Vienna, Austria) in RStudio, with the haven, dplyr, tidyr, broom, gtsummary, gt, DescTools, ResourceSelection, pROC, car and logistf packages.

Prolonged mechanical ventilation was recorded only for the 2025 part of the cohort, so it was examined as a predefined subgroup analysis in those patients (n = 842).

Results

Cohort and IABP use

The cohort was 1224 patients: 382 operated on in the second half of 2024 and 842 in 2025 (Fig. 1). An IABP was used in 57 (4.7%) — 16 before surgery, 13 during and 28 afterwards. The support-location comparison covers 25 OR-IABP patients (13 intraoperative insertions and 12 preoperative ones still running at the wean) and 28 ICU-IABP patients. Four more patients had a preoperative balloon removed before the wean; they belong to neither group and are absent from that comparison.

Patients with and without IABP

Patients who needed a balloon were no different in age, body mass index, diabetes, hypertension or renal function (Table 1). They were more often women (36.8% versus 18.9%; $p < 0.001$) and more often had urgent surgery (64.9% versus 40.8%; $p < 0.001$). EF was preserved in everyone by definition and the median was 65% in both groups, but values sat lower in the IABP group (interquartile range 55–65 versus 60–65; $p = 0.004$). Both CPB time (median 122 versus 106 min; $p < 0.001$) and cross-clamp time (74 versus 63 min; $p = 0.006$) were longer.

Table 1
Preoperative and operative characteristics according to IABP use

Variable	No IABP (n = 1167)	IABP (n = 57)	p value
Age, years	61.0 [54.4–68.0]	62.8 [54.0–71.0]	0.337
Body mass index, kg/m²	26.8 [24.3–29.7]	27.2 [24.4–30.0]	0.773
Ejection fraction, %	65.0 [60.0–65.0]	65.0 [55.0–65.0]	0.004
Preoperative creatinine, mg/dL	0.9 [0.8–1.0]	0.8 [0.7–1.0]	0.137
Preoperative eGFR, mL/min/1.73 m²	89.0 [74.0–99.0]	90.0 [68.0–100.0]	0.991
Systolic pulmonary artery pressure, mmHg	25.0 [25.0–30.0]	25.0 [21.0–35.0]	0.577
Cardiopulmonary bypass time, min	106.0 [86.0–129.8]	122.0 [99.0–155.0]	< 0.001
Aortic cross-clamp time, min	63.0 [50.0–78.0]	74.0 [56.0–91.0]	0.006
Female sex	221 (18.9)	21 (36.8)	< 0.001
Smoking history	647 (56.6)	25 (45.5)	0.104
Diabetes mellitus	568 (48.8)	27 (48.2)	0.927
Hypertension	750 (64.7)	36 (63.2)	0.817
Hyperlipidaemia	669 (59.9)	26 (48.1)	0.085
COPD or asthma	102 (8.8)	5 (8.8)	0.997
Previous stroke	70 (6.1)	5 (8.8)	0.392
Extracardiac arteriopathy	178 (19.2)	10 (21.3)	0.728
Preoperative dialysis	13 (1.1)	1 (1.8)	0.490
Non-sinus rhythm on admission	26 (2.2)	1 (1.8)	1.000
Previous pacemaker or ICD	3 (0.3)	0 (0.0)	1.000
Right ventricular dysfunction	3 (0.3)	1 (1.9)	0.170
Urgent operation (reference: elective)	476 (40.8)	37 (64.9)	< 0.001

Values are median [interquartile range] or n (%). Tests used: Mann–Whitney U test; Pearson's chi-square test; Fisher's exact test. Percentages use the patients with data. Data were largely missing only for Systolic pulmonary artery pressure, mmHg (No IABP n = 817, IABP n = 43); Extracardiac arteriopathy (No IABP n = 926, IABP n = 47). COPD chronic obstructive pulmonary disease, eGFR estimated glomerular filtration rate, IABP intra-aortic balloon pump, ICD implantable cardioverter-defibrillator.

Operative mortality was 49.1% with a balloon and 2.3% without (p < 0.001) (Table 2). In-hospital mortality was 49.1% versus 2.2%, and 30-day mortality 43.9% versus 1.9%. Re-exploration was more frequent with a balloon (26.3% versus 3.9%; p < 0.001), and so was heavy transfusion: 71.9% received four units or more, against 23.7% of the rest (p < 0.001). Among survivors, median hospital stay was 7.0 days with a balloon and 6.0 without (p < 0.001).

