Temporary circulatory support with surgically implanted microaxial pumps in postcardiotomy cardiogenic shock following coronary artery bypass surgery

Wiebke Sommer, MD, Rawa Arif, MD, Jamila Kremer, MD, Sameer Al Maisary, MD, Markus Verch, MD, Ursula Tochtermann, MD, Matthias Karck, MD, Anna L. Meyer, MD, Gregor Warnecke, MD

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Early implementation of temporary circulatory support with microaxial pumps in postcardiotomy cardiogenic shock following CABG surgery leads to superior survival

September 2017 – October 2022
All patients undergoing CABG surgery requiring postoperative support with an Impella 5.0/5.5 pump (n=42).

Subgroups:
- Simultaneous Impella implantation: n=27
- Delayed Impella implantation: n=15

Simultaneous implementation of Impella therapy during initial CABG surgery led to a more favorable patient survival, most likely due to the combined advantages of hemodynamic support and LV unloading in patients with ischemic cardiomyopathy.
Temporary circulatory support with surgically implanted microaxial pumps in postcardiotomy cardiogenic shock following coronary artery bypass surgery

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Data acquisition: WS, UT, MV, SA, JK, MK, RA, GW, AM
Data analysis: WS, RA, GW
Writing of Manuscript: WS, RA, GW, AM
Review of Manuscript: all authors

Abbreviations

ACT – Activated Clotting Time
CABG – Coronary Artery Bypass Graft
Central Picture Legend
CABG and simultaneous Impella therapy shows superior survival in ischemic cardiomyopathy.

Central Message
Early simultaneous CABG and Impella implantation led to more favorable survival probably due to the combined advantages of hemodynamic support and LV unloading.

Perspective
Treatment of postcardiotomy shock following CABG surgery with surgically implantable microaxial pumps combines hemodynamic support whilst simultaneously unloading the left ventricle. In this analysis, survival in patients with ischemic cardiomyopathy was favorable, when implementation of the Impella support was initiated early during CABG surgery as compared to delayed Impella implantation.
Abstract

Objectives: Patients with ischemic cardiomyopathy undergoing CABG surgery may develop postcardiotomy cardiogenic shock. In these cases, implantation of an Impella 5.0 or 5.5 microaxial pump offers full hemodynamic support whilst simultaneously unloading of the left ventricle.

Methods: Pre-, peri- and postoperative data of all patients receiving postoperative support with an Impella 5.0 or 5.5 after CABG surgery between 09/2017 and 10/2022 were retrospectively collected. Cohort built-up was performed according to the timing of Impella implantation, either simultaneous during CABG surgery or delayed.

Results: A total of n=42 patients received postoperative Impella support of which 27 patients underwent simultaneous Impella implantation during CABG surgery and 15 patients underwent delayed Impella therapy. Preoperative LV-EF was similarly low in both groups (26.7±0.7% vs. 24.8±1.3%; p=0.32). In the delayed cohort, Impella implantation was performed after a median of 1(1;2) days after CABG surgery. Survival after 30 days (75.6% vs. 47.6%, p=0.04) and 1-year (69.4% vs. 29.8%, p=0.03) was better in the cohort receiving simultaneous Impella implantation.

Conclusion: The combined advantages of hemodynamic support and LV unloading with microaxial pumps may lead to a favorable survival in patients with left ventricular failure following CABG surgery. Early implantation during the initial surgery shows a trend towards a more favorable survival as compared to patients receiving delayed support. (Fig. 4)

Keywords: postcardiotomy cardiogenic shock, Impella 5.5, Impella 5.0, CABG surgery, ischemic cardiomyopathy, LV unloading, temporary mechanical support
Introduction

Postcardiotomy cardiogenic shock represents a major complication, entailing the inability to wean a patient off cardiopulmonary bypass following cardiac surgery.\(^1\) Given the increasing morbidity of patients being accepted for cardiac surgery as well as the increasing number of procedures being performed in urgent patients, the need for postoperative extracorporeal support for left ventricular failure represents a daily clinical dilemma.\(^2\) With regard to published postoperative survival, the ideal setting for postcardiotomy extracorporeal support remains to be identified.\(^3\) Veno-arterial extracorporeal life support (V/A-ECMO) implanted either centrally or peripherally for either left-, right- or biventricular failure following cardiac surgery shows an overall survival not exceeding 25-42% in recent literature.\(^1,3-10\)

