Echocardiographic findings in minimally invasive coronary artery bypass grafting: The role of intrathoracic CO_2 – insufflation and single lung ventilation

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ABSTRACT

Background: Current options for surgical treatment of coronary single vessel disease range from beating heart procedure without cardiopulmonary bypass via a mini thoracotomy (MIDCAB) to totally endoscopic robot-assisted techniques (TECAB) with cardiopulmonary bypass. Both procedures are associated with considerable stress even before revascularization such as single lung ventilation, temporary coronary occlusion, Luxatio cordis, intrathoracic CO_2 insufflation and extended bypass and operating time.

The aim of the this study was to document the extent of intraoperative segmental wall motion abnormalities (SWMA) by echocardiography, and to identify variables affecting SWMA.

Materials and Methods: Forty patients with coronary single vessel disease were included in the study. 16 patients were operated with the MIDCAB technique, and 24 patients underwent TECAB. In both groups of patients sequential transesophageal echocardiograms (2D-loops) were recorded and analyzed. Hemodynamic and electrocardiographic data as well as oxygenation parameters were acquired during echo exams. In both groups of patients mild, but significant perioperative SWMA were identified, which increased in the course of the operation. These SWMA were more pronounced in the TECAB as compared to the MIDCAB group. Independent of operating time these changes disappeared completely until the ends of surgery. Significant hemodynamic or elektrocardiographic modifications were not observed.

Conclusion: The application of minimally invasive techniques for the surgical treatment of coronary single vessel disease is associated with significant perioperative SWMA. The more pronounced SWMA in the TECAB group may be a consequence of intrathoracic CO_2-insufflation. Both techniques can be applied without significant myocardial ischemia, provided that appropriate intraoperative monitoring is performed, and intrathoracic CO_2 pressure in TECAB patients is limited.

INTRODUCTION

The surgical treatment of coronary artery disease has changed towards less invasive procedures in recent years. These new techniques are essentially based on two rationales: reduced surgical trauma by limited incisions, and beating heart techniques without the use of cardiopulmobnary bypass (CPB). Grafting of the internal thoracic artery (ITA) to treat isolated left anterior descending (LAD) stenosis via a small, left anterior thoracotomy (Minimally invasive direct vision coronary artery bypass (MIDCAB)) without CPB is a safe alternative to standard CABG with sternotomy and CPB [Calafiore 1998]. The most recent development is a robot-assisted totally endoscopic technique (totally endoscopic coronary artery bypass; (TECAB)) [Damiano 2000, Falk 2000]. In contrast to the MIDCAB technique the anastomosis is performed on CPB in TECAB operations.

Both procedures require single lung ventilation for ITA cutdown and anastomosis in order to allow adequate exposure. For TECAB operations additional carbon dioxide (CO_2) insufflation is necessary, to optimize visualizytion and instrument movements [Kessler 2000].

A number of studies described hemodynamic compromise during enhanced intrathoracic pressure by CO_2 insufflation or hypoxia from SLV [Ohtsuka 1999, Hill 1996], but to date a combination of both has not been assessed with regard to myocardial function. The aim of the present study is to elucidate the impact of these minimally-invasive surgical techniques on myocardial function.

MATERIALS AND METHODS

After approval of the institutional ethical committee and informed written consent 40 patients with symptomatic coronary single vessel disease of the LAD underwent coronary artery bypass grafting. 16 patients were operated on the beating heart with the MIDCAB technique. In 24 patients totally endoscopic techniques (TECAB) were performed on CPB with the telemanipulation system DaVinci (Intuitive Surgical, Mountain View, CA), and the Port Access system (Heartport, Redwood City, CA)

All patients received intramuscular premedication with 0.06 mg Fentanyl and 3 mg Droperidol 30 min prior to the induction of anesthesia. On arrival in the preoperative holding area intravenous access, five lead surface electrocardiogram (ECG) and noninvasive blood pressure monitoring (NIBP) were established. In addition, direct arterial pressure monitoring (IBP) was instituted into the left radial artery.