Table 2
Early postoperative outcomes according to IABP use

Variable	No IABP (n = 1167)	IABP (n = 57)	p value
Hospital stay, days (all patients)	6.0 [5.0–7.0]	7.0 [4.0–9.0]	0.345
Hospital stay, days (survivors only)	6.0 [5.0–7.0]	7.0 [6.0–9.0]	< 0.001
Operative mortality	27 (2.3)	28 (49.1)	< 0.001
In-hospital mortality	26 (2.2)	28 (49.1)	< 0.001
30-day mortality	22 (1.9)	25 (43.9)	< 0.001
Re-exploration	46 (3.9)	15 (26.3)	< 0.001
Tracheostomy	9 (0.8)	2 (3.5)	0.090
Blood transfusion, units			< 0.001
0 units	290 (24.9)	1 (1.8)	
1 unit	224 (19.2)	5 (8.8)	
2–3 units	376 (32.2)	10 (17.5)	
≥4 units	276 (23.7)	41 (71.9)	

Values are median [interquartile range] or n (%). Operative mortality means death during the index hospital stay, or within 30 days of surgery. Hospital stay is also given for survivors alone, because an early death shortens the recorded stay. Tests used: Mann–Whitney U test; Fisher's exact test; Pearson's chi-square test. Percentages use the patients with data. Data were largely missing only for Hospital stay, days (survivors only) (IABP n = 29).

Outcomes by insertion period

The three insertion groups were broadly alike at baseline, with three exceptions (Table 3). Nearly all patients given a preoperative balloon had urgent surgery (93.8%; p = 0.008). Patients given a postoperative balloon were the oldest (mean 65.9 ± 9.5 years; p = 0.008). Bypass time also differed and was longest where the balloon went in during surgery (median 154 min, against 101.5 min preoperatively and 129 min postoperatively; p = 0.043).

Table 3
Preoperative and operative characteristics according to IABP insertion period

Variable	Preoperative (n = 16)	Intraoperative (n = 13)	Postoperative (n = 28)	p value
Age, years	56.5 ± 10.8	60.0 ± 7.5	65.9 ± 9.5	0.008
Body mass index, kg/m²	25.6 [23.4–27.9]	27.0 [25.0–29.0]	28.2 [25.9–31.0]	0.126
Ejection fraction, %	60.0 [53.8–65.0]	65.0 [65.0–65.0]	62.5 [53.8–65.0]	0.066
Preoperative creatinine, mg/dL	0.8 [0.6–1.0]	0.8 [0.7–1.0]	0.9 [0.8–1.1]	0.229
Preoperative eGFR, mL/min/1.73 m²	96.0 [72.8–111.0]	93.0 [78.0–101.0]	84.5 [63.8–95.5]	0.176
Systolic pulmonary artery pressure, mmHg	25.0 [21.2–35.0]	25.0 [22.5–25.0]	27.5 [22.8–35.0]	0.501
Cardiopulmonary bypass time, min	101.5 [91.5–129.0]	154.0 [102.0–168.0]	129.0 [113.2–152.2]	0.043
Aortic cross-clamp time, min	66.5 [48.5–77.2]	90.0 [58.0–100.0]	74.0 [56.8–91.5]	0.200
Female sex	6 (37.5)	6 (46.2)	9 (32.1)	0.634
Smoking history	8 (57.1)	6 (46.2)	11 (39.3)	0.548
Diabetes mellitus	9 (56.2)	6 (46.2)	12 (44.4)	0.745
Hypertension	10 (62.5)	10 (76.9)	16 (57.1)	0.523
Hyperlipidaemia	7 (43.8)	5 (38.5)	14 (56.0)	0.541
COPD or asthma	3 (18.8)	1 (7.7)	1 (3.6)	0.174
Previous stroke	0 (0.0)	1 (7.7)	4 (14.3)	0.412
Extracardiac arteriopathy	3 (23.1)	1 (11.1)	6 (24.0)	0.798
Preoperative dialysis	0 (0.0)	0 (0.0)	1 (3.6)	1.000
Non-sinus rhythm on admission	1 (6.2)	0 (0.0)	0 (0.0)	0.509

Values are mean ± standard deviation, median [interquartile range] or n (%). Tests used: One-way ANOVA; Kruskal–Wallis test; Fisher–Freeman–Halton exact test; Pearson's chi-square test. Percentages use the patients with data. Data were largely missing only for Systolic pulmonary artery pressure, mmHg (Preoperative n = 10, Intraoperative n = 11, Postoperative n = 22); Smoking history (Preoperative n = 14); Hyperlipidaemia (Postoperative n = 25); Extracardiac arteriopathy (Preoperative n = 13, Intraoperative n = 9, Postoperative n = 25). NA marks a variable that no patient had in any group, so it could not be tested. Abbreviations as in Table 1.

Variable	Preoperative (n = 16)	Intraoperative (n = 13)	Postoperative (n = 28)	p value
Previous pacemaker or ICD	0 (0.0)	0 (0.0)	0 (0.0)	NA
Right ventricular dysfunction	1 (6.7)	0 (0.0)	0 (0.0)	0.509
Urgent operation (reference: elective)	15 (93.8)	8 (61.5)	14 (50.0)	0.008

Values are mean ± standard deviation, median [interquartile range] or n (%). Tests used: One-way ANOVA; Kruskal–Wallis test; Fisher–Freeman–Halton exact test; Pearson's chi-square test. Percentages use the patients with data. Data were largely missing only for Systolic pulmonary artery pressure, mmHg (Preoperative n = 10, Intraoperative n = 11, Postoperative n = 22); Smoking history (Preoperative n = 14); Hyperlipidaemia (Postoperative n = 25); Extracardiac arteriopathy (Preoperative n = 13, Intraoperative n = 9, Postoperative n = 25). NA marks a variable that no patient had in any group, so it could not be tested. Abbreviations as in Table 1.