The lack of cardiac recovery in a sizeable proportion of patients on V/A-ECMO following postcardiotomy failure may be due to the absence of active left ventricular venting and increased cardiac afterload. Impella devices being placed in the LV with active drainage of the left ventricle result in decreased wall tension of the ventricle as well as attenuating LV afterload. Utilization of surgically implanted Impella devices (5.0 or 5.5) represents a prospect to combine full left-sided hemodynamic support whilst unloading the LV, thus facilitating LV recovery.\(^11-12\) The aim of this retrospective analysis was to analyze the potential of Impella 5.0 and 5.5 devices in patients with postcardiotomy failure following CABG surgery.

Methods

All patients receiving Impella 5.0 or 5.5 support after CABG surgery between September 2017 and October 2022, either in the same procedure or delayed after the CABG surgery due to low cardiac output were included into the retrospective data analysis. Pre-, perioperative as well as postoperative patient characteristics were retrospectively collected and survival up to 1 year after cardiac surgery was obtained. Urgency of CABG surgery was defined as either elective,
urgent (within 3 days after CABG indication) or emergency surgery, which was performed immediately after indication.

Primary endpoint of this analysis was in-hospital as well as one-year-survival. Secondary endpoints were Impella-associated complications, specifically cerebrovascular events during the course of Impella treatment as well as severe bleeding events defined by requiring >2 red packed cells per 24 hours. Outcome of patients that received simultaneous Impella implantation within the initial surgery was compared to patients receiving delayed Impella implantation during the postoperative course.

The local institutional ethical review board approved the analysis (S-759/2021; University of Heidelberg, date of approval:11/2021).

Definition of cardiogenic shock
Cardiogenic shock prior to initial CABG surgery as well as postcardiotomy cardiogenic shock leading to Impella implantation were defined following current AHA guidelines as blood pressure <90mmHg or need of vasopressors to maintain a blood pressure >90mmHg and at least one sign of hypoperfusion (e.g. confusion, cold extremities, oliguria, increased serum lactate, increased creatinine, increased liver enzymes, metabolic acidosis).¹³

The decision for the implantation of an extracorporeal support device as well as the decision which device (e.g. Impella, ECMO) was made by the surgeon in charge.

Vasoactive inotropic score (VIS)
The vasoactive inotropic score (VIS) was retrospectively calculated in both groups prior to Impella implantation. In the simultaneous group, the score was calculated using the catecholamine support required when cardiopulmonary bypass was reduced and weaning off CPB failed, in the delayed group, VIS was calculated immediately postoperatively upon arrival.
on ICU and additionally immediately prior to delayed Impella implantation. The VIS was calculated using a modified score by Nguyen et al.\textsuperscript{14}:

\[
\text{VIS} = \text{dopamine dose (µg/kg/min)} + \text{dobutamine dose (µg/kg/min)} + 100 \times \text{epinephrine dose (µg/kg/min)} + 10 \times \text{milrinone dose (µg/kg/min)} + 10,000 \times \text{vasopressin dose (U/kg/min)} + 100 \times \text{norepinephrine dose (µg/kg/min)} + 10 \times \text{phenylepinephrine dose (µg/kg/min)}
\]

\textit{Impella implantation technique and ICU standard treatment regimen}

Impella was implanted intraoperatively within the primary cardiac procedure or secondarily immediately following the decision to support a patient with delayed Impella therapy. As described previously\textsuperscript{11,15,16}, Impella 5.0 and 5.5 devices were implanted using a right or left subclavian access. Briefly, in general anesthesia, a lateral incision underneath the clavicle was performed and the subclavian artery was dissected. A 10mm-prosthesis was anastomosed to the artery and the Impella device was inserted through a sheath after placement of the corresponding wire in the left ventricle using fluoroscopy. Correct placement of the Impella device was monitored using transesophageal echocardiography. Anticoagulation during the insertion procedure was performed using heparine aiming for an activated clotting time (ACT) >250s, maintenance anticoagulation on ICU aimed for an ACT of 160-180s. In patients showing postoperative bleeding, heparine treatment was reduced or even ceased for a maximum of 24 hours postoperatively.

