Myocardial enzyme release in totally endoscopic coronary artery bypass grafting on the arrested heart

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Objective: Robotic totally endoscopic coronary artery bypass grafting enables coronary artery bypass grafting without sternotomy or thoracotomy. However, longer cardiopulmonary bypass and aortic endo-occlusion times are currently required compared with those of standard coronary artery bypass grafting operations. We investigated whether longer operation times affect the myocardial enzyme release and the postoperative course.

Methods: From 2001 through 2006, 85 patients with a median age of 58 years (range, 31–76 years) underwent totally endoscopic coronary artery bypass grafting on the arrested heart by using the da Vinci telemanipulator and remote access perfusion through the femoral vessels (Estech or Heartport). The operations involved the left internal thoracic artery–left anterior descending coronary artery or diagonal branch (n = 74); right internal thoracic artery–right coronary artery (n = 2); double-vessel left internal thoracic artery–obtuse marginal branch/circumflex artery and right internal thoracic artery–left anterior descending coronary artery (n = 8); and double-vessel left internal thoracic artery–left anterior descending coronary artery and saphenous vein graft–right coronary artery (n = 1). Totally endoscopic coronary artery bypass grafting duration was 254 minutes (range, 178–710 minutes), cardiopulmonary bypass time was 114 minutes (range, 57–428 minutes), and aortic endo-occlusion time was 65 minutes (range, 28–230 minutes).

Results: The postoperative ventilation time was 8 hours (range, 0–278 hours), and the intensive care unit stay was 20 hours (range, 11–389 hours). The postoperative stay at our department was 6 days (range, 4–22 days), and we observed no hospital deaths in this series. Forty-five percent of the patients had an increased postoperative peak creatine kinase MB level, and 75% had an increased troponin T level. Postoperative peak creatine kinase MB levels significantly increased with totally endoscopic coronary artery bypass grafting duration (r = 0.588, P < .001), cardiopulmonary bypass time (r = 0.521, P < .001), and aortic endo-occlusion time (r = 0.400, P < .001) and translated into moderately prolonged intensive care unit stay (r = 0.432, P < .001) and ventilation time (r = 0.517, P < .001). Creatine kinase MB levels were not associated with sex, age, or EuroSCORE. The postoperative left ventricular ejection fraction did not differ significantly from the preoperative left ventricular ejection fraction.

Conclusions: Myocardial protection can be established in arrested heart totally endoscopic coronary artery bypass grafting operations. An influence of increased myocardial enzyme release on postoperative ventilation time and intensive care unit stay is detectable but does not translate into an early mortality or a decrease in left ventricular ejection fraction.

Myocardial enzyme release after standard coronary artery bypass grafting (CABG) occurs frequently and has been documented, especially for creatine kinase MB (CK-MB), troponin T, and troponin I.1,3 Totally endoscopic CABG (TECAB) is an evolving technology and is meanwhile an...
established procedure at our department of cardiac surgery.4–8 The advantage of TECAB is the avoidance of sternotomy or thoracotomy. Furthermore, hybrid revascularization concepts with endoscopic internal thoracic artery grafting and percutaneous coronary intervention can be realized.9,10 Earlier resumption of daily activities, such as housework, driving a car, or biking, has been demonstrated for TECAB operations compared with results from sternotomy operations.11

Our procedure of choice for arrested-heart TECAB (AHTECAB) is to use femoral access cardiopulmonary bypass (CPB) with balloon endo-occlusion of the ascending aorta and intermittent antegrade cardioplegia. CPB times and aortic endo-occlusion times (ie, myocardial ischemic times) are longer compared with those of conventional CABG techniques. Hence, we aimed to quantify myocardial enzyme release and to compare results with historical values of standard CABG operations from the literature. Furthermore, we wanted to find preoperative, operative, and postoperative factors that are associated with an increased myocardial enzyme release. Finally, we investigated whether the myocardial enzyme release impaired myocardial contractility.

Materials and Methods
The institutional review board approved the TECAB operations, and informed consent was obtained from all patients.

Surgical Technique
Eighty-five patients (EuroSCORE 1 [range, 0–5]) were intended to undergo AHTECAB with the da Vinci telemanipulator (Intuitive, Inc) through 3 left-sided (right-sided in 2 right internal thoracic artery [RITA]-right coronary artery [RCA] grafts) thoracic ports (1 camera port in the fifth and 2 working ports in the third and seventh intercostal spaces). Femoral access CPB was established with balloon endo-occlusion of the aorta for cardiac arrest, followed by antegrade cardioplegia (ESTECH from ESTECH, Inc; Heartport from Heartport, Inc), as described in previous publications.5–7

Patient demographics are listed in Table 1.

