Comparison of halothane and desflurane anaesthesia on shunt and selected haemodynamic parameters during thoracosurgical procedures

Waldemar Machała[1], Renata Szebla[2], Jakub Perdeus[3], Damian Obrzut[1], Katarzyna Śmiechowicz[1], Jacek Rysz[4], Beata Mamełka[5]

[1]2nd Department of Anaesthesiology and Intensive Care, University Clinical Hospital No. 2, Medical University of Lodz, Poland
[2]Anaesthesiology and Intensive Care Department, Specialist Health Care Department of Tuberculosis and Pulmonary Diseases in Kielce, headquarters in Checiny, Poland
[3]Thoracic Surgery Ward, Specialist Health Care Department of Tuberculosis and Pulmonary Diseases in Kielce, headquarters in Checiny, Poland
[4]University Clinical Hospital No. 2, Medical University of Lodz, Poland
[5]Department of Laboratory Diagnostics and Clinical Biochemistry, University Clinical Hospital No. 2, Medical University of Lodz, Poland

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Corresponding author:
Waldemar Machała MD
2nd Department of Anaesthesiology and Intensive Care
University Clinical Hospital No. 2
Medical University of Lodz
Żeromskiego 113
90-569 Lodz, Poland
Phone: +48 42 639 35 01
Fax +48 42 639 35 03
E-mail: waldemar@machala.info
w.machala@skwam.lodz.pl

Abstract

Introduction: Anaesthesia for lung surgical procedures usually requires one lung ventilation (OLV). This procedure, which facilitates the surgery, is the cause of breathing and respiratory disorders. The anaesthetic agent used in the procedure may stop physiological reactions of the organism which are the consequences of OLV. The aim of the study was the comparison of influence of inhalation anaesthesia with halothane and desflurane on shunt and selected haemodynamic parameters.

Material and methods: 52 patients in the first and second physical status degree according to ASA scale operated on for lung cancer (non-microcellular) with thoracosurgical procedures. The anaesthesia method – balanced: the combination of extradural or thoracic paravertebral anaesthesia (fentanyl) with general anaesthesia (oxygen + air) with halothane (HAL) or desflurane (DES). Anaesthetics administered at the concentration of 1 MAC. Shunt and haemodynamic parameters were monitored with a Swan-Ganz catheter.

Results: the kind of anaesthetic used had no influence on shunt value. The shunt value underwent statistically significant increase after OLV was started, without however differences related to the anaesthetics used. Halothane triggered considerable decrease of SVR leading to hypotension. Both anaesthetics decreased left ventricular stroke work index (LVSWI) and the coronary perfusion pressure value and right ventricular stroke work index. Halothane did not cause any changes in pulmonary vascular resistance, which resulted in a lack of change in blood pressure in the pulmonary artery. In contrast, desflurane anaesthesia caused a statistically insignificant increase in PVR value which was accompanied by a statistically insignificant increase in blood pressure in the pulmonary artery.

Conclusions: 1. Halothane and desflurane may both be used as anaesthetics with patients operated on with one lung ventilation (OLV); their influence on shunt is similar. 2. Halothane seems to be safer for anaesthetizing patients with pulmonary hypertension – its administration does not increase PVR value. 3. For patients with limited coronary vascular reserve, desflurane appears to be worth recommending. The less distinct influence on SVR than halothane results in the fact that the increase in arterial blood pressure does not trigger an increase in coronary perfusion pressure (risk of acute myocardial ischaemia).

Key words: one-lung ventilation (OLV), halothane, sevoflurane, shunt, Swan-Ganz catheter.

