Haemodynamic response to thoracoscopy and thoracotomy

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Short title:

Haemodynamics in thoracoscopy

Summary

Operations in the pleural cavity are connected with circulatory changes in pulmonary circulation and thus general changes in haemodynamics as well. As far it is known, these changes are influenced by position of the patient's body on the operation table and by the introduction of artificial pneumothorax. Thoracoscopy is an advanced surgical approach in thoracic surgery but its haemodynamic effect is not known up to date. The aim of the presented study was therefore to compare the haemodynamic response in operations carried out by open (thoracotomy - TT) and closed (thoracoscopy - TS) surgical approach. 38 patients have been monitored throughout the operation – from introduction to anaesthesia to completing the surgery. Monitored parameters: systolic blood pressure (BPs), diastolic blood pressure (BPd), O_2 saturation (SaO_2), systolic blood pressure in pulmonary artery (BPPAs), diastolic blood pressure in pulmonary artery (BPPAd), wedge pressure (P_W), central venous pressure in right atrium (CVP), cardiac output (CO) and total peripheral resistance (TPR). No significant difference has been found in haemodynamic response between the groups TT and TS. Significant changes were detected in the courses of haemodynamic parameters during the whole surgical procedure in both technical approaches. The most prominent changes were found after the position of patients was changed to the hip position (significantly decreased BPs, BPd, MAP, SaO_2 and BPPAs) and 5 minutes after the pneumothorax was established (restoration of the cardiac output to that initial value and significant decrease of the TPR). It can be concluded that the TS causes almost identical haemodynamic changes like the TT.

Key words

Haemodynamics, pulmonary circulation, thoracoscopy, thoracotomy

Introduction

There are repeated reports about haemodynamic changes during the operation in pleural cavity (Hill *et al.* 1996, Jones *et al.* 1993, Ohtsuka *et al.* 1999, Polis *et al.* 2002, Vassiliades 2002, Ohtsuka *et al.* 2001). Low-pressure pulmonary circulation may serve as a blood reservoir due to its substantive capacity. A short-term increase in blood volume in pulmonary circulation causes dilatation of pulmonary vessels, but the blood pressure in this region increases only moderately. Thus the pulmonary circulation may be engaged as a quasi-buffer system during short-term vacillation in blood volume. First changes in pulmonary circulation occur already in the introduction to anaesthesia, when the patient is positioned on the back and anaesthetics are administered (Ohtsuka *et al.* 1999, Brock *et al.* 2000, Zobel *et al.* 1994, Forlanini 1988).

Further haemodynamic changes occur during the hip placement (Brock *et al.* 2000, Forlanini 1988). In this position, and after the surgical table is repositioned, the mean blood pressure increases in vessels below the pulmonary valve due to increment of hydrostatic pressure while in regions above the valve the pressure simultaneously diminishes. The pressure might be even negative in comparison to a pressure in alveoli in these regions. It logically results in decreased alveolar perfusion as the alveolar pressure compresses the capillaries. In extreme situations, the partial respiratory gas pressures could be altered in well ventilated but non-perfused alveoli (Ohtsuka *et al.* 2001, Brock *et al.* 2000, McFaden and Robbins 1998, Mack 1993).

Next, the situation is changed by accomplishing of the artificial pneumothorax as partial gas pressures in the alveoli of non-ventilated but well perfused lung are starting to change. Partial pressures of O_2 decrease, while partial pressures of CO_2 increase. Ventilation changes in pneumothorax influence ventilation/perfusion ratio. Functional perfusion shunt occurs in non-ventilated lung. The heamodynamics is also influenced by metabolic functions of lungs (Vassiliades 2002, McFaden and Robbins 1998, Mack 1993, Kvasnicka *et al.* 1998, Vokurka 2003, Čiernik and Vokurka 2006).

As mentioned above, changes in haemodynamics caused by a surgery in the pleural cavity are well known. There is, however, lack of information on the haemodynamics during thoracoscopic procedures and that is why this study was designed to clear up if any difference in haemodynamic response between two groups of patients occurs – one group operated via posterolateral thoracotomy, the other one just thoracoscopied (Pafko *et al.* 1998).

