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Safety and feasibility of minimally invasive coronary artery bypass surgery early after drug eluting stent implantation due to acute coronary syndrome

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Safety and feasibility of minimally invasive coronary artery bypass surgery early after drug eluting stent implantation due to acute coronary syndrome

Short title: EACAB after DES implantation for acute coronary syndrome

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WHAT'S NEW?

The evidence on use of surgical approach after temporary withdrawal of dual antiplatelet therapy in patients who received drug eluting stent (DES) for acute coronary syndrome treatment is limited. In current study, we evaluate a cohort of patients that underwent percutaneous revascularization for acute coronary syndrome and were referred for endoscopic, atraumatic coronary artery bypass grafting (EACAB) as a second stage of revascularization in a maximal time interval of 180 days. Investigation towards composite endpoint of MACCE (Major Adverse Cardiac and Cerebrovascular Events), defined as death, myocardial infarction, cerebrovascular incident and repeat revascularization was evaluated. Despite temporary withdrawal of $P2Y_{12}$ inhibitor prior to the surgery, the long-term results were satisfactory in this group, presenting with 17.4% occurrence of MACCE in median follow-up of 1338.5 days (3.7 years). As such, EACAB is a safe and feasible method of revascularization in patients who received DES within 180 days prior to the surgery.

ABSTRACT

Background: The evidence of performing minimally invasive coronary artery surgery early after drug eluting stent (DES) implantation due to acute coronary syndrome (ACS) is limited.

Aim: The aim of the study is to determine the safety and feasibility of this approach.

Methods: This registry includes 115 (78% male) patients from 2013–2018, who underwent non-LAD percutaneous coronary intervention (PCI) due to ACS with contemporary DES implantation (39% diagnosed with myocardial infarction at baseline), followed by endoscopic atraumatic coronary artery bypass (EACAB) surgery within 180 days, after temporary $P2Y_{12}$ inhibitor discontinuation. Primary composite endpoint of MACCE (Major Adverse Cardiac and Cerebrovascular Events), defined as death, myocardial infarction (MI), cerebrovascular incident and repeat revascularization was evaluated in long- term follow-up. The follow-up was collected via telephone survey and with National Registry for Cardiac Surgery Procedures.

Results: Median (interquartile range [IQR]) time interval separating both procedures was 100.0 (62.0–136.0) days. Median (IQR) follow-up duration was 1338.5 (753.0–2093.0) days and was completed from all patients with regard to mortality. Eight patients (7%) died; 2 (1.7%) had a stroke; 6 (5.2%) suffered from MI and 12 (10.4%) required repeat revascularization. Overall, the

incidence of MACCE was 20 (17.4%).

Conclusions: EACAB is a safe and feasible method of LAD revascularization in patients who received DES for ACS within 180 days prior to surgery, despite early dual antiplatelet therapy discontinuation. The adverse event rate is low and acceptable.

Key words: EACAB; MIDCAB; antiplatelet; hybrid; acute coronary syndrome

INTRODUCTION

The definition of hybrid coronary revascularization is not well established, but it surely addresses the initial, planned strategy of performing concomitant or staged surgical and percutaneous revascularization. When considering hybrid strategy, most studies refer to sternal- sparing surgical procedure, such as MIDCAB (minimally invasive direct coronary artery bypass grafting), EACAB (endoscopic, atraumatic coronary artery bypass grafting) or TECAB (totally endoscopic coronary artery bypass grafting). Some reports consider traditional full-sternotomy OPCAB (off-pump coronary artery bypass grafting) surgery with full sternotomy as a stage of planned hybrid procedure as well. Although the definition of hybrid treatment is unclear, there is a group of patients which seems to lie beyond its scope.

In many acute coronary syndrome cases (ACS), particularly myocardial infarction (MI), direct revascularization of the infarct related artery is of highest priority. Those patients often undergo successful percutaneous treatment. The procedure is urgent and it is acceptable not to gather a heart-team to treat the target lesions. Other arteries with significant stenosis stand in a need of decision on further strategy.

If complementary left anterior descending (LAD) revascularization is required, those subjects may be referred to cardiac surgeon for minimally invasive bypass grafting with the use of left internal thoracic artery (LITA). As such, the decision of merging percutaneous and surgical procedure is made after the first stage of treatment. However, such a strategy requires temporary P2Y12 inhibitor withdrawal, which still generates doubts regarding increased perioperative and long-term risk of adverse cardiovascular events .

Clinical guidelines underline the efficacy of coronary artery bypass grafting as a treatment for multivessel coronary artery disease and essential role of LITA-LAD bypass graft [1]. This role

was the basis for development of minimally invasive approaches, such as EACAB.

It must be noted that the classic coronary artery bypass grafting (CABG) procedure has its drawbacks. Firstly, saphenous vein grafts have limited patency and may be inferior to new generation drug eluting stents. Furthermore, risk of various wound complications associated with the sternotomy is estimated at 0.4-8.0% [2-4]. A minimally invasive approach may reduce morbidity, pain, scarring, and recovery time when compared to classic bypass grafting with sternotomy. The EACAB procedure with the use of endoscopic internal thoracic artery harvest provides optimal quality and long- term patency of LITA-LAD graft [5].

When significant lesion in left anterior descending is diagnosed during percutaneous revascularization of other arteries, which are infarct related, the proper timing of surgical LAD treatment remains a matter of debate. Some studies that refer to the hybrid revascularization report a few hours of time interval separating the procedures as optimal, others consider 180-day interval acceptable [6]. However, no reports refer to hybrid revascularization of acute coronary syndrome cases. Regardless, early, temporary withdrawal of P2Y12 inhibitor is required for the surgical stage of revascularization.

The aim of the study is to determine the safety and feasibility of minimally invasive coronary artery bypass surgery early after drug eluting stent implantation due to acute coronary syndrome.