Abbreviations index:

OLV – one lung ventilation
MAC – minimal alveolar concentration
TPVA – thoracic paravertebral anaesthesia
TEA – thoracic epidural anaesthesia
FiO_2 – fraction of inspired O_2
BMI – body mass index
BSA – body surface area
HR – heart rate
BP – blood pressure
MAP – mean arterial pressure
SpO_2 – oxygen saturation of haemoglobin
MPAP – mean pulmonary arterial pressure
CVP – central venous pressure
PCWP – pulmonary capillary wedge pressure
CI – cardiac index
SVI – stroke volume index
LVSWI – left ventricular stroke work index
RVSWI – right ventricular stroke work index
CPP – coronary perfusion pressure
SVR – systemic vascular resistance
PVR – pulmonary vascular resistance
HPV – hypoxic pulmonary vasoconstriction
Q_s/Q_t – shunt

Introduction

One lung ventilation (OLV) gives the surgeons excellent operating conditions [1]. Despite the fact that the indications for OLV for most thoracosurgical procedures are relative, they are, however, performed routinely [1, 2]. Lateral placement of the patient and exclusion of the lung under procedure causes disorders in itself, the most prominent of which are changes in cardiac outcome, oxygenation and breathing mechanics [3]. The most troublesome is increase of shunt (Q_s/Q_t), invariably leading to decrease of pressure in blood oxygen (pO_2). The factor which limits Q_s/Q_t is hypoxic pulmonary vasoconstriction (HPV) occurring in the non-ventilated lung. Due to HPV the blood flow in the excluded lung decreases from 40 to 30-35% of cardiac outcome [3]. With the person not subject to anaesthesia, the blood flow in the non-ventilated lung may, due to HPV, decrease even by 50%; hence, the ratio of blood flow in the ventilated to non-ventilated lung will equal 80:20 [4]. Some anaesthetics, mostly inhalation ones and techniques of local anaesthesia (thoracic paravertebral anaesthesia, epidural anaesthesia), stop HPV, leading to hypoxia [5, 6]. Therefore, it is important to select them in such a way that desaturation occurs marginally. This is quite difficult since inhalation anaesthetics (except desflurane) are preferred in anaesthetizing patients with pulmonary diseases due to their beneficial influence on lower air ducts (bronchiectasia and lowering of air duct resistance).

The aim of this study was to compare the influence of inhalation anaesthesia with halothane and desflurane on shunt and selected haemodynamic parameters.

Material and methods

The study was carried on 52 patients treated with thoracosurgical procedures in the Clinic of General Surgery, Thoracic Surgery and Oncology Surgery at the Medical University of Łódź and the Thoracic Surgery Ward at the Hospital in Chęciny. The patients were diagnosed with lung cancer (non-microcellular). The approval to carry out the study was issued by the Bioethics Committee at the Medical University of Łódź and the Bioethics Committee of Świętokrzyski Medical Association in Kielce. The condition imposed on employing research protocol was patients' approval to participate in the study and their first and second physical status degree according to the ASA scale. The patients were randomized by computer randomizing software and assigned to two groups: HAL (n=26) and DES (n=26). Patients from the HAL group were anaesthetized with halothane and the patients from the DES group with desflurane. Demographic parameters are presented in Table I; they were comparable in both groups. On the procedure day, the patients were orally premedicated with midazolam. The following ranges of study were established:

I. Prior to anaesthetic administration (10-30 min).
II. Immediately after anaesthesia induction (after tube placement control) – dorsal position, the patients were ventilated with 100% oxygen; no breathing mixture of inhalation anaesthetics was included.
III. After establishing breathing mixture (two-lung ventilation) – dorsal position.
IV. 5 minutes following OLV – lateral position.
V. 30 minutes following OLV – lateral position.
VI. 5 minutes following two-lung ventilation or pulmonary artery ligation of the lung under procedure.
VII. 30 minutes following two-lung ventilation or pulmonary artery ligation of the lung under procedure.
VIII. 5-10 minutes prior to extubation – dorsal position.
IX. 15 minutes following extubation.

The anaesthetic procedure (except the inhalatory anaesthetic used) was identical in both groups. In the operating theatre the peripheral vein cannula was introduced; crystalloid infusion was initiated; ECG, SpO_2 and NiBP monitoring were started. The subsequent procedures included:

- the catheter was introduced into the epidural space (TEA), or into the paravertebral space (TPVA) on the side under procedure; in the Th_4-Th_7 space. Trial dose of lidocaine with Adrenaline 1:2 000 000 was administered.
- A cannula with the diameter of 8F was introduced into the internal jugular vein (on the side of the lung under procedure), through which the Swan-Ganz catheter (SGC) was introduced into the pulmonary artery. The position of the catheter was