After induction of anesthesia with sufentanil (25 µg), etomidate (0.2 mg/kg) and succinylcholine (1 mg/kg), the patients were intubated with a left endobronchial 37-41 F double-lumen tube (Kendall, Neustadt, Germany). Correct position of the tube was verified by both auscultation and fiberoptic bronchoscopy. For TECAB procedures, a second arterial line was introduced into the right radial artery, once the patient was anesthetized. In addition, a pulmonary vent catheter for cardiopulmonary bypass with Port-Access technique was inserted via the right internal jugular vein and positioned by transesophageal echocardiographic guidance. Pulse oxymetry, ECG, IBP, and central venous pressure (CVP) were recorded continuously regardless of surgical technique.

Anesthesia was maintained with an endtidal concentration of 1.1 to 1.4 vol.% enflurane with air in oxygen (FiO_2 0.5). The respiratory rate was set to 10 breaths per minute, and tidal volume was set to 8-10 ml/kg and adjusted by means of repeated arterial blood gas analyses to achieve $PaCO_2$ and pH within normal ranges of 32 to 45 mmHg and 7.34 to 7.47, respectively. During the period of SLV, initial respiratory rate, tidal volume and inspired oxygen concentration were maintained unless the arterial oxygen saturation as measured by pulse oximetry dropped below 92%, or if arterial blood gas analyses performed in short intervals throughout SLV showed PaO_2 less than 100 mmHg. If one or both conditions applied, the fraction of inspired oxygen was increased to 100%, and continuous positive airway pressure (CPAP) of oxygen pressure was added to the non-ventilated lung. The next step was to add positive endexpiratory pressure (PEEP) to the dependent lung. Both CPAP and PEEP were incrementally increased to a maximum of 10 cm H_2O if necessary. Similar to double-lung ventilation, respiratory rates and tidal volumes were adjusted to achieve pH as described above and $PaCO_2$ around 40 mmHg.

During cardiopulmonary bypass (CPB) in TECAB patients, anesthesia was maintained by continuous administration of 4 mg/kg per hour of propofol, supplemented by pancuronium for muscle relaxation. In addition, 25 µg sufentanil were administrated for analgesia whenever deemed necessary. All patients received continuous infusions of dopamine (3 µg/kg/min) and diltiazem (3 mg/h).

Surgical technique MIDCAB

A 7-8 cm anterolateral mini thoracotomy was perfgormed in the 4th intercostal space to allow preparation of the left ITA, and consecutive anastomosis to the LAD on the beting heart during single lung ventilation (SLV). Similar to TECAB operations double lung ventilation (DLV) was resumed after proper hemostasis.

Surgical technique TECAB

The surgical procedure was performed by the use of the „Da Vinci“ computer enhanced telemanipulator system through a leftsided transthoracic approach. After institution of SLV and carbon dioxide insufflation with positive pressure of 10-12 mmHg, the left internal thoracic artery was dissected, and than CPB was instituted via the femoral artery and vein. ITA harvesting was finished after initiation of CPB. After occlusion of the ascending aorta with an endoaortic balloon catheter and application of antegrade cardioplegia, the left ITA was grafted onto the LAD. Weaning from CPB was achieved under SLV after extensive reperfusion and rewarming. Double-lung ventilation was reinstituted after surgical hemostasis and carbon dioxide deflation.

In every instance, the double lumen tube was replaced by a single lumen tube at the end of the operation, and the patient was transferred to the intensive care unit (ICU).

Data sampling

To evaluate PaO_2. $PaCO_2$, and serum lactate levels, arterial blood gas analyses were performed immediately prior to incision during double-lung ventilation as a baseline value (Baseline), 30, 90, and 120 min after institution of SLV (SLV +30 min, SLV +90 min., SLV +120 min) prior to initiation of CBP, and 15 min after double-lung ventilation was restarted after weaning from CPB (End) (Table 1). In every instance, the samples were immediately analyzed in a laboratory next to the operating room (ABL3, Acid Base Laboratory/Hemoxymeter, Radiometer, Copenhagen, Denmark). At the same time points, intrathoracic CO_2 pressure, and automated ST-segment analysis for leads I, II and V_5 were recorded. An ST-segment alteration of ≥1 mm (0.1 mV) from baseline was considered evidence of ischemia. CK and CK-MB levels were determined preoperatively and 12 hours after surgery.