Methods and patients

In total, 38 patients have been involved in prospective non randomized study - 19 undergoing thoracotomy (TT), 19 thoracoscopy (TS) (Table 1). All of them underwent a surgery in the 1st Surgical Department of General Teaching Hospital and the First Faculty of Medicine, Charles University, Prague. The study was approved by the ethic committee; all patients signed an informed consent.

In order to obtain homogenous set of patients only those with NYHA I or II were included, the exclusion criteria were significant valve defects, left ventricle failure, primary or secondary pulmonary hypertension.

Pulmonary artery catheter (Corodyn P1, B. Braum) was placed 2 to 16 hours prior to the operation under x-ray control in the non-operated lung. Before the first measurement, blood clotting was prevented with continuously administered heparin. Deep vein thrombosis was prevented with low-molecular heparin in routine prophylactic dose, for the first time administered after the catheter was inserted. In order to gain the most accurate record, all the measurements were repeated three times in two-minute intervals.

All patients of both groups underwent the surgery in a total anaesthesia. For all of them a selective lung ventilation was used with a possibility to ventilate only one lung. Patients who were planned for toracotomic procedure received an epidural analgesic catheter immediately in preoperative period.

In both groups of patients a wide range of operating procedures was performed. Namely, the procedures included: 1) in the TS group: simple diagnostic thoracoscopies, and pleurodeses for pulmonary emphysema and spontaneous pneumothorax, 2) in the TT group: non-anatomic lung resections, resections of bullae, anatomic lung resections (lobectomy). The patients could not be randomized for ethic reasons as the surgical approach (TS or TT) had to be chosen according to a type of surgical procedure.

The 11 measurements were accomplished in an operating theatre in the both groups in the following pattern:

1st measurement: in the position on the back before any anaesthesia was administered,

2nd measurement: in the same position after the introduction to anaesthesia and intubation (both lungs were ventilated),

3rd measurement: in the same position (only the non-operated lung ventilated),

4th measurement: in the hip position (the patient lies with the underpinned chest on an operating table on a contralateral side to that where an operation is conducted),

5th measurement: in the same position just after the pneumothorax was established,

6th measurement: in the same position 5 minutes after the pneumothorax was established,

7th to 10th measurements: in the same position, each measurement performed 15 minutes after the previous,

11th measurement: in the same position after the operated lung was unfolded and both lungs were ventilated again.

Following parameters were recorded:

systolic blood pressure (BPs), diastolic blood pressure (BPd) and mean arterial pressure (MAP) – all of them by the invasive approach (Arteriofix B. Braun),

O_2 saturation (SaO_2) – pulse oximetry (RAD-5, Masimo corp. USA),

systolic blood pressure in pulmonary artery (BPPAs), diastolic blood pressure in pulmonary artery (BPPAd), wedge pressure (P_W), central venous pressure in right atrium (CVP) – all of them invasive approach (Corodyn P1, B. Braum),

cardiac output (CO) – ultrasonography, esophageal probe (PEF-510MA, Nemio SSA-550A Toshiba Medical syst.).

Total peripheral resistance (TPR) was calculated using the formula TPR = MAP / CO.

Each final value was computed as the arithmetic mean from the three measured values as all the measurements were repeated three times (as mentioned above).

For a statistic evaluation the T-test for 2 independent statistical samples was used.

Results

1. The courses of haemodynamic parameters during the whole surgical procedure (Figures 1, 2, 3 and 4):

There are mostly just subtle changes in the low-pressure circulation: We have found only significant decrease of the BPPAs after the position of patients was changed to the hip position and increase of both BPPAs and BPPAd after the pneumothorax was established.

While the low-pressure circulation is relatively stable during the whole surgical procedure there are dramatic changes in the high-pressure circulation: We have found significant decrease in the blood pressure parameters (BPs, BPd and MAP) after the position of patients was changed to the hip position followed by immediate increase to the initial values. Next decrease was detected 20 minutes after establishing of the pneumothorax. The CO has decreased after anaesthesia was administered and has kept impaired until the 5^{th} minute after establishing of the pneumothorax. Even more pronounced changes almost reverse to those of the CO were found in the TPR. The SaO2 was increased after anaesthesia was administered while in the 5th minute after establishing of the pneumothorax a significant decrease of the SaO2 was found.