METHODS

Patients

Consecutive patients initially hospitalized in our center (Center of Cardiology and Cardiac Surgery, American Heart of Poland, Bielsko-Biała) due to ACS in years 2013–2018 were eligible for the approach and retrospective analysis if they met several criteria based on the heart team assessment. First of all, the arterial anatomy and distribution of lesions was verified by both cardiologist and cardiac surgeon (LAD was feasible for bypass grafting and other diseased arteries were feasible for PCI). Further, the patient was eligible for endoscopy- assisted coronary artery bypass grafting based on anatomy (severe obesity excludes the patient) and medical course (exclusion of patients with pleural adhesions, after chest radiation and with severe respiratory disease and no option to ventilate only one lung). Notably, in acute myocardial infarction heart-team assessment was not mandatory for the treatment of infarct related artery- in those cases it was acceptable to undergo the heart-team consultation following percutaneous procedure.

Consent for surgical treatment was required at the time of the heart-team assessment. Finally, the urgency of LAD revascularization was taken into consideration- we aimed to continue the dual antiplatelet therapy without interruption for at least 2 months (preferably 3 months, if possible). In all other cases, different revascularization options were considered. Every case was treated individually to choose optimal protocol for each patient.

The acceptable maximal time interval separating both procedures was 180 days. Consequently, patients who exceeded this timeframe were excluded from the analysis. Patients who underwent the revascularization of LAD (left anterior descending) as ACS-related artery or an unsuccessful attempt for LAD revascularization as a single procedure or did not receive DES for non-LAD revascularization were excluded. No further limitations for study inclusion were presented, as both number of treated vessels and device selection are highly dependent on the patient and the procedure itself.

Procedures

Percutaneous revascularization: the percutaneous revascularization of acute coronary syndrome related artery was conducted in a hemodynamic room, urgently after admission to cardiology department. All the patients had significant LAD stenosis based on angiography, which was evaluated by entire heart team. The decision whether to proceed with functional assessment of the LAD stenosis was based on heart-team consultation . From the entire cohort, 22 (19.1%) patients had FFR/iFR for the confirmation of LAD stenosis.

EACAB surgery: each patient underwent an EACAB surgery with the use of thoracoscope for internal mammary harvest and left anterolateral mini-thoracotomy for LITA-LAD anastomosis. After entering the operating room and induction of the anesthesia, each patient was intubated with a double-lumen endotracheal tube. After positioning (the patient was slightly elevated on the left side with a suspension of the left arm), single right lung ventilation was initiated. The 3rd (anterior axillary line), 5th (medial axillary line) and 7th (anterior axillary line) intercostal spaces were used for port introduction. Left internal thoracic artery (LITA) was harvested with the use of a harmonic blade (Ethicon, New Jersey, US) under endoscopic vision (Karl Storz, Tuttlingen, Germany). Before the LITA clipping, heparin was given in a dose of 1.5 mg/kg. The target activated clotting time (ACT) was 200–300 seconds. Left anterolateral mini-thoracotomy was made for the left anterior descending (LAD) exposure. The LITA-LAD anastomosis was made

using a continuous 8.0 Prolene suture (Ethicon, New Jersey, US) during epicardial LAD stabilization (Octopus Nuvo stabilizer; Medtronic, Minneapolis, US).

Procedure hospitalizations

Percutaneous procedure: Blood pressure, saturation, electrocardiogram and diuresis monitoring were conducted for 24 hours after the procedure. Dual antiplatelet therapy was initiated before the stenting procedure, $P2Y_{12}$ antagonists were used obligatorily. The echocardiography was performed before (if possible) and after the procedure. The patient was usually discharged two or three days following an uncomplicated procedure.

Surgical procedure: No control coronary angiography was performed routinely after percutaneous procedure. Clopidogrel or ticagrelor were withdrawn 5 or 3 days prior to the surgical treatment, respectively. None of the patients received prasugrel. No heparin bridging therapy was administered routinely. However, in case of need for oral anticoagulation, the patients were switched to low-molecular weight heparin instead of their oral medication 7 days prior to surgery. Aspirin treatment was not ceased prior to surgery . The EACAB procedure was performed on the second day following admission to the hospital. After the surgery, constant invasive blood pressure, saturation, ECG, diuresis and drainage monitoring was conducted for 48 hours. Dual antiplatelet therapy was initiated on the first day following surgery and maintained for at least one year from percutaneous procedure. The chest x-ray was done after the surgery and after 24 hours from the surgery, after removal of the chest tube. Control echocardiography was performed 48 hours after the procedure and whenever it was indicated with accordance to the patient's clinical status. The patients were discharged to the rehabilitation department for rehabilitation and 30-day observation.

Follow-up observation

On their admission to hospital, the patients gave their consent for data processing and long-term follow up evaluation as a part of quality assessment for hospital recognition purposes. As such, a telephone survey database was analyzed to assess the outcome and primary endpoint in this group of patients. Whenever the patient was unavailable, an authorized patient's correspondence person was contacted. In addition, the National Registry for Cardiac Procedures was checked to obtain 100% follow-up regarding mortality.

Research ethics board consent

No formal ethical approval was necessary for the quantitative part of the study. The report is a dataset analysis, the data was readily available and did not include any intervention to the patients or participants. The patients gave their permission on data processing for clinical and scientific purposes on their admission to hospital.

Primary endpoints

The investigation towards the composite endpoint of MACCE, defined as death, myocardial infarction, stroke and repeat revascularization was conducted through both hospitalization and long- term follow-up.

Secondary endpoints

Secondary endpoints included hospitalization complications (atrial fibrillation; kidney injury- which was defined with accordance to RIFLE criteria as two times postoperative creatine raise; fall in ejection fraction; cardiac biomarker release after surgical treatment).