The pharmacological strategy upon arrival on ICU was weaning of vasopressor support whilst maintaining low-dose inotropic support in most cases, especially when biventricular impairment was noted. Central venous saturation (>70%) as well as serum lactate monitoring were continuously performed for hemodynamic monitoring.

Regular echocardiography examinations of left and right ventricle ejection fraction, local wall motion abnormalities as well as valve abnormalities were assessed. Early weaning off
mechanical ventilation was intended in all patients and mobilization of the patient in the chair with ongoing Impella support was performed whenever possible.

**Weaning of Impella support**

Following hemodynamic stabilization and weaning of vasopressor medication as well as signs of cardiac recovery in echocardiography, weaning off extracorporeal support was started. Step-wise reduction of the Impella device was performed over multiple days whilst closely monitoring central venous saturation, lactate and vasopressor demand as well as LV function on echocardiography. Echocardiographic parameters that were monitored on a daily basis included left ventricular ejection fraction as well as left ventricular end-diastolic diameter. Weaning was suspended and deferred when the patient required increasing doses of vasoactive agents (e.g. norepinephrine), showed continuously low central venous saturation (<60%) or increasing serum lactate levels. Similarly, weaning was postponed in case of new signs for end-organ impairment (e.g. increase of transaminases).

When all parameters indicating a sufficient hemodynamic situation were stable whilst continuously reducing the Impella support, explantation of the device was performed typically using only local anesthesia infiltration in non-intubated patients.

**Statistical analysis**

Data was collected and analyzed retrospectively. Categorical variables were summarized as frequencies and percentages. For comparison of continuous as well as categorical values, non-parametric testing was performed using Mann-Whitney-U-tests. Continuous variables were described as mean ± standard deviation or median and interquartile ranges as appropriate. Survival was analyzed using log-rank testing. All statistical analyses were performed using Graph Pad Prism 9.0 (San Diego, CA, USA) for MacOs.
Results

Preoperative patient characteristics

A total of 42 patients were included into the retrospective analysis qualifying for postcardiotomy low cardiac output syndrome following CABG surgery with postoperative Impella 5.0 or 5.5 treatment. During the same time, a total of 2741 solitary CABG procedures were performed in our center, the proportion of patients requiring hemodynamic support with a microaxial pump was therefore 1.53%. Simultaneous Impella implantation within the initial surgery was performed in 27 patients, whereas 15 patients received a delayed Impella implantation. Median follow-up in the simultaneous group were 166 (25; 215) (Median (IQR)) days and 22 (6;185) days in the delayed group.

Median age of the cohorts was similar (72.6 (63.9; 76.2 ) yrs vs. 70.8 (67; 75) yrs; p=0.71) and the majority of patients was male (81.5% vs. 93.3%; p=0.39). All patients presented with coronary artery disease.

Cardiovascular risk factors including arterial hypertension (81.5% vs. 86.7%; p=0.64), history of smoking (66.7% vs. 46.7%; p=0.48), hyperlipidemia (81.5% vs. 53.3%; p=0.19), diabetes (59.2% vs. 46.7%; p=0.52) and familiar predisposition for cardiac diseases (11.1% vs. 13.3%; p>0.99) were similarly distributed in both cohorts. (Tab.1)

The majority of patients in both cohorts presented with advanced heart failure categorizing in NYHA class III (48.1% vs. 66.7%; p=0.34) or class IV (51.9% vs. 26.7%; p=0.19). In the simultaneous group, six patients were in cardiogenic shock prior to CABG surgery, whereas only one patient in the delayed group showed signs of cardiogenic shock preoperatively (22.2% vs. 6.7%; p=0.39). Similarly, preoperative need for pharmaceutical catecholamine support was necessary in 9 patients in the simultaneous group and in one patient of the delayed group (33.3% vs. 6.7%; p=0.07). Most patients in both cohorts presented with an acute myocardial infarction (88.9% vs. 66.7%; p=0.12) with accompanying elevated cardiac enzymes preoperatively.
(CKMB 75.5±96.4 U/l vs. 49.8±63.1 U/l; p=0.88). Mean preoperative LV ejection fraction was not different in both cohorts (26.7±9.4% vs. 24.8±11.3%; p=0.32). (Tab.1)