2. Following differences between both procedures (thoracotomy vs. thoracoscopy) have been found significant (Figure 5 and 6):

Pw is significantly higher in thoracotomy in the 2nd measurement (when both lungs are ventilated). CO is significantly higher in thoracotomy in the 3rd measurement (when non-operated lung is ventilated). TPR is significantly higher in thoracotomy in the 1st measurement (before anaesthesia) and lower in the 5th measurement (after the pneumothorax was established) and 11th measurement (after the operated lung was unfolded and both lungs were ventilated again).

No significant differences have been found in any of the BPs, BPPAs or CVP measurements.

In other variables (BPd, SaO_2, and BPPAd) only minor and presumably to each other unrelated differences have been found. Therefore, there is no indication of different haemodynamic load during thoracotomy and thoracoscopy.

Discussion

Our working hypothesis that the two surgical approaches (TT x TS) at the time of the operation are leading to the same changes in physiological processes in the human body was confirmed. Peroperative changes are identical or similar in both groups. Some differences could be expected in the postoperative period, at the time of healing and recovery.

Optimization of operational techniques in thoracic surgery aims to positive affection of post-operative state and possibly reduces potential complications which can accompany particularly older patients with co-morbidity or altered patients. Complex surveillance of tissue and organ response epitomizes a possibility how to evaluate theoretical models in clinical setting with a high clinical significance (Kvasnička *et al.* 1998, Goris and Trentz 1995, Šiller and Havlíček 2004, Bříza *et al.* 2002).

Both approaches to operation in pleural cavity require adequate (and for both the same) position on the operation table, equally the selective ventilation of both lungs and thus possible operation on collapsed lung is desirable. Usually, there is no analogy to laparoscopy that is mini-invasive endoscopy in abdominal cavity, where overpressure is needed. This contributes to pressure changes and therefore to changes in circulation in central veins (Goris and Trentz 1995, Šiller and Havlíček 2004, Čiernik and Vokurka 2006, Andrus 1994). Such a capnopleural overpressure can be used, when collapse of pleural parenchyma is limited. In our groups this technique was not used, as it significantly influences haemodynamics as was previously demonstrated (Demes *et al.* 2001).

But as the overpressure technique is not generally used, we do not have to take changes in circulation in the area of semi-rigid thoracic wall and elastic lungs into consideration. The question of mediators release resulting in the tissue response apparently does not affect the immediate post-op period.

In recent ten years some controversial findings were reported as for hemodynamic effect of the CO_2 insufflation during thoracoscopy particularly when combined with changes in patient position (Vitali *et al.* 2000, Byhahn *et al.* 2001, Tomescu *et al.* 2007), but it seams to be more obvious now that these changes are not significant. Our findings support this conclusion and moreover they demonstrate that no adverse hemodynamic effects appear during more invasive procedure – thoracotomy. Only very small differences were found also when only one lung was ventilated (increased CO) in spite of fact that one-lung ventilation increases mechanical stress in the lung and affects not only ventilation but also perfusion and thus it can theoretically affect also hemodynamic parameters.

As for the courses of haemodynamic parameters during the whole surgical procedure it needs to be emphasized that both operating techniques can result in major hemodynamic changes. These changes are mostly pronounced when a patient is placed in a lateral hip position, at the time when unilateral lung ventilation is being started and at the time when we create an artificial pneumothorax.

According to our measurements, placement of a patient on his/her side had the major impact on the hemodynamic changes. In that moment, we recorded a decrease of both the systolic and diastolic blood pressure and a decrease of the systolic pressure in the pulmonary artery. The cardiac output declined and the total peripheral resistance increased after induction of anaesthesia. We consider these changes to be a sign of circulatory subcompensation resulting from decreased venous return, altered blood pressures, mediastinal shift after opening of pleural cavity and overall increase of peripheral vascular resistance. Our further results do not show such considerable changes like at the time of artificial pneumothorax accomplishing. We suppose that a decrease of the peripheral resistance after accomplishing of the artificial pneumothorax has resulted in the restoration of the cardiac output. We think that an appropriate anaesthesia and our effort to prevent more pronounced hemodynamic changes have stopped subsequent haemodynamic deterioration. Oxygen saturation has been increasing after induction of anaesthesia and was decreasing after creation of artificial pneumothorax. These findings could be explained by the fact that artificial ventilation closes arterio-venous shunts in a non-ventilated lung what is quite opposite situation in comparison to a spontaneous ventilation.