Operative mortality climbed across the preoperative, intraoperative and postoperative groups: 18.8%, 38.5% and 71.4% (p = 0.002) (Table 4). The same pattern held for 30-day mortality (6.2%, 38.5% and 67.9%; p < 0.001) and re-exploration (0%, 15.4% and 46.4%; p < 0.001). Among survivors, median stay was 7.0, 7.5 and 9.0 days (p = 0.017). These are descriptive, unadjusted comparisons.

Table 4
Early postoperative outcomes according to IABP insertion period

Variable	Preoperative (n = 16)	Intraoperative (n = 13)	Postoperative (n = 28)	p value
Hospital stay, days (all patients)	7.0 [6.0–8.2]	6.0 [4.0–8.0]	6.5 [3.8–10.5]	0.677
Hospital stay, days (survivors only)	7.0 [6.0–7.0]	7.5 [6.5–11.8]	9.0 [8.8–12.2]	0.017
Operative mortality	3 (18.8)	5 (38.5)	20 (71.4)	0.002
In-hospital mortality	3 (18.8)	5 (38.5)	20 (71.4)	0.002
30-day mortality	1 (6.2)	5 (38.5)	19 (67.9)	< 0.001
Re-exploration	0 (0.0)	2 (15.4)	13 (46.4)	< 0.001
Tracheostomy	1 (6.2)	0 (0.0)	1 (3.6)	1.000
Blood transfusion, units				0.109
0 units	0 (0.0)	1 (7.7)	0 (0.0)	
1 unit	1 (6.2)	1 (7.7)	3 (10.7)	
2–3 units	6 (37.5)	2 (15.4)	2 (7.1)	
≥4 units	9 (56.2)	9 (69.2)	23 (82.1)	

Values are median [interquartile range] or n (%). Tests used: Kruskal–Wallis test; Pearson's chi-square test; Fisher–Freeman–Halton exact test. Percentages use the patients with data. Data were largely missing only for Hospital stay, days (survivors only) (Preoperative n = 13, Intraoperative n = 8, Postoperative n = 8).

Operating-room versus ICU balloon support

The two groups matched on most measured characteristics: sex, body mass index, smoking, diabetes, hypertension, hyperlipidaemia, chronic obstructive pulmonary disease, previous stroke, renal function, pulmonary artery pressure, EF, CPB time and cross-clamp time (Table 5). Only age reached significance: ICU-IABP patients were older (65.9 ± 9.5 versus 58.5 ± 9.1 years; p = 0.006). Urgent surgery was more common in the OR-IABP group, but only borderline (76.0% versus 50.0%; p = 0.051). As far as we could measure it, then, preoperative acuity favoured the ICU-IABP group; only age favoured OR-IABP.

Table 5
Preoperative and operative characteristics: OR-IABP versus ICU-IABP

Variable	OR-IABP (n = 25)	ICU-IABP (n = 28)	p value
Age, years	58.5 ± 9.1	65.9 ± 9.5	0.006
Body mass index, kg/m²	27.1 [23.8–29.0]	28.2 [25.9–31.0]	0.109
Ejection fraction, %	65.0 [55.0–65.0]	62.5 [53.8–65.0]	0.331
Preoperative creatinine, mg/dL	0.8 [0.7–1.0]	0.9 [0.8–1.1]	0.159
Preoperative eGFR, mL/min/1.73 m²	93.0 [78.0–107.0]	84.5 [63.8–95.5]	0.117
Systolic pulmonary artery pressure, mmHg	25.0 [21.2–28.8]	27.5 [22.8–35.0]	0.333
Cardiopulmonary bypass time, min	131.0 [99.0–160.0]	129.0 [113.2–152.2]	0.796
Aortic cross-clamp time, min	72.0 [56.0–92.0]	74.0 [56.8–91.5]	0.762
Female sex	10 (40.0)	9 (32.1)	0.552
Smoking history	12 (50.0)	11 (39.3)	0.438
Diabetes mellitus	12 (48.0)	12 (44.4)	0.797
Hypertension	17 (68.0)	16 (57.1)	0.416
Hyperlipidaemia	11 (44.0)	14 (56.0)	0.396
COPD or asthma	4 (16.0)	1 (3.6)	0.176
Previous stroke	1 (4.0)	4 (14.3)	0.355
Extracardiac arteriopathy	3 (15.8)	6 (24.0)	0.710
Preoperative dialysis	0 (0.0)	1 (3.6)	1.000
Non-sinus rhythm on admission	0 (0.0)	0 (0.0)	NA
Previous pacemaker or ICD	0 (0.0)	0 (0.0)	NA
Right ventricular dysfunction	1 (4.3)	0 (0.0)	0.469

Values are mean ± standard deviation, median [interquartile range] or n (%). OR-IABP means the balloon was working as the patient came off cardiopulmonary bypass: balloons put in during surgery, plus preoperative balloons kept running for the wean. ICU-IABP means a rescue balloon started in the intensive care unit, in a patient who left the operating room without one. Tests used: Independent-samples t test; Mann–Whitney U test; Pearson's chi-square test; Fisher's exact test. Percentages use the patients with data. Data were largely missing only for Systolic pulmonary artery pressure, mmHg (ICU-IABP n = 22, OR-IABP n = 18); Hyperlipidaemia (ICU-IABP n = 25); Extracardiac arteriopathy (ICU-IABP n = 25, OR-IABP n = 19). NA marks a variable that no patient had in any group, so it could not be tested. Abbreviations as in Table 1.