Table I. Demographic parameters in the study

	Halothane n=26 (23)	Desflurane n=26
Age [years]	47-76 (average 61)	31-82 (average 59)
Sex	M: 17 (16) F: 9 (7)	M: 19 F: 7
Height [cm]	161-180 (171)	156-181 (170)
Weight [kg]	45-102 (74)	46-105 (70)
BSA [m^2]	1.42-2.24 (1,88)	1.44-2.26 (1.81)
BMI [kg/m^2]	165-35.3 (25)	15.3-37.2 (24.1)
Side of procedure [R/L]	13/13 (11/12)	17/9
Type of procedure		
Pulmonectomy	9 (6)	4
Bilobectomy	1	1
Lobectomy	7	8
Wedge lung resection	7	11
Exploratory operation	2	2

verified by blood pressure curve obtained from the distal part of the SGC.

- Following the Allen test, the cannula was introduced into the radial artery, thus starting direct arterial blood pressure monitoring.

The following parameters were monitored continuously: heart rate (HR), heart bioelectric activity (ECG), blood saturation (SpO_2), arterial blood pressure with invasive and non-invasive method: BP and NiBP, central venous pressure (CVP), pulmonary arterial pressure (PAP), body temperature (T) and breathing parameters; parameters monitored periodically included cardiac output (CO), pulmonary capillary wedge pressure (PCWP), gasometry of arterial and mixed venous blood and haemoglobin concentration. After obtaining those results, it was possible to determine so-called calculated parameters. In order to calculate them, the authors used generally available models. The following parameters were assessed: cardiac index (CI), coronary perfusion pressure (CPP), pulmonary and systemic vascular resistance (PVR and SVR), stroke volume index (SVI) and left and right ventricular stroke work index (LVSWI and RSVWI). For haemodynamic monitoring the Oxmetrix (Abbott Laboratories; USA) CO monitor was used. After assessing the first range, TEA and TPVA were carried out with 0.1 mg fentanyl in 15 ml 0.9% NaCl. The anaesthesia was induced with propofol, fentanyl (1-2 µg/kg); striated muscles were relaxed with cis-atracurium. On obtaining the desired degree of muscle relaxation (verified with TOF Guard apparatus) the patients were intubated with a double-lumen tube (without hook) in such a way that the bronchial end was placed in the non-operated lung. The placement of the tube was verified auscultatorily. The composition of the breathing mixture was determined in such a way that FiO_2 was within the range of 0.35-0.45. The concentration of halothane and desflurane was 1 MAC; its value was corrected in Vol./% regarding the patient's age. During the period of anaesthetic saturation (first 20 minutes) the fresh gas flow was 5.9 l/min. After that, the flow was reduced to 2 l/min for halothane and 0.5 l/min for desflurane. Disorders in patients' oxygenation (desaturation) was treated (interchangeably or simultaneously) by prolonging the inspiration phase and increasing oxygen concentration. If those efforts did not increase SpO_2 and it was necessary to use PEEP in the ventilated lung or CPAP in the non-ventilated lung or to implement temporary two-lung ventilation (TLV), the patients were disqualified from the research protocol. Relaxing agents were administered according to TOF values. None of the patients required administration of analgesics. The anaesthesia was completed with 100% oxygen ventilation; after regaining breathing efficiency, the patient was extubated. After approx. 15-20 minutes following the extubation (after taking the blood sample from the last range), the SGC was removed. The vascular sluice (cannula) was maintained for 72 hours.

Statistical analysis was carried out for 23 patients from the HAL group (n=23) and 26 patients from the DES group (n=26). Patients number 3, 10 and 21 from the halothane group were not assessed. The reason was introduction of the catheter (Swan-Ganz) into the pulmonary artery of the operated patient and necessity of its removal from the pulmonary artery in the VII time range.