Transesophageal echocardiography

All examinations were performed in a 30° right supine position. A Vingmed System Five echocardiography device with a multiplane 5-7 MHz transesophageal echo (TEE) probe was used (GE Vingmed, Horten, Norway). Device settings were as follows: frequency 6.7 MHz, power 4 dB, depth 14 cm, frame rate 70-80/min. A transgastric transversal view of the left and right ventricles was chosen at the level of the left ventricular papillary muscles. An ECG triggered cine-loop of 3 cardiac cycles of each ventricle was acquired at the above mentioned intervals, and directly stored on the image processing system (Echo PAC v. 6.1, Vingmed, Horten Norway) for off-line analysis. During data acquisition, the patient was disconnected from ventilation in end expiration. Analysis of segmental wall motion aberation (SWMA) was carried out by dividing the left ventricle in 6 segments according to the guidelines of the American Society of Echocardiography, and the Society of Cardiovascular Anesthesiologists [Shanewise 1999]. As the septal segments were considered as totally left ventricular structures, the right ventricle was divided into 4 segments (anterior, lateral, posterior, inferior).

Right and left ventricular ejection fraction (RVEF, LVEF) and fractional shortening (RVFS, LVFS) were also registered from the M-mode loop. All exams were performed by two independent equally experienced echocardiographers. The second echocardiographer had no information regarding hemodynamic or clinical data of the patients. To quantify interobserver variability, 20 randomly chosen TEE-loops were analyzed by the two observers. All 120 segments were included. The concordance of regional wall motion analysis was 90%. A difference of 2 or more points per segment was defined as discrepancy. Interobserver variability in quantifying segmental wall motion alterations (SWMA) was about 5%.

Statistics

All data are presented as mean _ standard deviation or median and range when appropriate. Calculation and data analysis were performed using a statistical package (GraphPad InStat 3.1, GraphPad Software, San Diego, CA). Statistical significance was determined with either Friedman test and Bonferroni post test, Wilcoxon-Mann-Whitney test, or Fisher’s Exact test. Differences were considered to be statistically significant if *P* was less than 0.05.

RESULTS

Forty patients with coronary single vessel disease of the LAD underwent surgical revascularisation with an ITA graft to the LAD. The surgeon decided on the use of an open approach via a left anterolateral thoracotomy on the beating heart (MIDCAB, n=16) or the completely endoscopic technique with the use of CPB (TECAB, n=24). The operative technique was was not changed in any of these patients.

Regarding demographic data no statistically significant differences were present between groups. No patient showed segmental wall motion abnormalities (SWMA) in preoperative fluoroscopy.

Oxygenation, SLV and ECG

Upon initiation of SLV the PaO_2 markedly declined in both groups, which persisted almost throughout SLV and recovered to baseline after resumption of DLV. While $PaCO_2$ showed minor changes in the MIDCAB group, TECAB patients experienced a significant increase in $PaCO_2$ during SLV with continuous intrathoracic CO_2-Pressure of 10 mmHg (Table 2). In both groups automatic ST segment analysis (I, II and V5) did not indicate significant ischemia during the study period.

The preoperative CK level was 32.2 ± 4.7 (MIDCAB) or 29.4 ± 5.8 U/l respectively (TECAB, P n.s.), and increased to 142.8 ± 58.0 (MIDCAB, $P<0.0001$ vs. preoperative CK) or 1.228.5 ± 1.020.5 U/l (TECAB, $p<0.0001$ vs. preoperative CK, $P=0.0001$ vs. MIDCAB) in the postoperative period. Preoperativ CK-MB was not assessed because of low CK concentrations < 100 U/l. Postoperative CK-MB max. amounted to 5.4 ± 1.3 (MIDCAB) or 31.2 ± 26.9 U/l (TECAB, $P<0.05$), and thus remained below 10% of total CK. Serum lactate was not elevated during SLV and prior to CPB (MIDCAB baseline level: 9.5 ± 3.7 mg/dl; TECAB baseline level: 11.4 ± 2.7 mg/dl; *P* n.s.), and increased up to 11.1 ± 4.6 (MIDCAB, *P* n.s. vs. Baseline) and 32.3 ± 26.7 mg/dl (TECAB, P=0.0106 vs. Baseline; *P*=0.0033 vs. MIDCAB) after revascularization and weaning from CPB in the TECAB group, respectively.