The operations performed were left internal thoracic artery (LITA)-left anterior descending coronary artery (LAD) or Dg (n = 74); RITA-RCA (n = 2); double-vessel LITA–OM/circumflex artery and RITA-LAD (n = 8); and double vessel LITA-LAD and saphenous vein graft–RCA (n = 1). Two LITA-LAD and saphenous vein graft–marginal branch CABGs were performed through a sternotomy after conversion was necessary. In a total of 85 intended AHTECABs, 13 (15.3%) conversions were necessary (n = 1 minithoracotomy and n = 12 sternotomies). In the second half of the series, the conversion rate decreased to 4 (9.3%) of 43.

The TECAB duration was 254 minutes (178–710 minutes), CPB time was 114 minutes (57–428 minutes), and aortic endo-occlusion time was 65 minutes (28–230 minutes).

Postoperatively, the myocardial enzymes were measured at the time the patient arrived at the intensive care unit (ICU), as well as 4 hours, 8 to 12 hours, and 32 to 36 hours postoperatively.

Postoperative peak levels of absolute CK-MB could be obtained from 77 of 85 patients. Postoperative peak levels of troponin T were obtained from 47 of 85 patients because troponin T levels were measured only during the second two thirds of the study.

Statistical Analysis
Statistical analysis was carried out with SPSS 12.0 software (SPSS, Inc). Continuous variables are given as medians (minimum-maximum). Categoric variables are given as percentages. The Pearson correlation coefficient (r) was calculated for continuous variables. The Mann–Whitney U test was applied for comparisons of enzyme levels with categoric factors. The Wilcoxon test for paired samples was used to compare preoperative and postoperative left ventricular ejection fraction (LVEF).
Results
In our series, 45% of the patients had increased peak CK-MB levels greater than the locally used cutoff of 25 U/L (Figure 1). The median postoperative peak CK-MB level was 23 U/L (range, 7–883 U/L). Seventy-five percent of the patients had increased peak troponin T levels of greater than the locally used cutoff of 0.039 μg/L. The median postoperative peak troponin T level was 0.088 μg/L (0.01-6.17 μg/L). Postoperative troponin T and CK-MB levels showed a high correlation ($P < .001$, $r = 0.974$).

Myocardial infarction, confirmed by means of electrocardiographic changes, was found in 2 (2.4%) patients. The first patient underwent TECAB without conversion and showed a postoperative peak CK-MB level of 137 U/L. An intraoperative occlusion of the posterolateral artery occurred, which was treated with immediate percutaneous coronary angioplasty and stent placement. The preoperative LVEF of this patient was 53%, and the postoperative LVEF was 54%. In the second patient a double-vessel TECAB was intended, but conversion was required, and the patient showed a postoperative peak CK-MB level of 883 U/L. The reason for the myocardial ischemia was a stenosis of a marginal branch, which had been underestimated in significance preoperatively and required additional bypass grafting through a sternotomy. The preoperative LVEF of this patient was 62%, and the postoperative LVEF was 52%.

An increased CPB time was associated with an increased postoperative peak CK-MB level ($P < .001$, $r = 0.521$; Figure 2). An increased aortic endo-occlusion time was associated with an increased postoperative peak CK-MB level as well ($P < .001$, $r = 0.400$; Figure 3).

The postoperative ventilation time was 8 hours (range, 0-278 hours). The postoperative peak CK-MB levels were positively correlated to the postoperative ventilation time ($P < .001$, $r = 0.517$; Figure 4).

The postoperative length of stay at the ICU was 20 hours (range, 11–389 hours). Increased postoperative peak CK-MB levels were associated with an increased postoperative ICU stay ($P < .001$, $r = 0.432$; Figure 5).

The postoperative length of stay at our department of cardiac surgery was 6 days (range, 4–22 days). Increased postoperative peak CK-MB levels were associated with an increased postoperative length of stay ($P = .015$, $r = 0.279$; Figure 6).

The CK-MB levels were not associated with sex, age, EuroSCORE, preoperative serum creatinine levels of 1.2 mg/dL or more, history of smoking, diabetes mellitus, hypercholesterolemia, hypertriglyceridemia, arterial hypertension, chronic obstructive pulmonary disease, peripheral vaso-
cular disease, history of myocardial infarction, history of percutaneous coronary intervention, history of stroke, or carotid artery stenosis.

Conversion to minithoracotomy or sternotomy increased CPB time to 256 minutes (range, 83–428 minutes) compared with 100 minutes (range, 57–273 minutes) in unconverted patients ($P < .001$). Conversion also increased aortic endo-occlusion time to 153 minutes (range, 37–230 minutes) compared with 63 minutes (range, 28–172 minutes) in unconverted patients ($P = .005$). The peak CK-MB level of converted patients was 33 U/L (range, 18–883 U/L) versus 23 U/L (range, 7–137 U/L) in unconverted patients.