Statistical analysis

The data are presented as number (percentage) or median (interquartile range). Chi-square test was used for categorical data comparison. Kaplan-Maier curves for MACCE and its components were used to determine mortality and morbidity in a long term follow up. Logrank test was used to compare Kaplan-Meier estimates in subgroups. The *P*-value <0.05 was considered to be statistically significant. The data were analyzed using MedCalc v.18.5 (MedCalc Software, Ostend, Belgium).

Data availability statement.

The data underlying this article will be shared on reasonable request to the corresponding author.

RESULTS

In years 2013–2018 there were 2364 unstable angina hospitalizations, 1841 non-ST-segment elevation myocardial infarction (NSTEMI) hospitalizations and 998 ST-segment elevation

myocardial infarction (STEMI) hospitalizations. Among those cases, 1257 unstable angina patients (53.2%), 1196 NSTEMI cases (64.9%) and 513 (51.4%) STEMI cases had significant LAD stenosis treated invasively (2966 cases). Current study represents 3.9% of those patients.

The patients' baseline characteristics was typical for a population with multivessel coronary artery disease (Table 1). All of them underwent percutaneous ACS target vessel revascularization and received drug eluting- stent. Prior to EACAB surgery, median left ventricular ejection fraction was 55% (Table 2).

We did not notice any myocardial infarction, stroke or death between the procedures in the analyzed group. However, two cases who were hospitalized due to NSTEMI while being on list for EACAB, which changed initial strategy to other treatment and excluded them from further analysis (the study addresses safety and feasibility of EACAB surgery). Although no control coronary angiography was performed routinely between the procedures, in three cases it was done due to clinical symptoms. It confirmed significant LAD stenosis in each of them. However, the strategy remained unchanged and patients received surgery as planned.

During the surgical procedure, each patient received a LITA-LAD graft. Perioperatively, three patients required chest revision for bleeding. Other complication rate was low. They mostly included pleurocentesis and atrial fibrillation (Table 3).

Two deaths (1.7%) and two (1.7%) repeat LAD revascularization were reported in the perioperative period. 17 patients (14.8%) were lost to long-term follow-up. In total, 8 patients (7%) died (follow-up regarding mortality is complete), 6 (5.2%) suffered from myocardial infarction, repeat target vessel revascularization was performed in 12 (10.4%) cases and 2 patients (1.7%) had a stroke (Tables 4 and 5, Figure 1). Of note, two late LAD revascularization procedures were required due to LITA-LAD graft malfunction and one due to new stenosis distally from the graft. Overall primary composite endpoint of MACCE was estimated at 17.4% (Table 4, Figure 1). Six patients (5.2%) underwent coronary angiography due to suspicion of critical stenosis, but no intervention was required.

When comparing diabetic to non-diabetic cases, patients with diabetes had significantly higher myocardial infarction incidence during the follow-up (15.6% vs. 1.2%; $P = 0.002$) (Table 5). Patients with no diagnosis of arterial hypertension (and as such, limited HA-dedicated treatment) had significantly higher incidence of MACCE during follow-up (15.2% vs. 40%; $P = 0.049$) (Table 5).

Although we did not reveal the impact of baseline myocardial infarction on mortality following EACAB surgery or composite MACCE endpoint , a trend towards increase of adverse events in this group was visible (Figure 2).

DISCUSSION

As the evidence on the use of surgical approach after temporary withdrawal of dual antiplatelet therapy in patients who received drug eluting stent (DES) for acute coronary syndrome treatment is strongly limited, current study provides reliable data on this matter and has the longest follow-up observation.

Despite all disadvantages of surgical treatment, in multivessel coronary disease, CABG confers a long-term survival benefit over PCI-DES because of higher rates of complete revascularization achieved [7]. This should be considered when adjusting the treatment to patients' needs. As such, the hybrid revascularization must provide the advantages of both techniques with respect to the necessity of achieving complete revascularization.

Although reported treatment cannot be presented as a planned, hybrid strategy per se, its final long-term efficacy needs to be studied with comparison to hybrid procedures. The impact of initial acute coronary syndrome and consequences of early, temporary discontinuation of dual antiplatelet therapy can only be discussed when studies of planned, hybrid revascularization procedures with none of those factors are taken into comparative analysis.

Adams et al. [8] reported the five-year clinical outcome for one stage hybrid coronary revascularization — he demonstrated 91% survival, 94% freedom from angina and 87% freedom from any form of coronary intervention, which is quite similar to presented results. Other studies report 88.5% survival at 5 years and 76% at 10 years survival, with only 10% of patients requiring repeat revascularization [9, 10]. Our analysis confirms satisfactory outcomes and low adverse endpoint rates. From the clinical perspective, it is important to note that the LITA-LAD reduces the need for future revascularization in the non-LAD vessels while providing long-term relief from angina episodes [11].

The LITA-LAD anastomosis has been shown to be more durable than other arterial and vein grafts as well as coronary stents for treatment of LAD disease, with patency rates >90% at 5-year follow-up [2, 11, 12]. During the follow-up evaluation, we noticed only two incidents of repeat LAD revascularization due to graft failure. When IMA graft failure occurs, technical error is the

most common cause in the early postoperative period. In the subsequent weeks to months, localized neointimal hyperplasia may occur at the cleft between the native artery and the ITA graft at the anastomotic suture site, on the hood and on the floor of the native LAD, which can result in a localized stenosis [13, 14]. The rate of diagnosed graft failures in our report is low and acceptable.

Six incidences of myocardial infarction were reported in the long-term follow-up (5.2%). Furthermore, we reported no myocardial infarction perioperatively. Recent metanalysis concludes that 3.2% of patients treated with HCR suffered from a MI compared with 2.6% of patients undergoing CABG, with no statistical significance [15]. The low rate of MI may be a result of not only revascularization strategy, but also adequate timing of both procedures.