TEE findings

Left and right ventricular function was assessed in 144 (TECAB) or 96 data sets (MIDCAB). In the MIDCAB group 10 (10.4%) of 96 both left and right ventricles 10 out of 96 data sets (10.4%) showed either an intraoperative increase of scores by ≥2 points compared to baseline or a scores of ≥4 points. In TECAB patients left ventricular scores changed in 3 (2.1%) out of 144 data sets (P < 0,05 vs. MIDCAB) but right ventricular scores increased in 24 (16.7%) out of 144 samples (P < 0,05 vs. MIDCAB).

Left ventricular Function

During both TECAB and MIDCAB operations left ventricular ejection fraction (LVEF) and fractional shortening (LVFS) remained unchanged. In the segmental wall motion analysis a significant increase of SWMA during SLV was observed in 4 segments (inferior, septal, anteroseptal and anterior), as opposed to MIDCAB interventions where SWMA increased only in 2 segments (anteroseptal and posterior). When comparing both groups at 90 and 120 minutes SWMA in the septal segment was significantly more pronounced in TECAB versus MIDCAB cases (Table 3).

Right ventricular function

A statistically significant increase of both right ventricular EF, and FS could be observed during MIDCAB operations, while these changes were absent in the TECAB group. However, TECAB patients demonstrated increased SWMA in all but the anterior segments. This significant increase of SWMA was observed in MIDCAB patients as well and included anterior and inferior segments of the right ventricle. In several segments of the left ventricle TECAB patients exhibited more pronounced SWMA at 90 (inferior, septal and anterior segments) and 120 min. (inferior and posterior segments) (Table 4).

Except for continuous low-dose dopamine infusion, no patient needed further inotropic or vasopressor support due to hemodynamic instability during the operation. The median time of assisted ventilation after surgery was 130 (MIDCAB) and 480 minutes (TECAB; P=0.0014).

The duration of the individual phases of the operation are represented in Table 5.

DISCUSSION

In recent years a multitude of minimally invasive surgical techniques have evolved for coronary artery bypass grafting, that are based on two major strategies: One strategy aims to avoid the inflammatory and embolic sequelae of CPB by operating on the beating heart [Ascione 2000, Gu 1999, Matata 2000], on the other hand, the limitation of surgical access to reduce operative trauma has been pursued. Currently, coronary artery surgery is usually performed via a median sternotomy or a left anterolateral mini thoracotomy (MIDCAB) [Calafiore 1998, Repossini 2000]. Totally endoscopic robot-assisted myocardial revascularization, (TECAB), that offers the advantage of only minimal surgical trauma, has been performed on CPB with the help of the Port Access system in the vast majority of cases. This procedure has been limited mostly to the revascularization of the LAD and diagonal branches in the early experience [Falk 2000]. Therefore, MIDCAB and TECAB techniques are competing minimally invasive procedures for the revascularization of the anterior wall.

Both procedures expose the coronary artery patient to various risk and stress factors that add up to the actual surgical procedure. Both techniques are associated with reduced oxygenation [Banoub 1998, Lischke 1998] due to SLV, while TECAB procedures include the pathogenicity of CPB [Ascione 2000, Diegeler 2000, Struber 1999], the potential complications of the Port Access system [Wimmer-Greinecker 1999, the intrathoracic CO_2 insufflation [Hill 1996, Wolfer 1994] and currently substantially longer operation times [Chaney 2000]. MIDCAB interventions may be associated with potential intraoperative myocardial ischemia in the context of temporary occlusion of the target vessel, and the positioning of the heart may lead to hemodynamic impairment and rhythm disturbances [Mathieson 2000].