The statistical hypotheses concerning mean values were verified. The most fundamental question to be answered was whether these values differ considerably or not. With reference to the comparison of mean values of corresponding parameters for halothane and desflurane, the Cochran and Cox test was used. With

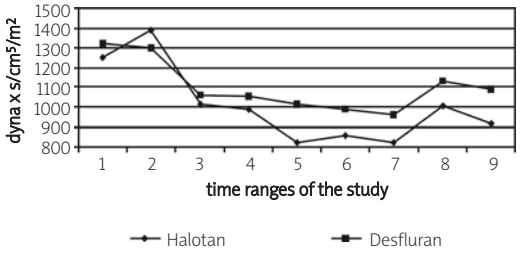

Figure 1. Systemic vascular resistance (SVR)

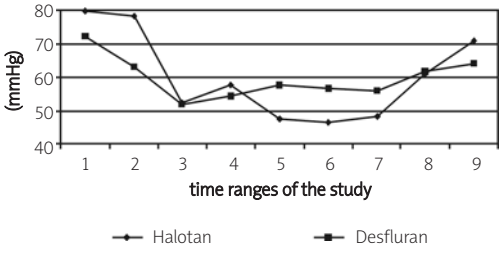

Figure 2. Coronary perfusion pressure (CPP)

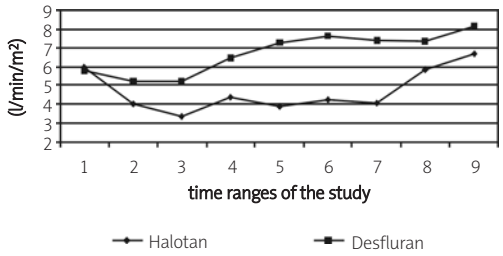

Figure 3. Right ventricular stroke work index (RVSWI)

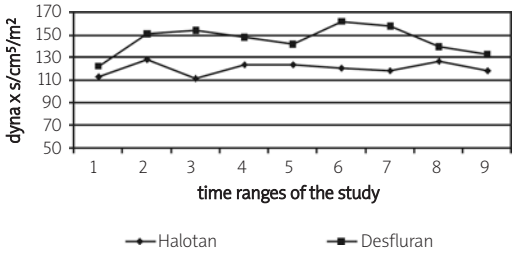

Figure 4. Pulmonary vascular resistance (PVR)

reference to the comparison of the results gathered in the following time ranges for halothane and desflurane, the Wilcoxon rank sum test was used. For verifying statistical hypotheses the level of significance of α=0.05 was established.

Results

During the anaesthesia with halothane and desflurane no differences between the anaesthetics used regarding shunt, cardiac index, mean arterial blood pressure and heart rate were observed. The anaesthetics had a similar influence on left ventricular stroke work index and coronary perfusion pressure values – one significantly and the other non-significantly reduced them.

Lowering of the arterial blood pressure – statistically significant as compared to the initial range – was a result of decrease of systemic vascular resistance (Figure 1) with simultaneous lack of changes in cardiac index. While the SVR value with desflurane anaesthesia did not go below the norm (and did not exceed the standard deviation value), halothane anaesthesia caused a decrease in SVR below the lower norm limit (SVR was statistically significantly different between groups; $p<0.05$).

Anaesthesia with both halothane and desflurane resulted in lowering of the left ventricular stroke work index – statistically significant compared to pre-anaesthesia period, but insignificant between the anaesthetics used. This fact, as well lowering of arterial blood pressure (not exceeding, however, the lower limit) similarly in both groups, was the reason for lowering of coronary perfusion pressure value: statistically significant regarding halothane and statistically insignificant regarding desflurane (Figure 2). Anaesthesia with halothane lowered its value as compared with desflurane.

The statistically significant differences in the influence of the anaesthesia on right ventricular stroke work index also came as surprise (Figure 3). Anaesthesia with halothane lowered its value throughout the entire anaesthesia. However, in anaesthesia with desflurane, increase of the RSVWI value was observed. In both cases $p>0.05$.

During the halothane anaesthesia no changes in pulmonary vascular resistance were observed (Figure 4), which resulted in no changes in pulmonary artery blood pressure (Figure 5). Desflurane anaesthesia triggered a statistically insignificant increase in PVR value, which was accompanied by a statistically insignificant increase in pulmonary artery blood pressure. The difference of the influence on pulmonary artery blood pressure was significant ($p<0.05$) between the two anaesthetics used.