The sporadic differences between both surgical approaches (TT vs. TS) were detected only in the beginning of the operations (Pw in the 2^{nd} measurement, CO in the 3^{rd} measurement and

TPR already in the 1st measurement). These changes could be at least partially explained by an epidural analgesic catheter that was implemented to the TT patients in a preoperative period.

Results of the study have fully confirmed working hypothesis. Peroperative response does not depend on the type of surgical approach (TT vs. TS), it is dependent on the position of the patients body (back vs. hip position) and performed procedures (anaesthesia, pneumothorax). Moreover it can depend on the severity of underlying disease and presumably on the extent of surgical performance (simple thoracoscopy, pleurodesis, small anatomic and non-anatomic lung resection x large anatomic lung resection - pneumonectomy). Available papers did not yet compare both of these surgical approaches (TT vs. TS). Results of monitoring during the operating performance (TT) are consistent with published studies (Ohtsuka *et al.* 1999, Brock *et al.* 2000, Zobel *et al.* 1994, Forlanini 1988).

Conclusion

According to evaluated data, we have not found any difference in haemodynamic response between the two methods - thoracotomy and thoracoscopy - but significant changes in the courses of haemodynamic parameters during the whole surgical procedure almost identical in both technical approaches. It means that thoracoscopy causes the same haemodynamic changes like thoracotomy does. From clinical point of view the choice of a surgical approach (TT vs. TS) has to be done just according to the extent of the planned performance without any regards to the hemodynamic processes in the body.

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Table 1. Patients involved in the study. Abbreviations: COBD – Chronic Obstructive Broncho-Pulmonary Disease, IHD – Ischaemic Heart Disease

GROUP:	**THORACOTOMY**			**THORACOSCOPY**		
	Total	Men	Women	Total	Men	Women
Numbers	19	16	3	19	13	6
Age – mean (range)	58 (33 - 68)			41 (19 - 68)		
ASSOCIATED DISEASES:						
COBD	2	2	0	2	1	1
IHD	5	4	1	3	3	0
Diabetes	4	4	0	2	1	1
Arterial hypertension	5	3	2	1	1	0
PREVIOUS THORACIC SURGERY:						
Numbers	0	0	0	0	0	0
PREVIOUS NON-THORACIC SURGERY:						
Appendectomy	1	1	0	3	3	3
Cholecystectomy	1	1	0	1	0	1