Variable	OR-IABP (n = 25)	ICU-IABP (n = 28)	p value
Urgent operation (reference: elective)	19 (76.0)	14 (50.0)	0.051

Values are mean ± standard deviation, median [interquartile range] or n (%). OR-IABP means the balloon was working as the patient came off cardiopulmonary bypass: balloons put in during surgery, plus preoperative balloons kept running for the wean. ICU-IABP means a rescue balloon started in the intensive care unit, in a patient who left the operating room without one. Tests used: Independent-samples t test; Mann–Whitney U test; Pearson's chi-square test; Fisher's exact test. Percentages use the patients with data. Data were largely missing only for Systolic pulmonary artery pressure, mmHg (ICU-IABP n = 22, OR-IABP n = 18); Hyperlipidaemia (ICU-IABP n = 25); Extracardiac arteriopathy (ICU-IABP n = 25, OR-IABP n = 19). NA marks a variable that no patient had in any group, so it could not be tested. Abbreviations as in Table 1.

The outcomes ran the other way (Table 6). Operative mortality was 32.0% for OR-IABP and 71.4% for ICU-IABP (p = 0.004); 30-day mortality was 24.0% and 67.9% (p = 0.001). Re-exploration was needed in 8.0% versus 46.4% (p = 0.002). Among survivors, median stay was 7.0 versus 9.0 days (p = 0.036).

Table 6
Early postoperative outcomes: OR-IABP versus ICU-IABP

Variable	OR-IABP (n = 25)	ICU-IABP (n = 28)	p value
Hospital stay, days (all patients)	7.0 [4.0–9.0]	6.5 [3.8–10.5]	0.979
Hospital stay, days (survivors only)	7.0 [6.0–9.0]	9.0 [8.8–12.2]	0.036
Operative mortality	8 (32.0)	20 (71.4)	0.004
In-hospital mortality	8 (32.0)	20 (71.4)	0.004
30-day mortality	6 (24.0)	19 (67.9)	0.001
Re-exploration	2 (8.0)	13 (46.4)	0.002
Tracheostomy	1 (4.0)	1 (3.6)	1.000
Blood transfusion, units			0.122
0 units	1 (4.0)	0 (0.0)	
1 unit	2 (8.0)	3 (10.7)	
2–3 units	7 (28.0)	2 (7.1)	
≥4 units	15 (60.0)	23 (82.1)	

Values are median [interquartile range] or n (%). Tests used: Mann–Whitney U test; Pearson's chi-square test; Fisher's exact test; Fisher–Freeman–Halton exact test. Percentages use the patients with data. Data were largely missing only for Hospital stay, days (survivors only) (ICU-IABP n = 8, OR-IABP n = 17).

Regression analyses

We modelled in-hospital mortality in the 53 patients with a classifiable support location; 28 of them (52.8%) died during the index stay. In this subgroup in-hospital and operative mortality identify the same patients. In univariable analysis, ICU-IABP carried higher odds of death than OR-IABP (odds ratio 5.31, 95% confidence interval 1.64–17.19; p = 0.005) (Table 7). Age (1.13 per year, 1.05–1.22; p = 0.001), female sex (4.00, 1.17–13.66; p = 0.027), lower preoperative eGFR (0.96 per mL/min/1.73 m², 0.94–0.99; p = 0.012) and urgent rather than elective surgery (0.14, 0.04–0.53; p = 0.003) were also associated with death.

Table 7
Logistic regression for in-hospital mortality: OR-IABP versus ICU-IABP

Variable	Odds ratio	95% CI	p value
Univariable (n = 53, deaths = 28)			
ICU-IABP (reference: OR-IABP)	5.31	1.64–17.19	0.005
Age, per year	1.13	1.05–1.22	0.001
Female sex	4.00	1.17–13.66	0.027
Preoperative eGFR, per mL/min/1.73 m²	0.96	0.94–0.99	0.012
Urgent operation (reference: elective)	0.14	0.04–0.53	0.003
Multivariable (n = 53, deaths = 28)			
ICU-IABP (reference: OR-IABP)	4.54	0.84–24.46	0.078
Age, per year	1.08	0.98–1.20	0.123
Female sex	5.44	0.93–31.74	0.060
Preoperative eGFR, per mL/min/1.73 m²	0.98	0.94–1.01	0.211
Urgent operation (reference: elective)	0.10	0.02–0.60	0.012
Firth penalised sensitivity analysis			
ICU-IABP (reference: OR-IABP)	3.56	0.82–17.91	0.090