The development of SWMA has been widely accepted as a sign of myocardial ischemia [Elhendy 2000, Feigenbaum 1999, Hogue 1997]. SWMA analysis can be employed für perioperative ischemia monitoring in patients at coronary risk. The accuracy of SWMA is based on interdisciplinary guidelines that allow exact interpretation of the extent of SWMA as an indirect scale of ischemia [Shanewise 1999].

Based on biventricular SWMA, the present study demonstrates, that new SWMA changes develop in both groups after onset of SLV, and before the onset of ECC.

In the course of surgery the SWMA increased significantly more in TECAB versus MIDCAB cases. In the TECAB group, the onset of SLV and intrathoracic CO_2- insufflations was associated with SWMA in 4 out of 6 segments of the left ventricle and 5 out of 6 segments of the right ventricle. In MIDCAB patients this was noted only in 2 out of 6 (LV) and 4 out of 6 segments (RV) respectively. The extent of the SWMA was more pronounced in TECAB patients in the septal segments of both ventricles as well as in the anterior and inferior segments of the right ventricle.

The SWMA before CPB may be associated with the pathophysiology of SLV, CO_2-Insufflation, reduced pO_2, temporary coronary occlusion and the positioning of the heart [Kessler 2000].

Both groups are exposed to the direct sequelae of SLV including pulmonary right to left shunt, altered ventilation conditions, and increased pulmonary vascular resistance [Zollinger 1999]. The less pronounced left ventricular SWMA in the MIDCAB group, advocate a significant role of CO_2 insufflation in the pathogenesis of SWMA. Since the SWMA completely regressed after recvascularization, we consider intrathoracic CO_2 insufflation with a pressure of 10 mmHg safe and tolerable in these patients. Since SWMA were observed immediately after the onset of SLV in the MIDCAB group, i.e. before the heart was positioned, it is unlikely that exposure of the heart or the use of stabilizers may affect cardiac output. Furthermore, only less pronounced hemodynamic changes have been reported during surgical exposure for the revascularisation of the LAD [Mathieson 2000]. Reduced PaO_2 during SLV cannot be absolutely ruled out as a potential cause of SWMA, even though an other group [Byhahn 2000] did not observe changes in myocardial metabolism in this situation.

The SWMA in the present study represent only mild alterations. In addition, the only significant changes in TECAB patients were observed before ECC and were not persistend in the more important post ECC-period as found in other studies [Leung 1989, London 1990] This may be due to different patient populations as Leung and coworkers examined patients with multivessel disease and unstable angina whereas the TECAB and MIDCAB procedures were performed in patients in single vessel disease.

Since we did not observe persisting SWMA even in the TECAB group after CPB, we conclude from the fact that in the current cohort examined neither the extended operating times nor CPB had an influence on direct postoperative outcome.

There was no change in biventricular EF and FS in patients who underwent TECAB. In MIDCAB patients right ventricular EF and FS even iincreased significantly during the operation when SWMA became more and more apparent and ventricular filling decreased due to surgical exposure. This is consistend with findings of other studies carried out on patients undergoing conventional CABG. We therefore agree with other investigators that EF and FS as well as filling pressures do not adequately reflect acute myocardial ischemia [London 1990].

Although we observed significant SWMA in both groups of patients, these were not accompanied by specific ST segment changes. This is compatible with studies demonstrating that, similar to hemodynamic changes, these ST segment changes rarely correlate with intraoperative SWMA [Leung 1998, Leung 1990] and therefore may not reflect mild myocardial ischemia. Serum lactate concentration as evidence of tissue hypoxia or ischemia remained stable despite occasional reduced PaO_2 during SLV. They increased only in TECAB patients after weaning from CPB. 12 hours after surgery, a significant increase of the CK was observed in both groups that was not accompagnied by an marked increase in CK-MB which allows to exclude relevant myocardial damage. The excessive rise in CK after TECAB procedures is probably caused by limb ischemia due to femoral cannulation for CPB with the Port-Access-system [Glower 1999].