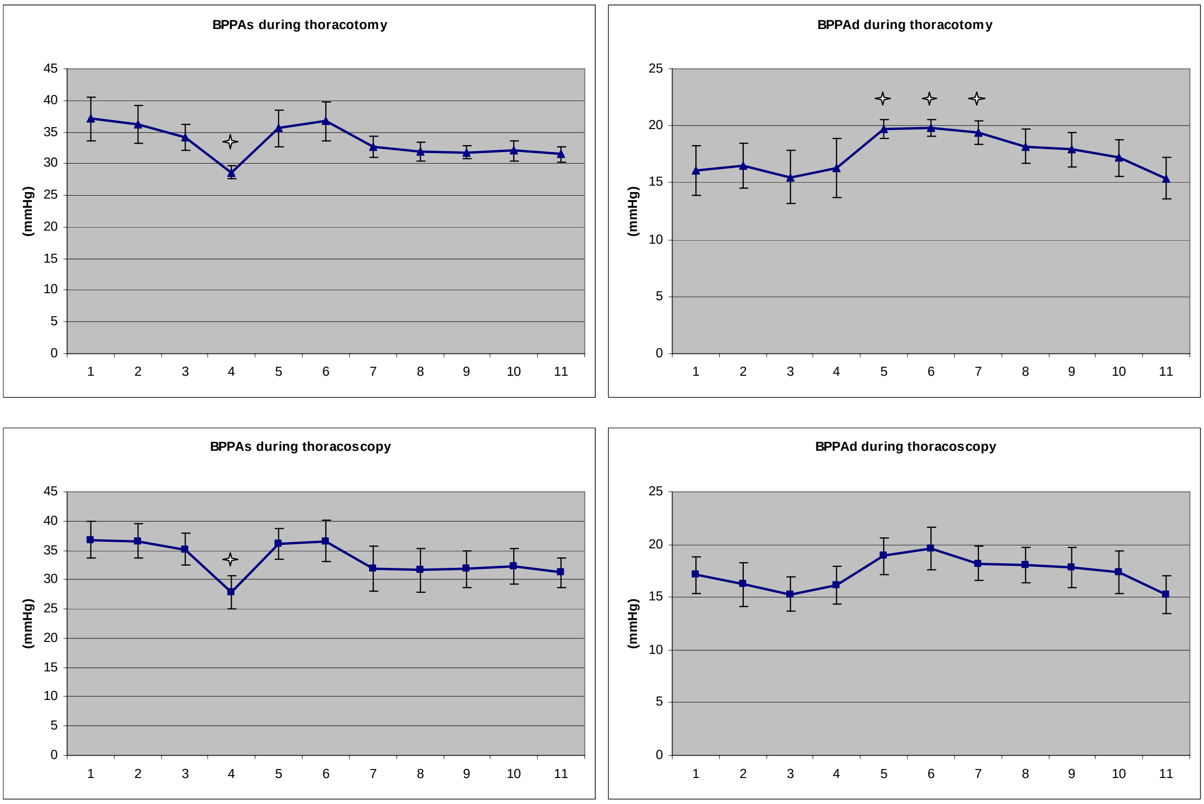

Figure 1: The course of systolic blood pressure in pulmonary artery (BPPAs) and diastolic blood pressure in pulmonary artery (BPPAd) during the whole surgical procedure in both technical approaches (statistically significant differences - $p<0.05$ - from the 1st measurement are indicated by stars).

Numbers of measurements (abscissa):

1st measurement: in the position on the back before any anaesthesia was administered,

2nd measurement: in the same position after the introduction to anaesthesia and intubation (both lungs were ventilated),

3rd measurement: in the same position (only the non-operated lung ventilated),

4th measurement: in the hip position,

5th measurement: in the same position just after the pneumothorax was established,

6th measurement: in the same position 5 minutes after the pneumothorax was established,

7th to 10th measurements: in the same position, each measurement performed 15 minutes after the previous,

11th measurement: in the same position after the operated lung was unfolded and both lungs were ventilated again.