**Peri- and postoperative patient characteristics**

The majority of surgeries were classified as “emergency” interventions in both groups (51.9% vs. 60.0%; p=0.75) and in 4 patients in the simultaneous group, surgery was performed as a “last resort” option. Urgent surgery was performed in 8 patients in the simultaneous group and in 2 patients of the delayed group (p=0.29). Elective surgery occurred more often in the delayed group (3.7% vs. 26.7%; p=0.04). (Tab.2)

The majority of patients underwent only coronary artery bypass grafting (CABG) in both groups (81.5% vs. 73.3%; p=0.70). Three patients in the simultaneous group underwent combined CABG and mitral valve surgery. Other surgeries included combined CABG and aortic valve replacement (3.7% vs. 20.0%; p=0.12), one patient in the delayed group underwent combined CABG and tricuspid valve reconstruction. One patient in the simultaneous group underwent re-do CABG surgery. Mean time on cardiopulmonary bypass was similar in both groups (167.7±58.3 min vs. 143.5±63.5 min; p=0.14). Similarly, mean aortic cross clamp time was not different in both groups (59.7±26.2 min vs. 73.9±28.4 min; p=0.19). Total duration of surgery was longer in the simultaneous group (374.2±78.3 vs. 295.4±72.9; p=0.0008), most likely due to the additional time for the Impella device implantation. (Tab.2)

In patients that underwent delayed Impella implantation, implantation was performed after a median of 1 (1;2) days after open heart surgery.

In the simultaneous group, the calculated vasoactive inotropic score at the end of CABG surgery when cardiopulmonary bypass weaning was attempted and subsequently failed was 37.3 points. In contrast, the delayed group showed a VIS of 23.8 points immediately after CABG surgery upon arrival on ICU. In this cohort, the calculated VIS increased to 36.9 immediately prior to delayed Impella implantation. (Fig. 3)
In the simultaneous group, 9 patients received an Impella 5.0 and 18 patients an Impella 5.5 device. In the delayed group, 6 patients received an Impella 5.0 and the remaining 9 patients underwent Impella 5.5 implantation. Duration of postoperative mechanical ventilation was similar in both groups after surgery (median 3.7 (0.8; 14.9) days vs. 9.9 (3.9; 17.7) days; p=0.09) and median time on ICU also did not differ between both cohorts (median 13 (8; 23) days vs. 17 (6; 26) days; p=0.92). Similarly, median total hospital stay was not different in both groups (20 (13; 24) days vs. 18 (8; 28) days; p=0.96). Renal replacement therapy for acute renal failure was necessary in 12 patients of the simultaneous group and 8 patients in the delayed group (p=0.75). Tracheostomy for weaning off mechanical ventilation was performed in 7 patients of the simultaneous group and in 5 patients of the delayed Impella group (p=0.73). Mobilization with ongoing Impella support at least into the chair was feasible in 66.7% (n=18) of the patient sin the simultaneous group and in 53.3% (n=8) of the patients in the delayed cohort.

Re-sternotomy for bleeding was necessary in 6 patients in the simultaneous group, one patient in the delayed group required surgical revision for bleeding (22.2% vs. 6.7%; p=0.39). Severe neurological complications occurred in three patients in the simultaneous group and in one patient in the delayed group (11.1% vs. 6.7%; p=>0.99). Complications included signs of a thrombo-embolic stroke with hemiparesis following Impella explantation and simultaneous permanent assist device implantation in one patient, one patient showed acute vision defects with thrombo-embolic strokes on the CT scan. Another patient presented with sub-acute drop foot syndrome, which was most likely not related to the microaxial pump therapy. The patient in the delayed group with a neurological complication suffered from a brachial plexus lesion following Impella implantation with residual weakness of the right arm. Three patients in the simultaneous group and one patient of the delayed group did not show sufficient cardiac recovery and therefore weaning off the temporary assist device in the absence
of end-organ dysfunction failed. These patients ultimately underwent permanent assist device (Heartmate 3™, Abbott, Abbott Park, IL, USA) implantation.