From the obtained follow-up twelve patients required urgent repeat target vessel revascularization; seven (6.1%) of them in DES-treated arteries. This result is satisfactory, but further observation may be crucial, as some studies report 21% DES-treated vessel failure at 5-year follow-up [12]. As mentioned previously, some cases of restenosis may remain undiagnosed, as angina may not be present due to patent LIMA-LAD anastomosis [11].

We diagnosed no stroke in the perioperative period and two incidences of stroke during the follow-up. Low incidence of cerebrovascular episodes is considered a strong point of minimally invasive approach, as cardiopulmonary bypass and aortic manipulation during CABG create a direct danger and may be causes of stroke. In a recently published analysis, the incidence of cerebrovascular events in the HCR group was 0.9% compared with 1.4% in the CABG [15]. In general, the risk of stroke after CABG varies across studies ranging from 0.0 % to 5.2 %, depending on study design, patient risk profile, operative techniques and the length of study follow-up [16, 17]. The cerebrovascular incident following coronary artery bypass grafting remains one of the most devastating complications after CABG surgery, entailing permanent disability and a 3–6 fold increased risk of death with a case-fatality rate up to 20 % [18–19].

Kidney injury and failure following coronary artery bypass grafting is concerning. The injury following the surgery is the second most common cause of AKI in the intensive care setting (after sepsis) and is associated with increased morbidity and mortality [20]. It must be noted that mortality rate (hospital discharge or 30-day mortality) is between 3.8% and 54.4% in patients who develop the injury and increases progressively with the degree of renal impairment. The 3.5% rate of kidney injury in the perioperative period is low and acceptable. However, some

reports indicate that renal failure following hybrid procedure is estimated at 1.7%, compared with 2.6% in the CABG groups [15].

Atrial fibrillation (AF) is a very common complication after surgical procedures. There are multiple concepts for pathogenesis, but no clear evidence regarding triggers for arrhythmia onset. Regardless, it worsens the postoperative state and prognosis and increases the length of ICU stay, length of hospitalization, and hospital costs considerably [21, 22]. Seven studies examined the incidence of postoperative atrial fibrillation- in the HCR group, the incidence of the fibrillation was 17%, compared with 19.2% in the CABG group [15]. We report even lower number of AF in the perioperative period, which according to most reports, makes this method superior to coronary artery bypass grafting in this matter.

It has been reported that 22.8% of HCR patients receive blood transfusion [15]. Our results are encouraging, as only 9.2% received blood products. However, this may be the result of time interval separating both surgical and percutaneous procedures, which could reach 180 days. Narrowing the time interval would probably increase the rate of transfusion requirements, as coronary angiography with angioplasty may lower the blood morphology parameters.

In a recent randomized trial comparing coronary artery bypass grafting, hybrid coronary revascularization and multivessel percutaneous intervention residual myocardial ischemia and MACCE were similar at 12 months [23]. Of note, more than one half of the patients had a prior MI (55.5%). The HCR patients had PCI within 3 days (in most cases at 24–48 h) after performing MIDCAB LIMA-LAD. The advantage of that protocol was assessing the early LIMA-LAD patency. The coronary angiogram showed LIMA thrombotic occlusion in 1 case (2.1%). Angiographic control at 12 months demonstrated 9 SVGs and 1 LIMA stenosis/occlusion in the CABG group (10/49, 20.4%), 3 LIMA stenoses/occlusions and 1 in-segment restenosis in the HCR group (4/49, 8.2%). Long term follow up is expected. The protocol of mandatory angiography provides some reasonable results regarding graft patency. However, invasiveness of the procedure must be taken into consideration. Our follow-up protocol does not assume routine angiography in asymptomatic patients.

The MERGING clinical trial provided late clinical outcomes of myocardial hybrid revascularization versus coronary artery bypass grafting for a three-vessel coronary artery disease [24]. The percutaneous phase was performed 48–72 hours after withdrawal of the chest tubes and administering a loading dose of clopidogrel (600 mg). The 2-year rate of major cardiovascular

events defined as death, myocardial infarction, stroke, or repeat revascularization was evaluated. However, authors note that hybrid coronary revascularization was associated with the increasing rates of major adverse cardiovascular events during 2 years of clinical follow-up, while the control group treated with conventional surgery presented with low complication rates during the same period. The adverse events included mainly incidence of unplanned revascularization, which increased over time in both groups, reaching 14.5% vs. 5.9% in the hybrid and in the CABG groups, respectively. Authors point that the patients underwent two invasive procedures either simultaneously or within days from each other. Also, iodine contrast and antithrombotic medications (for PCI step) were used in proximity to a major surgery (CABG step) as well as the minimally invasive nature of PCI is virtually canceled by the surgical procedure. In this matter, our study reports quite a different perspective, assuming that the longer timeframe separating both procedures may not necessarily worsen the outcome. As restenosis can result from several mechanisms including inflammation and oxidative stress [25], the beneficial effect of separating both procedures may be hypothesized. Those factors are present in on-pump as well as in the off-pump surgical procedures [26].

Study limitations

The study has its drawbacks: it is a single-center, retrospective analysis with no control group. Furthermore, although follow-up regarding mortality is complete, 85.2% follow-up regarding myocardial infarction, stroke, and repeat revascularization is available. The coronary angiography was not performed routinely in patients with no symptoms.

CONCLUSIONS

EACAB is safe and a feasible method of LAD revascularization in patients who received DES for ACS within 180 days prior to surgery, despite early DAPT discontinuation. The adverse events rate in the long- term outcome is low and acceptable.