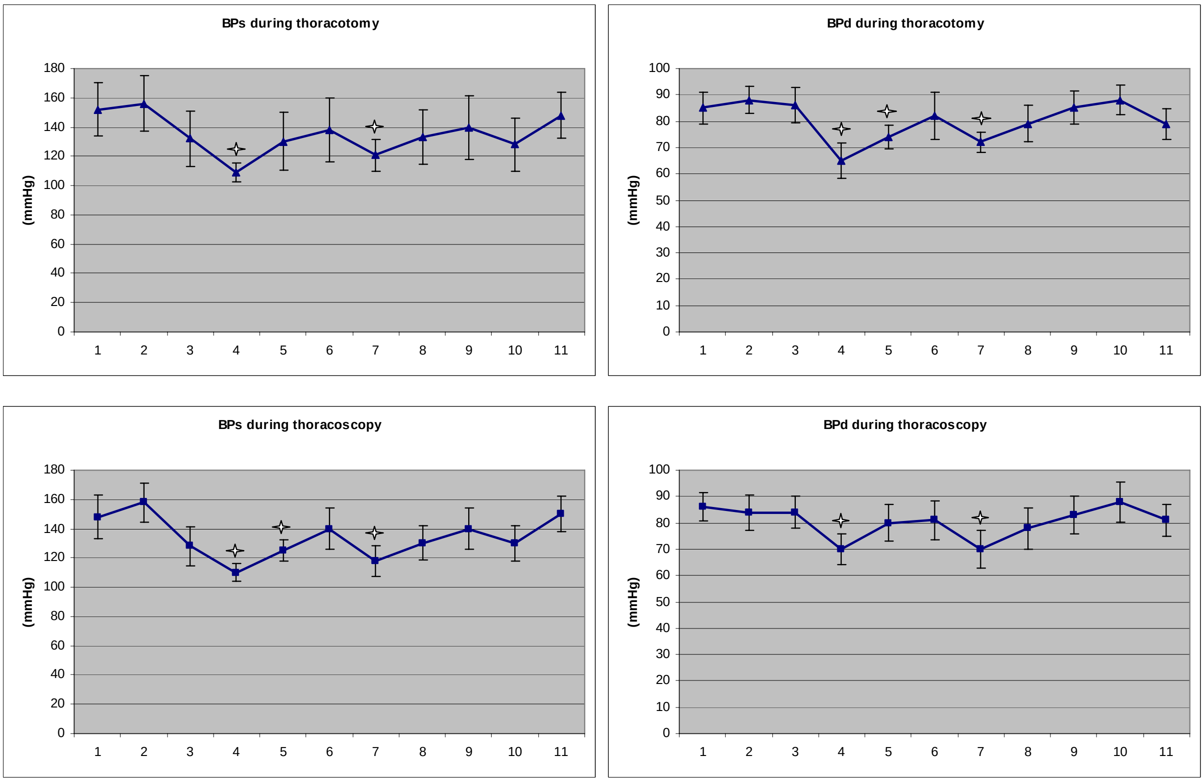

Figure 2: The course of systolic blood pressure (BPs) and diastolic blood pressure (BPd) during the whole surgical procedure in both technical approaches (statistically significant differences from the 1st measurement are indicated by stars). The numbers of measurements (abscissa) are identical with those on the Fig. 1.