**Survival**

Following cardiac surgery, overall 30-day survival of the cohort was 67.8% and 12-months survival was 58.1% in the entire cohort. (Fig. 1) Sub-analysis of patients receiving simultaneous vs. delayed Impella implantation following cardiac surgery showed a more favorable survival when receiving simultaneous hemodynamic support (30-day survival 77.8% vs. 47.6%). (Fig. 2) In-hospital survival was 33.3% in the delayed group and 70.4% in the simultaneous group. (Tab.3) Causes of death in the simultaneous group were sepsis (n=5) and multi-organ failure (n=3). One additional patient died due to COVID-19 following discharge. In the delayed group, Causes of death included multi-organ failure (n=9) and malignant arrhythmias (n=1).

Failure to wean off temporary left heart assistance due to contraindications for permanent devices led to the death of patient in both cohorts. In the simultaneous group, 14.8% (n=4) patients died while being on Impella support. In the delayed group, 46.7% (n=7) patients died during ongoing support.

**Discussion**

With this single-center experience, we were able to demonstrate a favorable postoperative survival in patients with postcardiotomy heart failure, that received simultaneous Impella support within the initial CABG surgery. Patients that received temporary LV assist device therapy delayed after CABG surgery showed an inferior survival, underlining the importance of early decision-making in these hemodynamically critical patients. The calculated vasoactive inotropic score, which has previously been validated as a predictive score for morbidity and mortality in pediatric and adult cardiac surgical patients\(^{17,18}\), reflects in the majority of patients in the simultaneous cohort the decision making process for an early Impella implantation.
However, VIS values in the delayed group show that some patients in this group may have required earlier extracorporeal support, reflecting a learning process within our center. Hemodynamic support with a surgically implanted Impella device as a bridge to recovery or permanent assist device implantation generates full left-sided cardiac output, whilst actively unloading the LV.\textsuperscript{19} Despite unfavorable preoperative characteristics in our cohort with >60% of the patients undergoing emergency cardiac surgery or even surgery as a last resort option and the majority of patients having an acute myocardial infarction preoperatively, these results highlight the advantages of this left-sided cardiac support setting. Postcardiotomy failure typically occurs in patients with either preoperative acute or chronic left heart impairment or in patients with intraoperative myocardial injury due to inadequate cardioplegia and represents a clinical dilemma with unfavorable outcome.\textsuperscript{20} Our cohorts reflect these risk factors, showing severely reduced left ventricular ejection fraction preoperatively.

The current consensus for postcardiotomy extracorporeal circulatory support primarily focuses on V/A ECMO support as the most familiar treatment strategy in cardiac surgery for treating patients with postoperative cardiac failure.\textsuperscript{3} Registry data from the Extracorporeal Life Support Organization (ELSO) has shown a steady increase of extracorporeal life support for postcardiotomy cardiogenic shock over the past decade, however, survival to discharge showed a steady decrease over the past 10 years ranging between 15-25%.\textsuperscript{21} These disappointing results were similarly described by Fukuhara et al, reviewing the outcome of postcardiotomy cardiogenic shock treated with multiple different extracorporeal support devices between 1993 and 2015, seeing survival rates between 25-50%.\textsuperscript{22} In contrast, the initial safety trial for Impella 5.0 in postcardiotomy shock showed a favorable outcome with 30 days and 1 year survival of 94% and 75%\textsuperscript{23}, however, strict inclusion criteria excluding CPR in the 24 hours prior to implantation as well as active myocardial infarction prior to implantation amongst other criteria prohibiting a comparison to “real life” clinical settings for postcardiotomy cardiogenic shock. David et al provided a first insight on
the utilization of the Impella 5.0 device in 29 patients with postcardiotomy failure, showing a survival to discharge of 58.6% in this cohort of whom the majority of patients suffered from non-ischemic cardiomyopathy.\textsuperscript{24}

The beneficial hemodynamic advantage of left ventricular microaxial pumps may be the reduction of LV wall distension whilst providing sufficient cardiac output, thus leading to cardiac recovery patient survival. Kawashima et al proved the benefit of direct LV venting in a large animal model with acute left-sided myocardial ischemia, comparing the Impella device with veno-arterial ECMO support. The findings revealed a decreased LVEDP as well as a better response to defibrillations for ventricular fibrillations in Impella supported animals as compared to ECMO supported animals.\textsuperscript{25}