Article information

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REFERENCES

1. Neumann FJ, Sousa-Uva M, Ahlsson A, et al. 2018 ESC/EACTS guidelines on myocardial revascularization. Eur Heart J. 2019; 40(1): 87–165, doi: 10.1093/eurheartj/ehy394, indexed in Pubmed: 30165437.
2. Harskamp R, Zheng Z, Alexander J, et al. Status quo of hybrid coronary revascularization for multi-vessel coronary artery disease. Ann Thorac Surg. 2013; 96(6): 2268–2277, doi: 10.1016/j.athoracsur.2013.07.093, indexed in Pubmed: 24446561.
3. Green K, Lynch D, Chen T, et al. Combining PCI and CABG: the role of hybrid revascularization. Curr Cardiol Rep. 2013; 15(4), doi: 10.1007/s11886-013-0351-9, indexed in Pubmed: 23420447.
4. Balachandran S, Lee A, Denehy L, et al. Risk factors for sternal complications after cardiac operations: a systematic review. Ann Thorac Surg. 2016; 102(6): 2109–2117, doi: 10.1016/j.athoracsur.2016.05.047.
5. Abusamra R, Król M, Milewski K, et al. Short and long-term results of endoscopic atraumatic coronary artery off-pump bypass grafting in patients with left anterior descending artery stenosis. Cardiol J. 2021; 28(1): 86–94, doi: 10.5603/cj.a2019.0006, indexed in Pubmed: 30701513.
6. Verhaegh A, Accord R, Garsse Lv, et al. Hybrid coronary revascularization as a safe, feasible, and viable alternative to conventional coronary artery bypass grafting: what is the current evidence? Minim Invasive Surg. 2013; 2013: 1–10, doi: 10.1155/2013/142616, indexed in Pubmed: 23691303.
7. Kowalewski M, Gozdek M, Zieliński K, et al. Long-term mortality after percutaneous coronary intervention with drug-eluting stents compared with coronary artery bypass grafting for multivessel and left main disease: a meta-analysis. Kardiol Pol. 2020; 78(7-8): 759–761, doi: 10.33963/kp.15397, indexed in Pubmed: 32483953.

8. Adams C, Burns D, Chu M, et al. Single-stage hybrid coronary revascularization with long-term follow-up†. Eur J Cardiothorac Surg. 2013; 45(3): 438–443, doi: 10.1093/ejcts/ezt390, indexed in Pubmed: 23956269.
9. Rosenblum J, Harskamp R, Hoedemaker N, et al. Hybrid coronary revascularization versus coronary artery bypass surgery with bilateral or single internal mammary artery grafts. J Thorac Cardiovasc Surg. 2016; 151(4): 1081–1089, doi: 10.1016/j.jtcvs.2015.10.061, indexed in Pubmed: 26687889.
10. Farid S, Ali JM, Stohlner V, et al. Long-Term Outcome of Patients Undergoing Minimally Invasive Direct Coronary Artery Bypass Surgery: A Single-Center Experience. Innovations (Phila. 2018; 13: 23–28, doi: 10.1097/IMI.0000000000000466, indexed in Pubmed: 29462051.
11. Hawkes A, Nowak M, Bidstrup B, et al. Outcomes of coronary artery bypass graft surgery. Vasc Health Risk Manag. 2006; 2(4): 477–484, doi: 10.2147/vhrm.2006.2.4.477, indexed in Pubmed: 17323602.
12. Etienne PY, D'hoore W, Papadatos S, et al. Five-year follow-up of drug-eluting stents implantation vs minimally invasive direct coronary artery bypass for left anterior descending artery disease: a propensity score analysis. Eur J Cardiothoracic Surg. 2013; 44(5): 884–890, doi: 10.1093/ejcts/ezt137, indexed in Pubmed: 23492989.
13. Otsuka F, Yahagi K, Sakakura K, et al. Why is the mammary artery so special and what protects it from atherosclerosis? Ann Cardiothorac Surg. 2013; 2: 519–526, doi: 10.3978/j.issn.2225-319X.2013.07.06, indexed in Pubmed: 23977631.
14. Harskamp R, Alexander J, Ferguson T, et al. Frequency and predictors of internal mammary artery graft failure and subsequent clinical outcomes. Circulation. 2016; 133(2): 131–138, doi: 10.1161/circulationaha.115.015549, indexed in Pubmed: 26647082.
15. Reynolds AC, King N. Hybrid coronary revascularization versus conventional coronary artery bypass grafting: Systematic review and meta-analysis. Medicine (Baltimore). 2018; 97(33): e11941, doi: 10.1097/MD.0000000000011941, indexed in Pubmed: 30113498.
16. Goy JJ, Kaufmann U, Goy-Eggenberger D, et al. A prospective randomized trial comparing stenting to internal mammary artery grafting for proximal, isolated de novo left anterior coronary artery stenosis: the SIMA trial. Stenting vs Internal Mammary Artery. Mayo Clin Proc. 2000; 75(11): 1116–1123, doi: 10.4065/75.11.1116, indexed in Pubmed: 11075740.