The covariates were picked in advance on clinical grounds, not by their univariable p values, and entered together. Model performance: likelihood-ratio $\chi^2 = 31.079$ on 5 degrees of freedom ($p < 0.001$); Nagelkerke $R^2 = 0.592$; Hosmer–Lemeshow $\chi^2 = 8.138$ on 8 degrees of freedom ($p = 0.420$); area under the receiver operating characteristic curve 0.906 (95% CI 0.826–0.986, DeLong method). Every variance inflation factor was below 2, so multicollinearity is not a concern. Because 28 deaths are being modelled with five covariates, Firth penalised regression with profile penalised-likelihood intervals was added as a sensitivity analysis. CI confidence interval, eGFR estimated glomerular filtration rate, IABP intra-aortic balloon pump, OR-IABP operating-room IABP support, ICU-IABP intensive care unit IABP support.

With support location, age, sex, eGFR and urgency entered together, ICU-IABP still carried higher odds of death, but the estimate no longer cleared the conventional threshold (adjusted odds ratio 4.54, 0.84–24.46; p = 0.078). Female sex was borderline in the same way (5.44, 0.93–31.74; p = 0.060). Urgent surgery stayed independently associated with lower odds of death (0.10, 0.02–0.60; p = 0.012), while age and eGFR lost significance. The model was significant overall (likelihood-ratio $\chi^2 = 31.079$, 5 degrees of freedom; $p < 0.001$), explained a good deal of the variance (Nagelkerke $R^2 = 0.592$), fitted well (Hosmer–Lemeshow $\chi^2 = 8.138$, 8 degrees of freedom; p = 0.420) and discriminated well (area under the curve 0.906, 0.826–0.986). Firth penalised regression, run because 28 deaths were modelled with five covariates, pointed the same way (3.56, 0.82–17.91; p = 0.090).

Prolonged mechanical ventilation subgroup

Among the patients for whom this was recorded (the 2025 subgroup, n = 842), none of 19 OR-IABP patients needed prolonged ventilation, against 7 of 17 ICU-IABP patients (41.2%; p = 0.002). The outcome was not available for the whole cohort and the numbers are small, so this is exploratory.

Discussion

Three findings stand out. First, among elective or urgent isolated CABG patients with preserved EF, a balloon was rarely needed (4.7%) but marked a group with very high early mortality. Second, the later the balloon went in, the higher the crude operative mortality. Third, patients who needed rescue support in the ICU died far more often than patients who came off bypass on a balloon, even though urgent surgery was more common in the latter group. The association weakened once we adjusted for the measured differences and no longer reached significance, so what we have is an association, not proof that timing causes the difference.

Why a homogeneous cohort matters

The IABP is one of the most used mechanical support devices in cardiac surgery, and there is no shortage of published outcome data. Most of it, however, spans the whole range of open-heart surgery. That is a real limitation, not a presentational one. How likely a patient is to need postoperative support depends in part on the operation: valve, aortic and combined procedures differ from isolated coronary surgery in ischaemic time, in loading conditions, and in how low output develops. Pool them, and any link between the timing of the balloon and the outcome carries the fingerprint of case mix. The largest recent series shows the problem. Sharma and colleagues studied 1114 IABP-supported patients out of 22 540 open-heart procedures and reported operative mortality of 11.4%, 8.2% and 25.8% for preoperative, intraoperative and postoperative insertion. Their cohort mixed isolated CABG, non-isolated CABG, valve and combined operations, and they themselves urged caution because the valve and combined subgroups were small [8].

We set out to avoid that. This cohort is isolated coronary surgery only, on-pump, with cross-clamping. Emergent and salvage operations are out, and so are patients with reduced ejection fraction. What is left

is a fairly uniform population: similar technique, similar ischaemic exposure, similar baseline ventricular function. When such a patient needs a balloon, it is more likely to reflect what happened during and after the operation than the type of operation itself. The price is a small number of IABP patients. We think a modest number of comparable, well-characterised patients answers a timing question more convincingly than a larger mixed series, and that these data are worth adding to a literature with few coronary-only cohorts.

What the timing seems to mean

The mortality gradient across insertion periods matches earlier reports. Parissis and colleagues found mortality of 18.2%, 33.3% and 58.3% with preoperative, intraoperative and postoperative balloons after open-heart surgery, and identified postoperative insertion as an independent marker of poor outcome [9]. In patients having extensive coronary endarterectomy, an intraoperative balloon was likewise followed by better early outcomes than a postoperative one, which carried roughly four times the mortality risk [10]. Those populations differ from ours, but the direction is the same, and a pattern that repeats across settings is unlikely to be a quirk of one hospital or one period.

The comparison that mattered most here was not the calendar time of insertion. In some patients the preoperative balloon sat idle through the operation and was switched back on for the wean. So we compared patients by whether support was already running when they left the operating room. That is the decision the surgical team actually faces: establish support during a difficult wean, or wait and see how the patient does in the ICU.