One important detail for a successful outcome following postcardiotomy failure appears to be the timing of Impella implantation. Our data suggests, that patients receiving early hemodynamic support within the initial surgery show a more favorable postoperative course as compared to patients undergoing delayed extracorporeal support. These differences in outcome may be due to the avoidance of high dosage postoperative catecholamine therapy in patients that underwent early Impella implantation, given the known side-effects of vasoconstrictive agents, that may lead to end-organ dysfunction as well as reduced peripheral blood circulation.\textsuperscript{26-28} The lower serum bilirubine peak in patients that received simultaneous Impella implantation as compared to patients with delayed LV support in our cohorts underlines the relevance of early extracorporeal device therapy.

Also, this data shows a median time on mechanical ventilation of 3.7 days in the simultaneous group and 9.9 days in the delayed group, suggesting a trend towards longer ventilation in patients in an initially critical hemodynamic state without early hemodynamic support. This is of special importance, since postoperative pneumonia remains a serious complication in postcardiotomy heart failure patients.\textsuperscript{4, 29}
Therefore, a center-specific strategy defining clinical parameters (including VIS, intra- and postoperative lactate trends, renal function, central venous saturation and clinical signs of hypoperfusion) when temporary extracorporeal assist device implantation should be performed, will be implemented in our center going forward.

One important benefit of the subclavian approach of postoperative Impella support is the advantage of a closed sternum, which allows early weaning off mechanical ventilation as well as the ability to mobilize the patient with ongoing Impella support.

**Limitations**

The study has the known limitations of a retrospective single-center analysis. Patients were neither randomized nor controlled. In addition, cohort sizes are small and results do not allow definite conclusions on LV recovery. Yet, the overall good outcome of this cohort demonstrates the potential to successfully bridge patients with postcardiotomy cardiogenic shock after CABG with microaxial pumps.

**Conclusion**

In conclusion, our data shows a favorable outcome of patients suffering from ischemic cardiomyopathy and concomitant postcardiotomy failure after CABG surgery when receiving early postoperative extracorporeal support with a surgically implantable microaxial pump, despite preoperatively severely reduced left ventricular ejection fraction in both cohorts. Future treatment modalities for postcardiotomy failure may focus further on active LV venting devices, which may lead to reduced LV wall distension, improved myocardial recovery with lower left ventricular end-diastolic pressure and therefore overall improved postoperative recovery in this challenging patient group.
References


**Figure legends**

Fig. 1.: Survival after CABG surgery. Kaplan-Meier analysis of all patients (n=42) requiring temporary mechanical support with an Impella microaxial pump following CABG surgery for ischemic cardiomyopathy. 95% Confidence Interval (Error bars).

Fig. 2.: Survival after CABG surgery. Kaplan-Meier analysis of patients that received either simultaneous (n=27) or delayed (n=15) hemodynamic support with an Impella 5.0 or 5.5 device following CABG surgery in ischemic cardiomyopathy. The cohort undergoing early simultaneous Impella implantation shows a significantly better survival (p=0.03) as compared to patients receiving delayed support. Censored events per group: Delayed=2, Simultaneous=4. 95% Confidence Interval (Error bars).

Fig. 3.: Vasoactive-inotropic score. Patients undergoing delayed Impella implantation presented with a median VIS of 23.8 upon arrival on ICU immediately after CABG surgery. The score increased subsequently to a median VIS of 36.9 immediately prior to Impella implantation. In the simultaneous group, the retrospectively calculated VIS was 37.3 in the OR when CPB was reduced and failed to wean prior to Impella implantation. Boxes show lower and upper quartiles, whiskers represent minimum and maximum values. Lines represent median values.