17. Roach G, Kanchuger M, Mangano C, et al. Adverse cerebral outcomes after coronary bypass surgery. N Engl J Med. 1996; 335(25): 1857–1864, doi: 10.1056/nejm199612193352501, indexed in Pubmed: 8948560.
18. Dacey LJ, Likosky DS, Leavitt BJ, et al. Perioperative stroke and long-term survival after coronary bypass graft surgery. Ann Thorac Surg. 2005; 79(2): 532–536; discussion 537, doi: 10.1016/j.athoracsur.2004.07.027, indexed in Pubmed: 15680829.
19. Tarakji KG, Sabik JF, Bhudia SK, et al. Temporal onset, risk factors, and outcomes associated with stroke after coronary artery bypass grafting. JAMA. 2011; 305(4): 381–390, doi: 10.1001/jama.2011.37, indexed in Pubmed: 21266685.
20. Mao H, Katz N, Ariyanon W, et al. Cardiac surgery-associated acute kidney injury. Cardiorenal Med. 2013; 3(3): 178–199, doi: 10.1159/000353134, indexed in Pubmed: 24454314.
21. Auer J, Weber T, Berent R, et al. Postoperative atrial fibrillation independently predicts prolongation of hospital stay after cardiac surgery. Europace. 2005; 7: S1–S1, doi: 10.1016/j.eupc.2005.08.003.
22. Banach M, Ostrowski S, Zasłonka J, et al. Is there a relation between preoperative atrial fibrillation and increased mortality after cardiac surgery? Folia Cardiol. 2005; 12(Suppl D): 102–104.
23. Ganyukov V, Kochergin N, Shilov A, et al. Randomized Clinical Trial of Surgical vs. Percutaneous vs. Hybrid Revascularization in Multivessel Coronary Artery Disease: Residual Myocardial Ischemia and Clinical Outcomes at One Year—Hybrid coronary REvascularization Versus Stenting or Surgery (HREVS). J Interv Cardiol. 2020: 5458064, doi: 10.1155/2020/5458064, indexed in Pubmed: 31969796.
24. Esteves V, Oliveira M, Feitosa F, et al. Late clinical outcomes of myocardial hybrid revascularization versus coronary artery bypass grafting for complex triple-vessel disease: Long-term follow-up of the randomized MERGING clinical trial. Catheter Cardiovasc Interv. 2020; 97(2): 259–264, doi: 10.1002/ccd.28710, indexed in Pubmed: 31922359.
25. Kornowski R, Hong M, Tio F, et al. In-Stent Restenosis: Contributions of Inflammatory Responses and Arterial Injury to Neointimal Hyperplasia. J Am Coll Cardiol. 1998; 31(1): 224–230, doi: 10.1016/s0735-1097(97)00450-6, indexed in Pubmed: 9426044.

26. Abrantes R, Hueb A, Hueb W, et al. Behavior of Ultrasensitive C-Reactive Protein in Myocardial Revascularization with and without Cardiopulmonary Bypass. Braz J Cardiovasc Surg. 2018; 33(6): 535–541, doi: 10.21470/1678-9741-2018-0235, indexed in Pubmed: 30652741.

Table 1. Patient characteristics

Baseline patient characteristics	n = 115
Male sex, n (%)	90 (78)
Female sex, n (%)	25 (22)
Age, years, median (IQR)	63.0 (57.0–70.0)
Acute coronary syndrome: STEMI, n (%)	23 (20)
Acute coronary syndrome: NSTEMI, n (%)	22 (19.1)
Acute coronary syndrome: Unstable angina, n (%)	70 (60.9)
Percutaneous target vessel (non-LAD) revascularization for ACS, n (%) More than one vessel treated, n (%) Number of implanted drug eluting stents, median (IQR) Treated artery: Circumflex/obtuse margin, n (%) Right coronary artery, n (%) Intermediate branch, n (%) Diagonal branch, n (%)	115 (100) 8 (6.9) 1.0 (1.0- 2.0) 49 (42.6) 68 (59.1) 4 (3.5) 2 (1.7)
Diabetes, n (%)	32 (27.8)
Insulin therapy, n (%)	15 (13)
Arterial hypertension, n (%)	105 (91.3)
Hypercholesterolemia, n (%)	98 (85.2)

Active smoking, n (%)	41 (35)
Asthma, n (%)	2 (1.7)
Chronic obstructive pulmonary disease, n (%)	2 (1.7)
Renal insufficiency, n (%)	5 (4.3)
History of stroke/TIA, n (%)	9 (7.8)
Atrial fibrillation, n (%)	3 (2.6)
Obesity, n (%)	25 (21.7)
BMI, kg/m^2, n (%)	27.78 (25.65–30.70)

Abbreviations: ACS, acute coronary syndrome; LAD, left anterior descending; TIA, transient ischemic attack

Table 2. Echocardiographic parameters prior to EACAB

Patient characteristics	**n = 115**
EF, %, median (IQR)	55.0 (45.0–60.0)
LA, mm, median (IQR)	39.0 (36.0–42.0)
LV ESD, mm, median (IQR)	35.0 (30.0–38.0)
LV EDD, mm, median (IQR)	52.0 (48.0– 6.0)
PW, mm, median (IQR)	10.0 (10.0–12.0)
IVS, mm, median (IQR)	11.25 (10.0–12.0)
RV, mm, median (IQR)	26.0 (24.0–29.0)

Abbreviations: EACAB, endoscopic atraumatic coronary artery bypass grafting; EF, ejection fraction; IVS, intraventricular septum; LA, left atrium; LV EDD, left ventricular end diastolic diameter; LV ESD, left ventricular end systolic diameter; RV, right ventricle

Table 3. Procedural aspects of EACAB surgery

EACAB procedure, number of patients, n (%)	115 (100%)
Time interval separating both stages, median (IQR)	100.0 (62.0–136.0)
LITA-LAD, n (%)	115 (100)
Chest revision, n (%)	3 (2.6)
Perioperative AF, n (%)	12 (10.4)
Renal injury (RIFLE classification – creatinine × 2) , n (%)	4 (3.5)
PRBC transfusion, n (%)	11 (9.6)
>2 units of PRBC, n (%)	4 (3.4)
Pleurocentesis, n (%)	16 (13.9)
Perioperative EF, %, n (%)	50.0 (50.0–55.0)

Abbreviations: LAD, left anterior descending artery; LITA, left internal thoracic artery; PRBC, packed red blood cells; RIFLE, classification for renal failure (risk, injury, failure, loss of function, end stage disease); other — see Table 2