Similar to CK-MB levels, the postoperative peak troponin T levels were associated with CPB time ($P < .001$, $r = 0.657$), aortic endo-occlusion time ($P < .001$, $r = 0.543$), postoperative ventilation time ($P < .001$, $r = 0.506$), postoperative length of stay at the ICU ($P = .002$, $r = 0.446$), and postoperative length of stay at our department of cardiac surgery ($P = .029$, $r = 0.322$). The postoperative peak troponin T levels were not significantly associated with sex, age, EuroSCORE, preoperative serum creatinine levels of 1.2 mg/dL or more, history of smoking, diabetes mellitus, hypercholesterolemia, hypertriglyceridemia, arterial hypertension, chronic obstructive pulmonary disease, peripheral vascular disease, history of myocardial infarction, history of percutaneous coronary intervention, history of stroke, or carotid artery stenosis. The peak troponin T level of converted patients was 0.751 μg/L (range, 0.104–6.170 μg/L) versus 0.07 μg/L (range, 0.001–0.322 μg/L) in unconverted patients ($P = .002$).

The postoperative LVEF could be obtained from 51 patients (by means of echocardiography or left-sided heart catheterization). The postoperative LVEF was 62% (range, 35%–75%) and did not differ significantly from preoperative values of 62% (range, 40%–86%; Figure 7).

There was no hospital death observed in this series.

Discussion

AHTECAB enables performing coronary surgery without sternotomy or thoracotomy. However, longer operative times need to be accepted to achieve this goal. In addition, a sophisticated femoral access perfusion system with balloon-carrying tips for aortic endo-occlusion and cardioplegic arrest is necessary. We found myocardial enzyme releases (CK-MB and troponin T) that are well comparable with those of standard CABG techniques.$^{1,2}$ Costa and colleagues$^1$ describe a postoperative abnormal CK-MB level increase in 61.9% of patients undergoing CABG in the Arterial Revascularization Therapies Study trial. By comparison, in our series only 45% of the patients had
increased (peak) CK-MB levels of greater than the locally used cutoff of 25 U/L. In 7.5% of standard, on-pump 1- to 2-vessel revascularizations, Gerola and associates\(^\text{12}\) found a postoperative myocardial infarction defined as a 5-fold (or more) increase of CK-MB levels. In our study 2.6% of the patients had peak CK-MB levels that reached greater than 5-fold of normal values. Thus, with our technique of AHTECAB, we can provide myocardial protection that meets the standards of current arrested-heart CABG through a sternotomy or that might even be better. Further direct comparison studies are necessary, however, to prove this.

We found a very reasonable association for aortic endo-oclusion time, which means myocardial ischemic time and peak CK-MB levels. The same correlation was found for CPB time and postoperative peak CK-MB levels. An interesting question was whether increased CK-MB levels translate into a longer postoperative ICU stay. Indeed, we found longer ventilation times and longer ICU stays to be associated with higher myocardial enzyme release. The increased CK-MB levels were even associated with a longer postoperative stay at our department. However, it has to be taken into consideration that this regression line was inclining very slowly, and after 6 days, the patients were generally discharged home.

We are aware that longer CPB times and aortic cross-clamp times are necessary in TECAB compared with standard CABG. We regard this as the payoff necessary to avoid sternotomy or thoracotomy. In 15% of the patients, however, a conversion to a larger incision was necessary; in the second half of this series, the conversion rate decreased to less than 10%. The conversion increased both CPB time and aortic endo-oclusion time and resulted in a significantly increased postoperative peak troponin T level but a nonsignificant increase in CK-MB level.

The most important question was of course the effect on clinical outcome and myocardial pump function. A zero hospital mortality in this series demonstrates the safe conduct of this demanding procedure. The absence of a loss of LVEF shows that the myocardial contractile function is preserved, despite postoperative myocardial enzyme releases. Furthermore, most of the patients in our series had normal preoperative LVEF values (with a median preoperative LVEF of 63%). Thus an increase of LVEF postoperatively could not be expected.

We conclude that myocardial protection can be achieved in AHTECAB operations. An influence of increased myocardial enzyme release on postoperative ventilation time and ICU stay is detectable. This, however, does not translate into early mortality or a decrease in LVEF.
Figure 7. Comparison between preoperative and postoperative left ventricular ejection fraction (LVEF) in patients who underwent totally endoscopic coronary artery bypass grafting on the arrested heart with femoral access cardiopulmonary bypass and aortic endo-occlusion. n.s., not significant.

References