Fig. 4.: Graphical abstract.
**Tab. 1. Patient characteristics**

<table>
<thead>
<tr>
<th></th>
<th>Simultaneous Impella Implantation (n=27)</th>
<th>Delayed Impella Implantation (n=15)</th>
<th>p value</th>
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<tr>
<td><strong>Age (yrs)(Median; IQR)</strong></td>
<td>72.6; 63.9-76.2</td>
<td>70.8; 67-75.6</td>
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<td><strong>Female (n;%)</strong></td>
<td>5;18.5</td>
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<td><strong>Caucasian (n;%)</strong></td>
<td>27; 100</td>
<td>15; 100</td>
<td>&gt;0.99</td>
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<tr>
<td><strong>BMI(Mean±SD)</strong></td>
<td>27.2±4.9</td>
<td>24.1±3.0</td>
<td>0.05</td>
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<tr>
<td><strong>BMI</strong>: Body mass index</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Diabetes mellitus (n;%)</strong></td>
<td>16; 59.2</td>
<td>7; 46.7</td>
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<td><strong>Arterial hypertension (n;%)</strong></td>
<td>22; 81.5</td>
<td>13; 86.7</td>
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<td><strong>Smoking (n;%)</strong></td>
<td>18; 66.7</td>
<td>7; 46.7</td>
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<td><strong>Hyperlipidemia (n;%)</strong></td>
<td>22; 81.5</td>
<td>8; 53.3</td>
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<td><strong>Preop mechanical ventilation (n;%)</strong></td>
<td>3; 11.1</td>
<td>1; 6.7</td>
<td>&gt;0.99</td>
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<tr>
<td><strong>Acute myocardial infarction (n;%)</strong></td>
<td>24; 88.9</td>
<td>10; 66.7</td>
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<tr>
<td><strong>Preoperative CK (U/l)(Mean±SD)</strong></td>
<td>551.7±811.4</td>
<td>310.7±499.1</td>
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<tr>
<td><strong>Preoperative CKMB (U/l)(Mean±SD)</strong></td>
<td>75.5±96.4</td>
<td>49.8±63.1</td>
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<td><strong>Preop LV-EF(%) (Mean±SD)</strong></td>
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<tr>
<td><strong>Preop cardiogenic shock (n;%)</strong></td>
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<td>1; 6.7</td>
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<td><strong>Preop pharmaceutical catecholamine support (n;%)</strong></td>
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<td>1; 6.7</td>
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<td><strong>NYHA I (n;%)</strong></td>
<td>-</td>
<td>-</td>
<td>-</td>
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<td><strong>NYHA II (n;%)</strong></td>
<td>-</td>
<td>1; 6.7</td>
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<td>10; 66.7</td>
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<td><strong>NYHA IV (n;%)</strong></td>
<td>14; 51.9</td>
<td>4; 26.7</td>
<td>0.19</td>
</tr>
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</table>

BMI: Body mass index; CK: creatine kinase; LV-EF: left ventricular ejection fraction; CPR: cardiopulmonary resuscitation; Cardiogenic shock definition: RR<90mmHg or need of vasopressors to maintain RR>90mmHg and sign at least one sign of hypoperfusion (confusion, cold extremities, oliguria, increased serum lactate, increased creatinine, increased liver enzymes, metabolic acidosis).13 Mann-Whitney-U-test
<table>
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<th>Tab. 2. Operative data</th>
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<tr>
<td><strong>Urgency of Surgery (n; %)</strong></td>
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<tr>
<td>Elective</td>
</tr>
<tr>
<td>Urgent</td>
</tr>
<tr>
<td>Emergency</td>
</tr>
<tr>
<td>„Last resort“</td>
</tr>
<tr>
<td><strong>Surgery (n; %)</strong></td>
</tr>
<tr>
<td>CABG</td>
</tr>
<tr>
<td>CABG+MVR</td>
</tr>
<tr>
<td>Re-do CABG</td>
</tr>
<tr>
<td>CABG+AVR</td>
</tr>
<tr>
<td>CABG+TVR</td>
</tr>
<tr>
<td><strong>Cardiopulmonary Bypass (min) (Mean±SD)</strong></td>
</tr>
<tr>
<td><strong>Aortic cross clamp time (min) (Mean±SD)</strong></td>
</tr>
<tr>
<td><strong>Duration of CABG surgery (min) (Mean±SD)</strong></td>
</tr>
<tr>
<td><strong>Delay of Impella Implantation after cardiac surgery (Days) (Median; IQR)</strong></td>
</tr>
</tbody>
</table>