Two explanations fit the difference we found. Support started earlier, during the wean, may keep low cardiac output from progressing to organ injury; the higher re-exploration rate and the prolonged ventilation among ICU-IABP patients fit a rougher postoperative course. Or postoperative balloons may simply mark the patients whose deterioration was worse, less predictable, or driven by something that happened after surgery. The interventional cardiology literature leans the same way: counterpulsation started after circulatory failure is established achieves little. IABP-SHOCK II found no mortality benefit in infarction with cardiogenic shock [13]; a meta-analysis of randomised trials found benefit in infarction without shock but none once shock had set in [14]; and a recent cohort of patients with infarction and shock found no reduction in in-hospital or one-year mortality, only longer ICU and hospital stays [15].

One feature of our data deserves emphasis. The difference we could measure between the two groups did not favour the group that did better. Urgent surgery was more common among OR-IABP patients than among ICU-IABP patients. So the group that came off bypass on a balloon was, on the evidence available, the group operated under more pressure, and it still had less than half the mortality. Only age favoured OR-IABP, and adjusting for the measured differences reduced the gap without closing it.

The adjusted analysis still calls for caution. Crude odds of death with ICU-IABP were more than five times higher, and the adjusted estimate stayed above four, but the confidence interval crossed one and the Firth model told the same story. With 28 deaths and five covariates the model sits at the edge of

what these data can carry, and the width of the interval shows it. None of this proves that starting a balloon in the operating room saves lives. What it does show is that needing one in the ICU marks a patient on a very bad trajectory.

What this might mean in practice

There is still something useful here. In a patient with preserved EF, needing a balloon is not a routine part of perioperative care; it flags a high-risk state despite a normal-looking preoperative ventricle. When the patient is already unstable coming off bypass, our data argue for close attention and for making the decision about mechanical support before organ injury becomes irreversible. That is a hypothesis to test prospectively, not a recommendation drawn from causal evidence.

Strengths and limitations

The study has real strengths. The cohort is contemporary and deliberately narrow — isolated on-pump CABG, preserved EF, no emergent or salvage cases — which limits the case-mix confounding that troubles mixed open-heart series. The definition of operative mortality is explicit. Every eligible patient was included. And separating rescue balloons from support already running at the wean may say more clinically than insertion time alone.

The limitations matter too. This is a single-centre retrospective study, and the decision to insert a balloon rested on clinical judgement rather than a protocol, so confounding by indication cannot be ruled out. Only 57 patients received a balloon and the support-location analysis rests on 28 deaths, which is fewer than six events per variable in the five-covariate model; the wide confidence intervals reflect that, and it is why we added the Firth analysis. The lower adjusted odds of death with urgent rather than elective surgery run against expectation, and most likely reflect the make-up of a small elective subgroup rather than any protective effect of urgency; that estimate should not be read causally. Several variables we would have liked were missing or incomplete: completeness of revascularisation, graft number and type, inotrope doses, detailed haemodynamics, how long the balloon ran and how it was weaned, and device complications such as limb ischaemia, vascular injury and thrombocytopenia. Postoperative atrial fibrillation, pneumonia, sepsis, stroke and perioperative infarction were not recorded consistently across the whole period, and prolonged ventilation only in the 2025 subgroup. Follow-up stops at hospital discharge and 30 days. Finally, the exclusions that made the cohort uniform also narrow who the results apply to.

Generalisability

These results apply most directly to adults with preserved EF having elective or urgent isolated on-pump CABG with cross-clamping, in centres with similar thresholds for temporary mechanical support. They should not be carried over to patients with reduced EF, off-pump CABG, concomitant procedures, or emergent and salvage surgery.

Conclusions

In patients with preserved EF having elective or urgent isolated on-pump CABG, an IABP was rarely needed, but when it was, early mortality was very high. Rescue support started in the ICU carried much higher crude operative mortality than support established before the patient left the operating room, despite less preoperative acuity in the rescue group. Adjustment weakened that association, and it cannot be read as cause and effect. What the findings do establish is that needing a balloon after surgery marks a particularly dangerous course. Whether recognising and supporting these patients earlier improves outcome needs prospective, multicentre study, ideally in coronary-only cohorts.

Abbreviations

CABG: coronary artery bypass grafting

CI: confidence interval

COPD: chronic obstructive pulmonary disease

CPB: cardiopulmonary bypass

EF: left ventricular ejection fraction

eGFR: estimated glomerular filtration rate

IABP: intra-aortic balloon pump

ICU: intensive care unit

ICU-IABP: intensive care unit IABP support

IQR: interquartile range

OR-IABP: operating-room IABP support

SD: standard deviation

Declarations

Ethics approval and consent to participate

The study was approved by the Scientific Research Ethics Committee of Koşuyolu High Specialization Training and Research Hospital (meeting date 25 August 2026; decision no. 2026/14/1559) and was conducted in accordance with the Declaration of Helsinki. Because the study is retrospective, individual informed consent was not required and the ethics committee waived it.

Consent for publication

Not applicable.

Availability of data and materials

The hospital records behind this study are not publicly available, because they hold personal health information protected under the Turkish Personal Data Protection Law (Law No. 6698). A de-identified dataset is available from the corresponding author on reasonable request, subject to institutional approval.