Our data show, that MIDCAB and TECAB procedures are accompanied by significant SWMA before myocardial revascularization. SWMA rapidly return to baseline after revascularization and did neither cause persistent hemodynamic instability nor required inotropic or vasopressor support, the perioperative patient risk can be estimated minor in both methods. Nevertheless, the right ventricular impact of intrathoracic CO_2 pressure on SWMA in TECAB-procedures is more important than the mechanical exposure of the LAD in the MIDCAB approach. However, further studies are needed to determine whether these data can be adopted to patients with multivessel coronary artery disease undergoing minimally invasive cardiac surgery.

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Table 1. Data collection in correlation to intraoperative stages in the MIDCAB and the TECAB-group

	DLV base	**SLV 30**	**SLV 90**	**SLV 120**	**DLV end**
MIDCAB	Prior to incision	IMA-Preparation	Start anastomosis	End anastomosis	After suture
TECAB	Proir to incision	IMA-Preparation, prior to ECC	IMA-Preparation prior to ECC	IMA-Preparation prior to ECC	After suture

IMA : internal mammary artery

ECC: extracorporeal circulation

Table 2. Oxigenation and intrathoracic CO_2-pressure

	PaO_2 (mmHg)		$PaCO_2$ (mmHg)		CO_2 - pressure (mmHg)	
	MIDCAB	TECAB	MIDCAB	TECAB	MIDCAB	TECAB
DLV base	210 ± 100	209 ± 96	41.1 ± 4.6	38.7 ± 6.3	-	-
SLV +30 min	91 ± 13	109 ± 64	39.7 ± 5.3	41.1 ± 5.3	-	9.3 ± 3.1
SLV +90 min	99 ± 23	107 ± 46	38.1 ± 3.7 *	45.1 ± 8.9	-	10.6 ± 3.4
SLV +120 min	107 ± 31	108 ± 46	37.7 ± 4.1 *	46.9 ± 10.0	-	9.7 ± 4.9
DLV end	244 ± 107	216 ± 87	37.4 ± 2.7 *	41.7 ± 5.8	-	-

: *P*<0,05 vs. DLV base

*: *P*<0,05 vs. TECAB

Table 3. EF, fractional shortening and SWMA of the left ventricle

	DLV base		SLV +30 min		SLV +90 min		SLV +120 min		DLV end	
	MIDCAB	TECAB	MIDCAB	TECAB	MIDCAB	TECAB	MIDCAB	TECAB	MIDCAB	TECAB
EF (%)	81.0 ± 13.7	81.9 ± 12.4	86.1 ± 10.4	85.4 ± 9.9	83.8 ± 12.3	86.6 ± 9.3	71.4 ± 17.6	84.6 ± 12.1	80.4 ± 8.8	85.8 ± 12.4
FS	45.5 ± 13.4	47,0 ± 14.7	53.9 ± 18.7	49.9 ± 12.4	50.8 ± 16.7	51.6 ± 12.9	42.4 ± 11.4	49.7 ± 13.3	42.9 ± 10.2	52.7 ± 16.7
Posterior*	1.14 ± 0.36	1,20 ± 0.56	1.57 ± 1.09	1.13 ± 0.51	1.14 ± 0.36	1.33 ± 0.62	1.02 ± 0.04*	1.27 ± 0.59	1.05 ± 0.05*	1.20 ± 0.56
Inferior #	1.14 ± 0.36	1,13 ± 0.35	1.57 ± 1,09	1.20 ± 0.41	1.42 ± 1.09	1.60 ± 0.51#	1.14 ± 0.36	1.53 ± 0.52#	1.05 ± 0.05	1.13 ± 0.35
Septal #	1.14 ± 0.36	1,06 ± 0.26	1.57 ± 1.09	1.47 ± 0.52#	1.14 ± 0.36	1.73 ± 0.46#	1.14 ± 0.36	1.73 ± 0.59#	1.05 ± 0.05	1.20 ± 0.41
Anteroseptal*#	1.05 ± 0.05	1,33 ± 0.49	1.57 ± 0.51*	1.60 ± 0.51#	1.43 ± 0.51*	1.80 ± 0.41#	1.42 ± 0.51*	1.73 ± 0.59#	1.05 ± 0.05	1.33 ± 0.49
Anterior #	1.05 ± 0.05	1,20 ± 0.41	1.28 ± 0.47	1.27 ± 0.46	1.14 ± 0.36	1.60 ± 0.63#	1.14 ± 0.36	1.33 ± 0.49	1.05 ± 0.05	1.07 ± 0.26
Lateral	1.05 ± 0.05	1,07 ± 0.26	1.14 ± 0.36	1.05 ± 0.05	1.05 ± 0.05	1.07 ± 0.26	1.05 ± 0.05	1.05 ± 0.05	1.05 ± 0.05	1.05 ± 0.05