CABG: coronary artery bypass grafting; MVR: mitral valve replacement; AVR: aortic valve replacement; TVR: tricuspid valve repair; Mann-Whitney-U-test
<table>
<thead>
<tr>
<th></th>
<th>Simultaneous Impella Implantation (n=27)</th>
<th>Delayed Impella Implantation (n=15)</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>ICU stay (days) (Median; IQR)</td>
<td>13 (8;23)</td>
<td>17 (6;26)</td>
<td>0.92</td>
</tr>
<tr>
<td>Mechanical ventilation (days) (Median; IQR)</td>
<td>3.7 (0.8; 14.9)</td>
<td>9.9 (3.9; 17.7)</td>
<td>0.09</td>
</tr>
<tr>
<td>Total Hospital stay (days) (Median; IQR)</td>
<td>20 (13; 24)</td>
<td>18 (8; 28)</td>
<td>0.96</td>
</tr>
<tr>
<td>Renal replacement therapy (n;%))</td>
<td>12; 44.4</td>
<td>8; 53.3</td>
<td>0.75</td>
</tr>
<tr>
<td>Bilirubine, max (mg/dl)(Mean±SD)</td>
<td>6.3±7.6</td>
<td>8.3±5.3</td>
<td>0.02</td>
</tr>
<tr>
<td>Tracheostomy (n;%))</td>
<td>7; 25.9</td>
<td>5; 33.3</td>
<td>0.73</td>
</tr>
<tr>
<td>Re-sternotomy for bleeding (n; %)</td>
<td>6; 22.2</td>
<td>1; 6.7</td>
<td>0.39</td>
</tr>
<tr>
<td>Cerebrovascular event</td>
<td>3; 11.1</td>
<td>1; 6.7</td>
<td>&gt;0.99</td>
</tr>
<tr>
<td>Duration of Impella support (days)(Median; IQR)</td>
<td>9 (6; 16)</td>
<td>14 (5; 16)</td>
<td>0.66</td>
</tr>
<tr>
<td>30-day survival (%)</td>
<td>77.8</td>
<td>47.6</td>
<td>0.04</td>
</tr>
<tr>
<td>6-months survival (%)</td>
<td>72.9</td>
<td>39.7</td>
<td>0.06</td>
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<tr>
<td>1-year survival (%)</td>
<td>72.9</td>
<td>29.8</td>
<td>0.03</td>
</tr>
</tbody>
</table>

ICU: intensive care unit; Mann-Whitney-U-test for categorical and continuous values, log-rank test for survival analysis
CABG and simultaneous Impella therapy leads to a favorable survival in ischemic cardiomyopathy.
Fig. 1

Survival after CABG Surgery

Time after Cardiac Surgery (days)

Probability of Survival

At risk: 42 28 25 23 22 22 19

n=42

95% CI
Fig. 2

Survival after CABG Surgery

- Simultaneous Impella Implantation (n=27)
- Delayed Impella Implantation (n=15)

p<0.01

<table>
<thead>
<tr>
<th>At risk</th>
<th>Simultaneous</th>
<th>Delayed</th>
</tr>
</thead>
<tbody>
<tr>
<td>27</td>
<td>21</td>
<td>15</td>
</tr>
<tr>
<td>30</td>
<td>19</td>
<td>6</td>
</tr>
<tr>
<td>60</td>
<td>18</td>
<td>5</td>
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<tr>
<td>90</td>
<td>17</td>
<td>5</td>
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<tr>
<td>120</td>
<td>17</td>
<td>5</td>
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<td>150</td>
<td>14</td>
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<tr>
<td>180</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Time after Cardiac Surgery (days)

Probability of Survival

95% CI
Fig. 3

**Vasoactive Inotropic Score**

- **Delayed Impella Implantation**
- **Simultaneous Impella Implantation**

![Graph showing Vasoactive Inotropic Score](image)
Early implementation of temporary circulatory support with microaxial pumps in postcardiotomy cardiogenic shock following CABG surgery leads to superior survival

September 2017 – October 2022
All patients undergoing CABG surgery requiring postoperative support with an Impella 5.0/5.5 pump (n=42).

Subgroups:
Simultaneous Impella implantation: n=27
Delayed Impella implantation: n=15

Survival after CABG Surgery

Simultaneous implementation of Impella therapy during initial CABG surgery led to a more favorable patient survival, most likely due to the combined advantages of hemodynamic support and LV unloading in patients with ischemic cardiomyopathy.