Competing interests

The authors declare that they have no competing interests.

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Clinical Trial Number

Not applicable.

Authors' contributions

MR designed the study, collected the data, carried out the statistical analysis and wrote the manuscript. ACT contributed to the design of the study, provided the data from the institutional adult cardiac surgery quality improvement programme, supervised the preparation of the manuscript and revised it critically for important intellectual content. HH collected data within the quality improvement team, contributed to the interpretation of the results and reviewed the manuscript. BBB collected data, checked the study dataset against the source records, and contributed to the interpretation of the results and to the revision of the manuscript. All authors read and approved the final manuscript, and all agree to be accountable for every aspect of the work.

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References

1. Ferguson JJ 3rd, Cohen M, Freedman RJ Jr, Stone GW, Miller MF, Joseph DL, et al. The current practice of intra-aortic balloon counterpulsation: results from the Benchmark Registry. J Am Coll Cardiol. 2001;38:1456–62. https://doi.org/10.1016/S0735-1097(01)01553-4.
2. Kochar A, Zheng Y, van Diepen S, Mehta RH, Westerhout CM, Mazer DC, et al. Predictors and associated clinical outcomes of low cardiac output syndrome following cardiac surgery: insights

from the LEVO-CTS trial. Eur Heart J Acute Cardiovasc Care. 2022;11:818–25. https://doi.org/10.1093/ehjacc/zuac114.

3. Pilarczyk K, Boening A, Jakob H, Langebartels G, Markewitz A, Haake N, et al. Preoperative intra-aortic counterpulsation in high-risk patients undergoing cardiac surgery: a meta-analysis of randomized controlled trials. Eur J Cardiothorac Surg. 2016;49:5–17. https://doi.org/10.1093/ejcts/ezv258.
4. Hu Y, Fan M, Zhang P, Li R. Preoperative prophylactic insertion of intraaortic balloon pumps in critically ill patients undergoing coronary artery bypass surgery: a meta-analysis of RCTs. J Cardiothorac Surg. 2024;19:489. https://doi.org/10.1186/s13019-024-02961-y.
5. Deppe AC, Weber C, Liakopoulos OJ, Zeriouh M, Slottosch I, Scherner M, et al. Preoperative intra-aortic balloon pump use in high-risk patients prior to coronary artery bypass graft surgery decreases the risk for morbidity and mortality: a meta-analysis of 9,212 patients. J Card Surg. 2017;32:177–85. https://doi.org/10.1111/jocs.13114.
6. Theologou T, Bashir M, Rengarajan A, Khan O, Spyt T, Richens D, et al. Preoperative intra-aortic balloon pumps in patients undergoing coronary artery bypass grafting. Cochrane Database Syst Rev. 2011;1CD004472. https://doi.org/10.1002/14651858.CD004472.pub3.
7. Zheng JB, Hua K, Zhang K, Song JG, Yang XY, Yang X, et al. Prophylactic intra-aortic balloon pump in patients with left main disease undergoing off-pump coronary artery bypass grafting. BMC Cardiovasc Disord. 2020;20:266. https://doi.org/10.1186/s12872-020-01554-6.
8. Sharma S, Nah JH, Siddarth V, Lai H, Liang S, Ong ZX, et al. A multivariate and retrospective analysis of the impact of intra-aortic balloon counterpulsation in open-heart surgery. Sci Rep. 2024;14:29534. https://doi.org/10.1038/s41598-024-81056-z.
9. Parissis H, Leotsinidis M, Akbar MT, Apostolakis E, Dougenis D. The need for intra aortic balloon pump support following open heart surgery: risk analysis and outcome. J Cardiothorac Surg. 2010;5:20. https://doi.org/10.1186/1749-8090-5-20.
10. Wu Z, Liu C, Fang Y, Wei H, Gu C. Intraoperative intra-aortic balloon pump improves 30-day outcomes of patients undergoing extensive coronary endarterectomy. J Cardiothorac Surg. 2020;15:223. https://doi.org/10.1186/s13019-020-01261-5.
11. Topcu AC, Yigit F, Yerlikhan EO, Ozgur MM, Turkal M, Hancer H, et al. Establishing a surgeon-led adult cardiac surgery quality improvement program. J Card Surg. 2025;3804482. https://doi.org/10.1155/jocs/3804482.
12. Overman DM, Jacobs JP, Prager RL, Wright CD, Clarke DR, Pasquali SK, et al. Report from The Society of Thoracic Surgeons National Database Workforce: clarifying the definition of operative mortality. World J Pediatr Congenit Heart Surg. 2013;4:10–2. https://doi.org/10.1177/2150135112461924.
13. Thiele H, Zeymer U, Neumann FJ, Ferenc M, Olbrich HG, Hausleiter J, et al. Intraaortic balloon support for myocardial infarction with cardiogenic shock. N Engl J Med. 2012;367:1287–96. https://doi.org/10.1056/NEJMoa1208410.