M ± SD

*: $P<0,05$ $\text{SWMA}_{\text{MIDCAB}}$ vs. base; #: $P<0,05$ $\text{SWMA}_{\text{TECAB}}$ vs.base; : $P<0,05$ $\text{SWMA}_{\text{MIDCAB}}$ vs. $\text{SWMA}_{\text{TECAB}}$

Table 4. EF, fractional shortening and SWMA of the right ventricle

	DLV base		**SLV +30 min**		**SLV +90 min**		**SLV +120 min**		**DLV end**	
	MIDCAB	TECAB	MIDCAB	TECAB	MIDCAB	TECAB	MIDCAB	TECAB	MIDCAB	TECAB
EF (%) *	56.4 ± 20.2	68.8 ± 13.8	70.1 ± 16,0*	67.9 ± 10.5	71.3 ± 13,6*	77.3 ± 11.6	65.5 ± 17.3*	66.9 ± 16.9	66.6 ± 16.9*	75.0 ± 14.0
FS *	26.5 ± 14.2	33.9 ± 11.8	35.1 ± 13,0	32.6 ± 8.4	35.5 ± 11,2	40.7 ± 10.7	32.8 ± 14.4	32.3 ± 13.9	33.1 ± 13.8*	39.5 ± 13.1
Posterior #	1.29 ± 0.47	1.47 ± 0.52	1.42 ± 0,51	1.93 ± 0.96#	1.57 ± 0,51	2.13 ± 0.92#	1.28 ± 0.47	1.93 ± 0.88#	1.14 ± 0.36	1.27 ± 0.46
Inferior * #	1.29 ± 0.47	1.40 ± 0.51	1.43 ± 0,76*	1,60 ± 0.51	1.43 ± 0,51*	2.13 ± 0.83#	1.29 ± 0.47	1.93 ± 0.88#	1.14 ± 0.36*	1.27 ± 0.59
Anterior *#	1.14 ± 0.36	1.07 ± 0.26	1.57 ± 1,09*	1.47 ± 0.52#	1.14 ± 0,36	1.73 ± 0.46#	1.14 ± 0.36	1.73 ± 0.59#	1.05 ± 0.05*	1.20 ± 0.41
Lateral #	1.05 ± 0.05	1.13 ± 0.35	1.29 ± 0,47	1.53 ± 1.06	1.29 ± 0,47	1.60 ± 0.83	1.29 ± 0.47	1.53 ± 0.64	1.14 ± 0.36	1.07 ± 0.26

M ± SD

*: *P*<0,05 $\text{SWMA}_{\text{MIDCAB}}$ vs. base; #: *P*<0,05 $\text{SWMA}_{\text{TECAB}}$ vs. base; : *P*<0,05 SWMA $_{\text{MIDCAB}}$ vs. $\text{SWMA}_{\text{TECAB}}$

Table 5. General Data

	MIDCAB (n=16)	TECAB (n=24)	Statistical significance
Anaesthesia (min.)	260 ± 65	582 ± 132	*P*<0.0001
Preparation (min.)	30 ± 8	63 ± 22	*P*<0.0001
Incision - closure (min.)	160 ± 43	408 ± 112	*P*<0.0001
Single lung ventilation (min.)	141 ± 28	181 ± 54	*P*=0.0339
ECC (min.)		192 ± 64	
Clamping (min.)		93 ± 34	
Mechanical ventilation (h)	2,2 (1,0 — 12,0)	8 (4 — 1.260)	*P*=0.0014

M ± SD or.median und range