Table 4. The long- term follow up analysis

Number of patients, n (%)	115 (100)
Follow- up time, days from EACAB	1338.5 (753.0–2093.0)
Follow-up completion for mortality, n (%)	115 (100)
Follow-up completion for other endpoints, n (%)	98 (85.2)
Overall MACCE (including mortality), n (%)	20 (17.4)
-MACCE- perioperative observation, n (%)	4 (3.5)
-MACCE- long- term observation, n (%)	16 (13.9)
Mortality (100% follow-up) , n (%)	8 (6.9)
-Mortality- perioperative observation, n (%)	2 (1.7)
-Mortality- long-term observation, n (%)	6 (5.2)
Myocardial infarction, n (%)	6 (5.2)
-Perioperative observation	0
-Long term observation, n (%)	6 (5.2)
Overall repeat revascularization in treated arteries, n (%)	12 (10.4)
Repeat revascularization- LAD, n (%)	5 (4.3)
-Perioperative observation, n (%)	2 (1.7)
-Long- term observation, n (%)	3 (2.6)
Repeat revascularization- non-LAD, n (%)	7 (6.1)
-Perioperative observation	0

-Long- term observation, n (%)	7 (6.1)
PCI in other coronary arteries, n (%)	2 (1.7)
Coronary angiography with no intervention, n (%)	6 (5.2)
Stroke, n (%)	2 (1.7)
-Perioperative observation	0
-Long term observation, n (%)	2 (1.7)

Abbreviations: CCS, Canadian Cardiovascular Society grading scale for anginaMACCE, major adverse cardiac and cerebrovascular events (death, myocardial infarction, cerebrovascular incident and repeat target vessel revascularization); PCI, percutaneous coronary intervention; other — see Table 2

Table 5. Distribution of attributes in groups defined by mortality, myocardial infarction, repeat revascularization, stroke and composite endpoint during follow-up

	Mortality (n = 8)	**Myocardial infarction (n = 6)**	**Repeat revascularization in treated arteries (n = 12)**	**Stroke (n = 2)**	**Composite endpoint (MACCE: death, stroke, repeat revascularization) (n = 20)**
Age, years	70.0 (59.5–76.2)	65.5 (63.0–70.0)	63.0 (58.0–69.0)	65.5	64.0 (58.5–70.2)
Diabetes (32 patients at baseline) Subgroup	4 (50%) Diabetic vs. non-diabetic[a]:	5 (83.3%) Diabetic vs. non-diabetic[a]:	2 (16.7%) Diabetic vs. non-diabetic[a]:	0 Diabetic vs. non-diabetic[a]:	8 (40%) Diabetic vs. in non-diabetic[a]:

analysis	4/32 (12.5%) vs. 4/83 (4.8%) *P* = 0.15	5/32 (15.6%) vs. 1/83 (1.2%) *P* = 0.002	2/32 (6.25%) vs. 10/83 (12%) *P* = 0.36	0/32 vs. 2/83 (2.4%) *P* = 0.39	8/32 (25%) vs. 12/83 (14.5%) *P* = 0.18
Arterial hypertension (HA) (105 patients at baseline) Subgroup analysis:	6 (75%) HA vs. non-HA[a]: 6/105 (5.7%) vs. 2/10 (20%) *P* = 0.09	5 (83.3%) HA vs. non-HA[a]: 5/105 (4.8%) vs. 1/10 (10%) *P* = 0.48	10 (83.3%) HA vs. non-HA[a]: 10/105 (9.5%) vs. 2/10 (20%) *P* = 0.30	2 (100%) HA vs. non-HA[a]: 2/105 (1.9%) vs. 0/10 *P* = 0.66	16 (80%) HA vs. non-HA[a]: 16/105 (15.2%) vs. 4/10 (40%) *P* = **0.049**
Active smoking (41 patients at baseline) Subgroup analysis:	3 (37.5%) Smokers vs. no-smokers[a]: 3/41 (7.3%) vs. 5/74 (6.7%) *P* = 0.91	2 (33.3%) Smokers vs. no-smokers[a]: 2/41 (4.9%) vs. 4/74 (5.4%) *P* = 0.90	5 (41.7%) Smokers vs. no-smokers[a]: 5/41 (12.2%) vs. 7/74 (9.5%) *P* = 0.65	0 Smokers vs. no-smokers[a]: 0/41 vs. 2/74 (2.7%) *P* = 0.29	8 (40%) Smokers vs. no-smokers[a]: 8/41 (19.5%) vs. 12/74 (16.2%) *P* = 0.56
Male sex (90 patients at baseline) Subgroup	5 (62.5%) Male vs. female[a]:	4 (66.7%) Male vs. female[a]:	10 (83.3%) Male vs. female[a]:	1 (50%) Male vs. female[a]:	16 (80%) Male vs. female[a]:

analysis:	5/90 (5.6%) vs. 3/25 (12%) *P* = 0.26	4/90 (4.4%) vs. 2/25 (8%) *P* = 0.48	10/90 (11.1%) vs. 2/25 (8%) *P* = 0.65	1/90 (1.1%) vs. 1/25 (4%) *P* = 0.33	16/90 (17.8%) vs. 4/25 (16%) *P* = 0.84
Obesity (25 patients at baseline) Subgroup analysis:	3 (37.5%) Obese vs. non-obese*: 3 /25 (12%) vs. 5/90 (5.6%) *P* = 0.26	3 (50%) O Obese vs. non-obese*: 3/25 (12%) vs. 3/90 (3.3%) *P* = 0.09	2 (16.7%) Obese vs. non-obese*: 2/25 (8%) vs. 10/90 (11.1%) *P* = 0.65	0 Obese vs. non-obese*: 0/25 vs. 2/90 (2.2%) *P* = 0.45	5 (25%) Obese vs. non-obese*: 5/25 (20%) vs. 15/90 (16.7%) *P* = 0.70

Data are presented as number (percentage) and median (interquartile range). [a]χ^2 test