14. Zheng XY, Wang Y, Chen Y, Wang X, Chen L, Li J, et al. The effectiveness of intra-aortic balloon pump for myocardial infarction in patients with or without cardiogenic shock: a meta-analysis and systematic review. BMC Cardiovasc Disord. 2016;16:148. https://doi.org/10.1186/s12872-016-0323-2.
15. Fang D, Yu D, Xu J, Ma W, Zhong Y, Chen H. Effects of intra-aortic balloon pump on in-hospital outcomes and 1-year mortality in patients with acute myocardial infarction complicated by cardiogenic shock. BMC Cardiovasc Disord. 2023;23:425. https://doi.org/10.1186/s12872-023-03465-8.

Figures

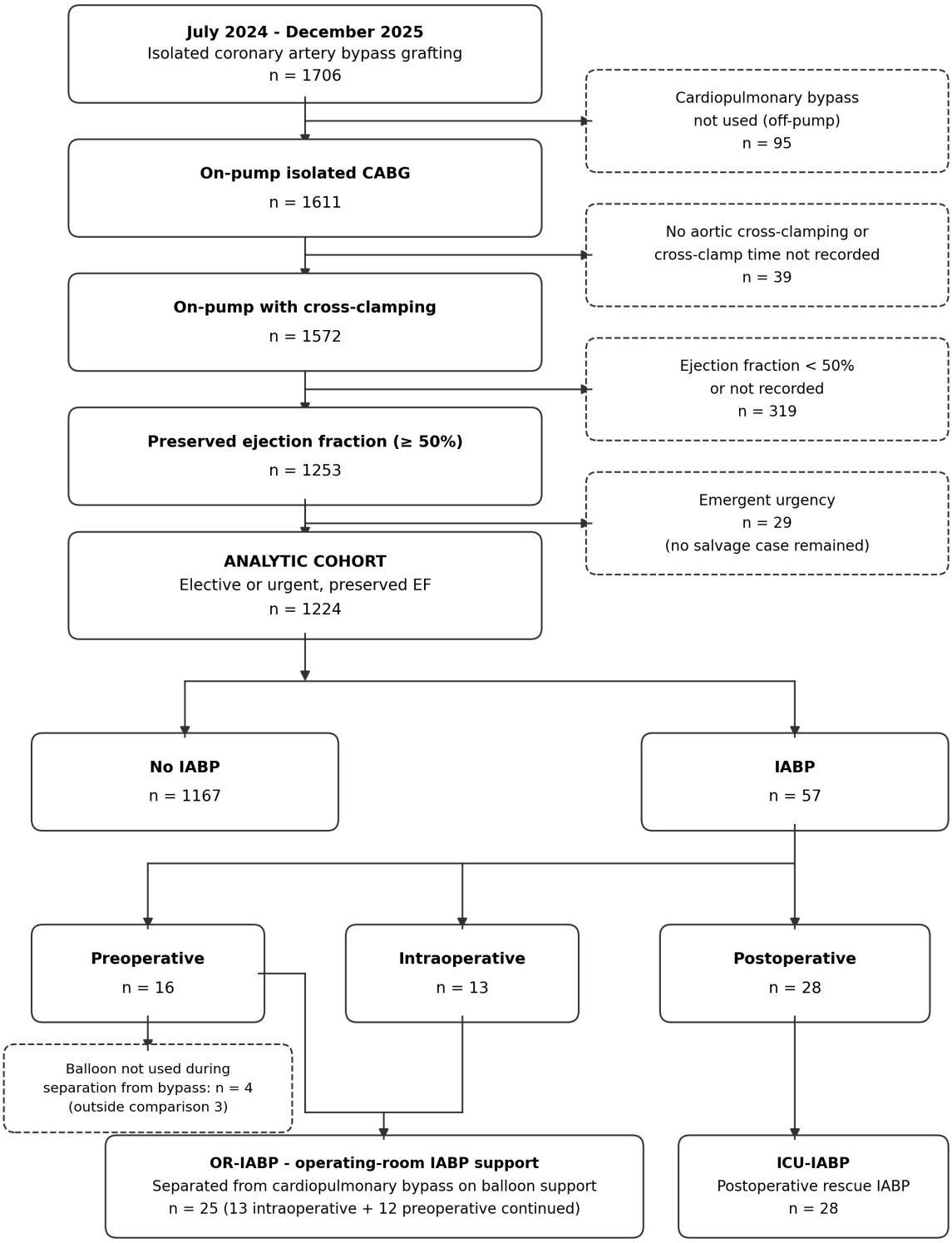


Figure 1

Participant flow diagram

Patients come from consecutive isolated coronary artery bypass procedures performed between 1 July 2024 and 31 December 2025. The exclusions leave 1224 patients (382 operated in the second half of 2024 and 842 in 2025): elective or urgent on-pump operations with aortic cross-clamping and preserved

ejection fraction. Patients given a balloon are shown by when it went in and by where support was running. The four patients whose preoperative balloon was not used to come off bypass fit neither support group and are described in the Methods. CABG coronary artery bypass grafting, EF ejection fraction, IABP intra-aortic balloon pump, OR-IABP operating-room IABP support, ICU-IABP intensive care unit IABP support.