The main aim of the study was to assess the influence of anaesthesia on shunt during OVL. After

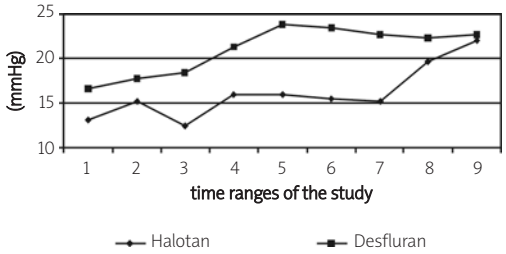

Figure 5. Mean pulmonary arterial pressure (MPAP)

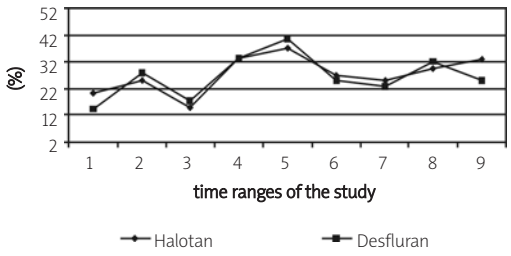

Figure 6. Shunt (Q_s/Q_t)

the analysis of the results, it may be circumspectly stated that the type of anaesthetic used on our material did not have any influence on shunt (Figure 6); the shunt value was statistically significantly increased following OLV implementation with no differences, however, between anaesthetics used. Only 6 patients (11%) demonstrated, after OVL implementation, desaturation below 60 mmHg, which required breathing mixture oxygen concentration increase.

Relating in a simple manner the changes in PVR as a determinant for HPV, we may attempt to state that desflurane did not impair HPV, since after OLV implementation the PVR value increased in relation to PVR with halothane anaesthesia.

Discussion

Halothane was synthesized by Fergusson, Suckling and Raventos in 1952 [7]. It was first used by Johnston in 1956 [8]. Halothane, to a small degree, changes systemic vascular resistance. Despite that, coronary blood flow is decreased, possibly secondarily to perfusion pressure decrease and oxygen demand [9]. The aforementioned phenomenon is accompanied by an increase in central venous pressure and decrease in stroke volume parallel to a lack of influence on heart rate (increase of sympathetic system activity and effect on atrioventricular node) [10].

Desflurane was synthesized by Ross Terrel at the beginning of the 1960s. The first clinical use occurred in 1990. FDA registered this preparation in 1992 [11]. During desflurane anaesthesia (concentration of 1 MAC) tachycardia can be observed (depending on the dose) which is accompanied by decrease of myocardial contractility and SVR volume decrease [11, 12]. Cardiac index does not, as a rule, change. Desflurane, being a vasodilator, dilates vessels, including the coronary ones. This activity results in heart rate increase. Nevertheless, SVR decrease and tachycardia trigger a decrease in coronary perfusion pressure – luxury perfusion syndrome [13]. The authors of the study did not observe the tachycardia and arterial blood pressure increase described by other researchers while quickly saturating the patients with desflurane up to concentrations higher than 1 MAC [14].

The available literature recommends, for patients who require OLV, anaesthesia with sevoflurane, isoflurane and desflurane, with no difference in their influence on shunt [15-17]. It is considered, however, that these agents cause inhibition of hypoxic pulmonary vasoconstriction [18, 19]. Only a few studies emphasize the fact that anaesthetics which decrease cardiac output (both by SVR decrease and myocardial contractility decrease) will result in an increase in shunt [20]. Anaesthetics which slightly alter CI and SVR and slightly disturb PVR (which approximately reflect HPV) will not increase Q_s/Q_t values.

Conclusions

1. Halothane and desflurane may be used with patients operated on with one lung ventilation (OLV); their influence on shunt is similar.
2. Halothane seems to be safer for anaesthetizing patients with pulmonary hypertension – its administration does not increase PVR value.
3. For patients with limited coronary vascular reserve, desflurane appears to be worth recommending. Its less distinct influence on SVR than halothane means that the increase in arterial blood pressure does not trigger an increase in coronary perfusion pressure (risk of acute myocardial ischaemia).

Acknowledgments

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