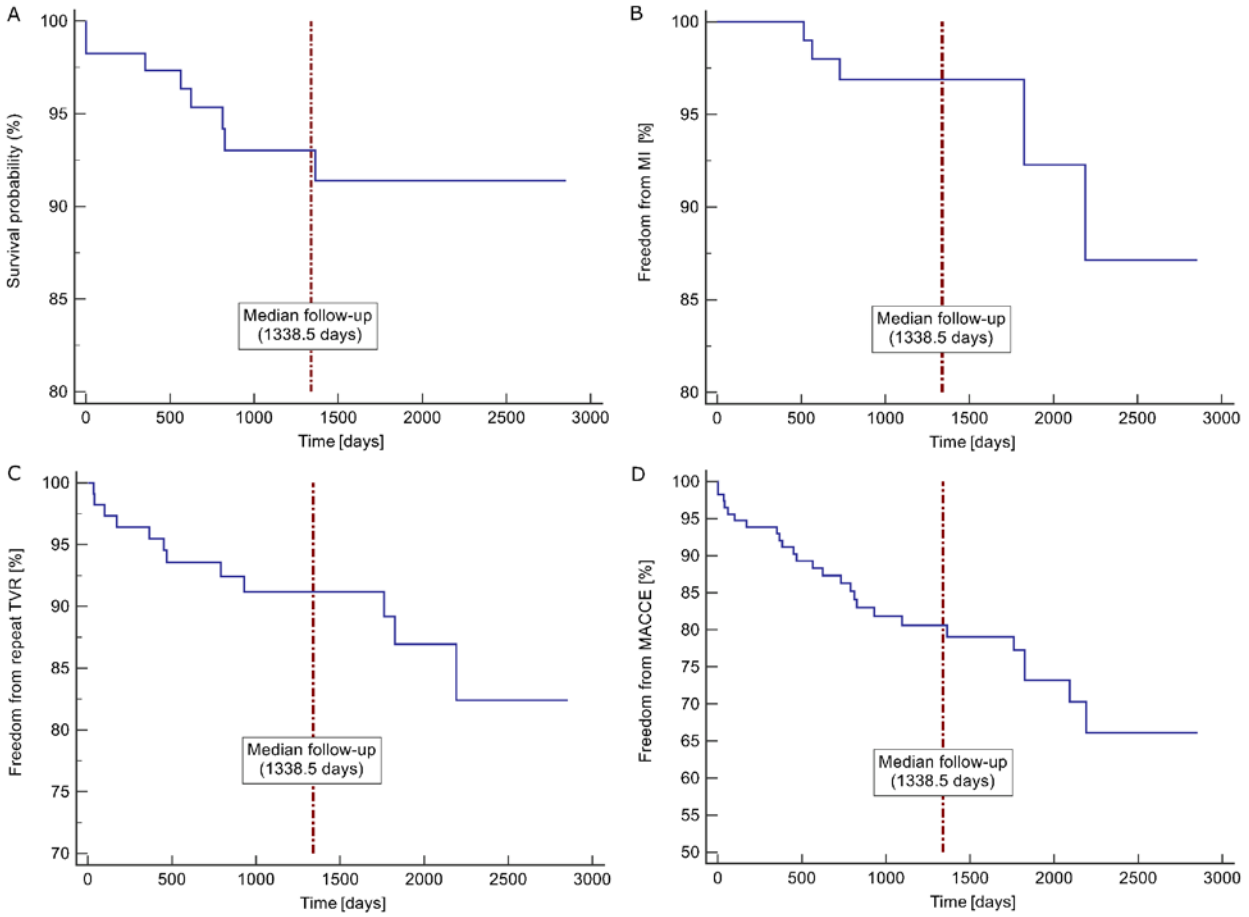

Figure 1. Kaplan-Meier curves for mortality (**A**), freedom from myocardial infarction (**B**), freedom from repeat revascularization (**C**) and freedom from MACCE **(D**) following EACAB surgery

Abbreviations: EACAB, endoscopic atraumatic coronary artery bypass grafting; MACCE, major adverse cardiac and cerebrovascular incidents (death, myocardial infarction, stroke, repeat revascularization); PCI, percutaneous intervention

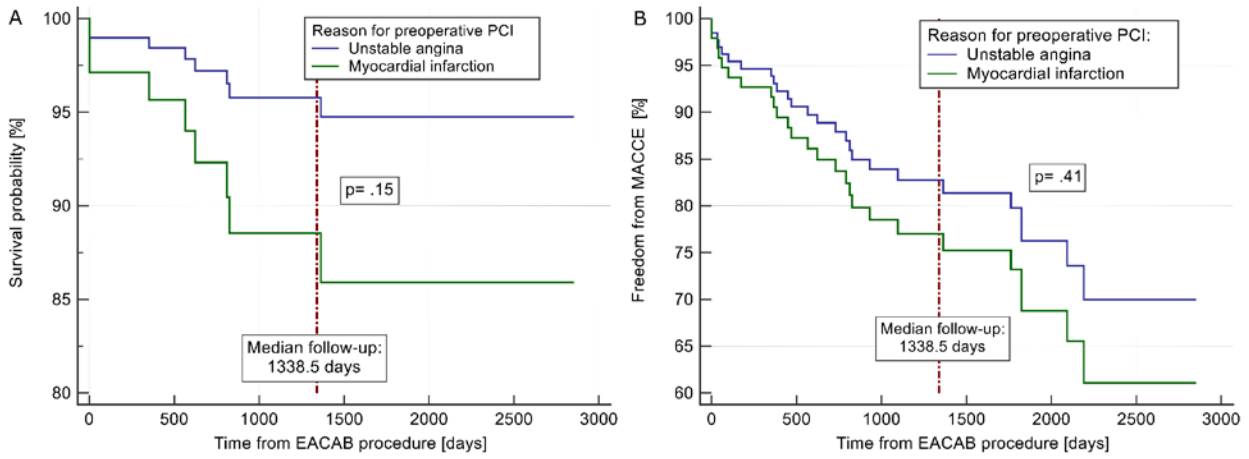

Figure 2. Kaplan–Meier curves for mortality (**A**) and freedom from MACCE (**B**) with relation to preoperative acute coronary syndrome. The *P*-values are for the log-rank test.

Abbreviations: see Figure 1