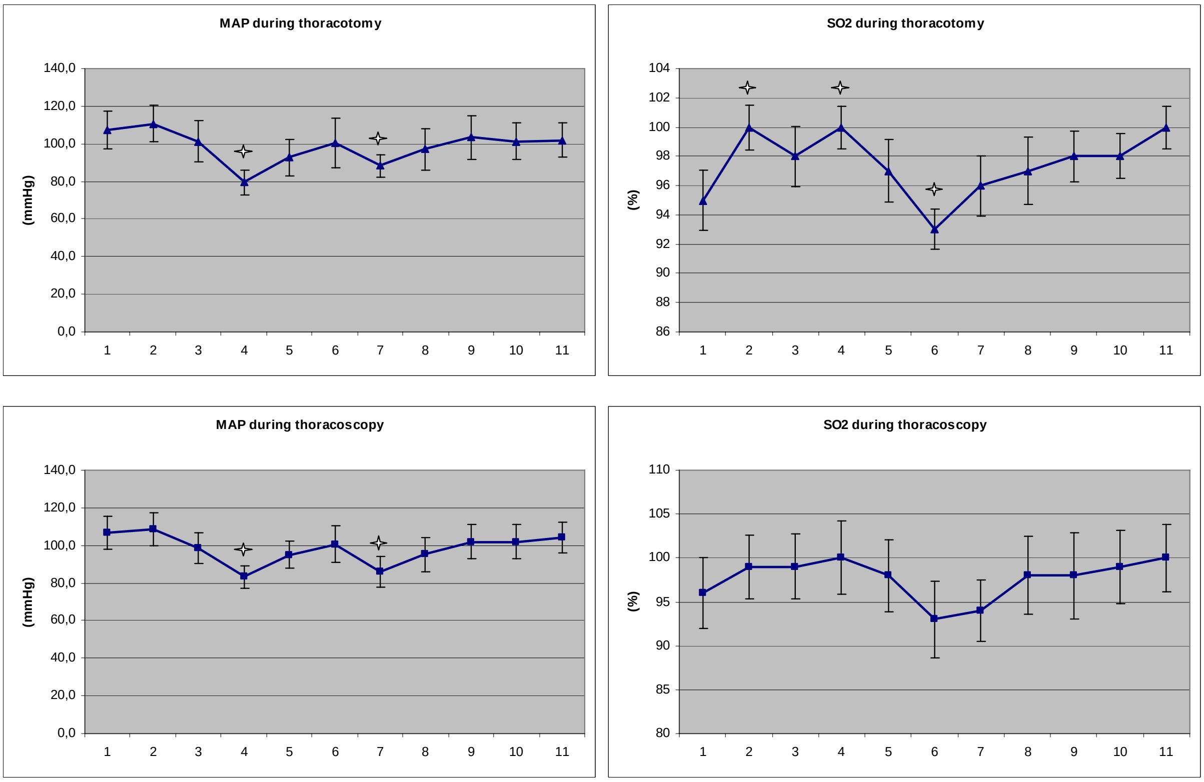

Figure 3: The course of mean arterial pressure (MAP) and O_2 saturation (SaO_2) during the whole surgical procedure in both technical approaches (statistically significant differences from the 1st measurement are indicated by stars). The numbers of measurements (abscissa) are identical with those on the Fig. 1.

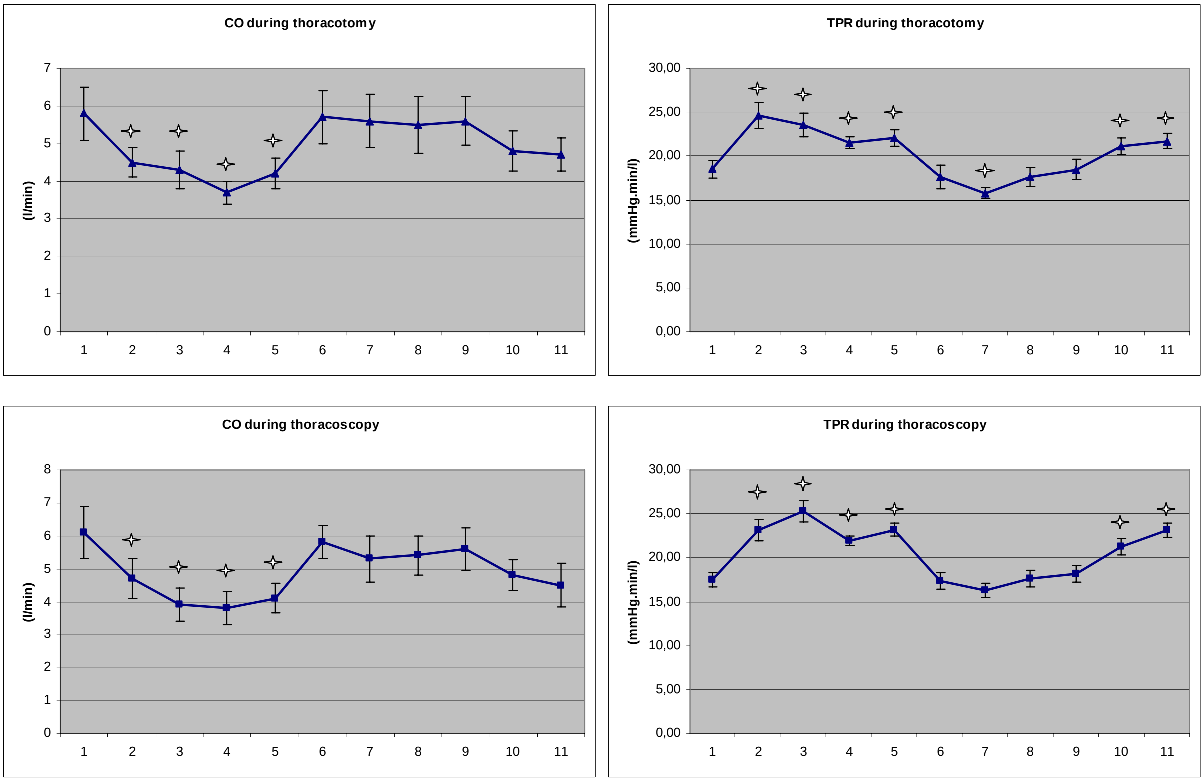

Figure 4: The course of cardiac output (CO) and total peripheral resistance (TPR) during the whole surgical procedure in both technical approaches (statistically significant differences from the 1st measurement are indicated by stars). The numbers of measurements (abscissa) are identical with those on the Fig. 1.

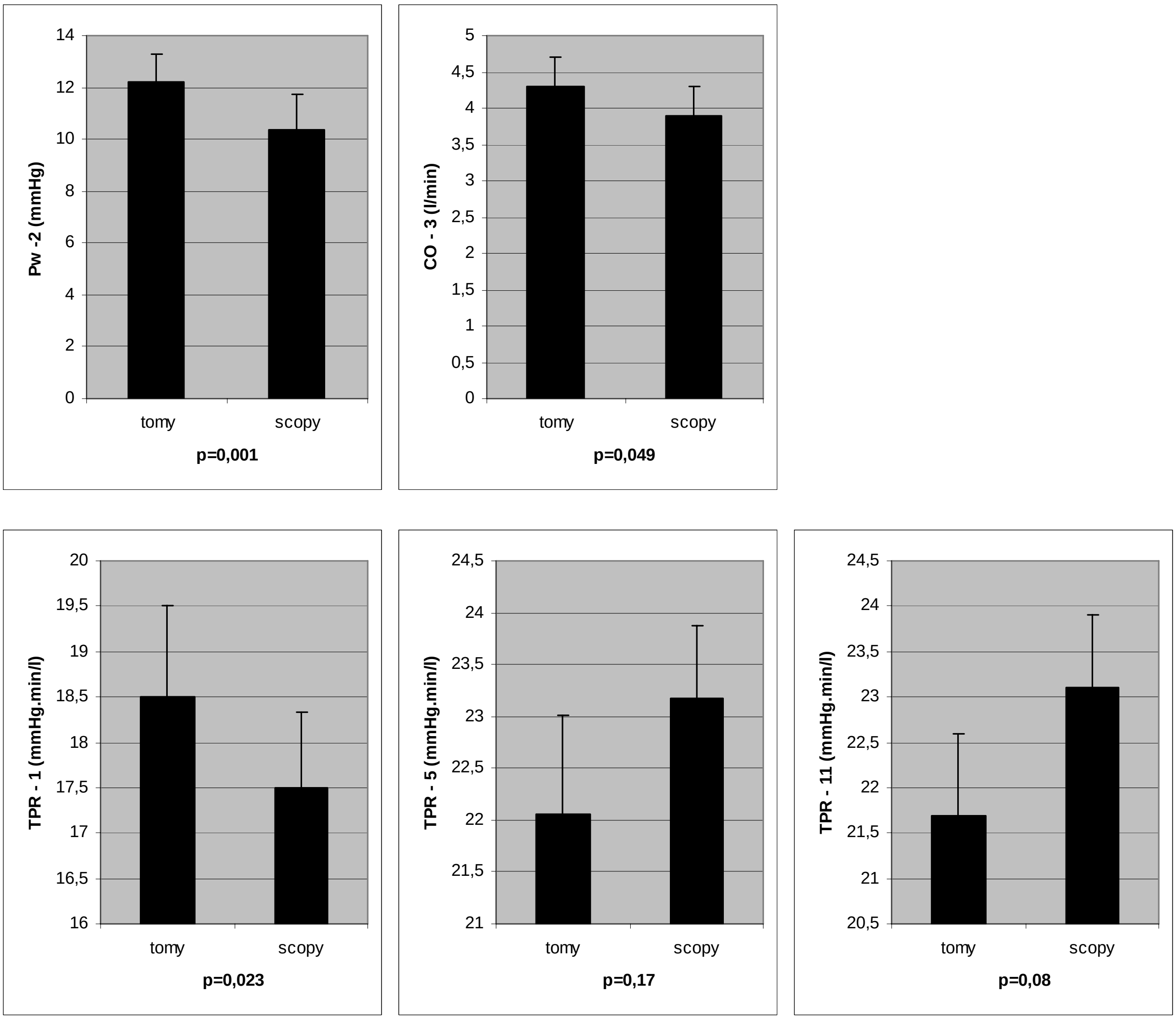

Figure 5: Significant differences between both procedures (thoracotomy vs. thoracoscopy): wedge pressure (Pw) in the 2nd measurement, cardiac output (CO) in the 3rd measurement, total peripheral resistance (TPR) in the 1st , 5th measurement and 11th measurement