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# Cerebral blood flow during single lung ventilation

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Original Article

# Cerebral blood flow during single lung ventilation

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**Aim:** Our aim was to show the effect of one-lung ventilation (OLV) on cerebral blood flow (CBF) by measuring carotid blood flow. This technique has been the subject of experimental and clinical studies.

**Materials and methods:** Carotid doppler flows were measured at 4 different times. Peak systolic velocity (PSV) and end diastolic velocity (EDV) were measured and pulsatility index (PI) and resistive index (RI) calculated.

**Results:** There were no significant changes in PSV, PI, RI, or flow volume in the normal or diseased sides at repeated measures ($P > 0.05$).There was no significant difference between the flow velocities, PIs, RIs, or flow volumes measured in the supine and decubitus positions during OLV. In addition, there was no significant difference between the flow parameters of the upper and lower carotids measured in the lateral decubitus position before and after OLV. There was no correlation between any of the flow parameters and duration of OLV.

**Conclusion:** OLV poses no additional risk in terms of CBF. However, further studies, supported by biochemical parameters and involving wider patient groups, are now needed.

**Key words:** Thoracotomy, cerebral hypoxia-ischemia, ventilation, doppler

## Introduction

The aim of this study was to determine the impact of one-lung ventilation (OLV) and the decubitus position on carotid artery flow dynamics in patients undergoing thoracotomy. Many previous studies have investigated the effects of OLV on local and systemic damage. However, the effects of OLV and thoracotomy position on cerebral blood flow (CBF) are unclear. To the best of our knowledge, there have been no prior reports of extracranial carotid doppler ultrasonography (US) investigation of CBF in thoracotomy patients.

## Materials and methods

In 2008 and 2009, 30 patients undergoing surgery in our clinic and requiring OLV were enrolled into this study. The procedure was approved by the ethics committee of our university. Patients with a history of carotid artery disease were excluded. No patients had any history of cerebrovascular disease. Patients who could not tolerate OLV were also excluded.

In the operating room all patients were sedated with 2 mg midazolam. The radial artery was cannulated before anesthesia induction. Electrocardiography, invasive blood pressure, pulse oximetry, and end tidal $CO_2$ were monitored. Anesthesia was induced with an intravenous bolus of propofol (2–2.5 mg/kg), fentanyl (2 µg/kg), and vecuronium bromide (0.1 mg/kg). After induction, a right or left double-lumen tube was inserted into the trachea. The tube position was confirmed by flexible bronchoscopy before and after patients were placed in the lateral position. Anesthesia was maintained

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with sevoflurane (1%–2%) in an oxygen–air mixture. Vecuronium bromide and fentanyl were given as needed to maintain neuromuscular blockade and analgesia. All patients underwent OLV.

All doppler US examinations were performed in the operating room. A number of tests, varying depending on duration of surgery, were performed in all patients:

1. In the supine position, at least 15 min after the start of general anesthesia;
2. In the lateral decubitus position after waiting for 15 min but before the OLV;
3. Again, 15 min after the start of OLV;
4. Hourly during OLV.

A 5–13 MHz broadband phased array transducer and GE Logic 5 Pro Ultrasound system were used for doppler imaging. Doppler examinations were performed by 1 of 2 trained radiologists. All patients were intubated during examination. The carotid artery was located and scanned with gray-scale ultrasound. It is very difficult to measure carotid artery flow in the lateral decubitus position. We found a suitable area for measuring carotid artery flow between the patient's shoulder and jaw. Color doppler was then used to identify blood flow. All doppler measurements were performed on the common carotid artery (CCA), 2 cm proximal to the bifurcation. A sample volume was placed in the center of the vessel in order to avoid natural turbulence at the edge of the lumen. The doppler angle was adjusted and maintained between 50° and 60° in order to avoid overestimation of velocity. Subsequently, spectral doppler was used to obtain flow velocities. Peak systolic velocity (PSV) and end diastolic velocity (EDV) were measured and pulsatility index (PI) and resistive index (RI) calculated. Time-averaged mean flow velocity (TAMV) was determined as the integral of the mean flow velocities of all moving particles passing the sample volume. The inner diameter (d) of the circular vessel was measured. Flow volume (FV) for each side was calculated using the formula $FV = TAMV \times (d/2) \times \pi$. All measurements were recorded.

For statistical analysis, mean and standard deviations of all doppler parameters were calculated for each side. The Kolmogorov–Smirnov test was used to show deviation from normal distribution. Student's t-test and the Mann–Whitney test were used to determine any significant difference between blood flow parameters in the normal and diseased sides. Repeated measures ANOVA was used to analyze the importance of change in the flow parameters during the first 3 repeated measurements in the 30 patients. Friedman's test was used to determine any difference in blood flow parameters related to duration of OLV. doppler parameters of 9 patients whose thoracotomy operations lasted more than 1 h were used in this last analysis. P-values less than or equal to 0.05 were considered statistically significant.

## Results

There were 30 patients with a mean age of 54.0 years (standard deviation: 15.7) enrolled in this study. None had signs of carotid vessel pathology at gray-scale ultrasound. Doppler flow parameters were measured bilaterally in the supine lateral decubitus positions before and after OLV in all 30 patients. The blood flow parameters measured during thoracotomy in all 30 patients are documented in the Table as group means and standard deviations. In 9 patients whose thoracotomies lasted more than 1 h, a second doppler measurement was also obtained at the end of the first hour of surgery. There were no significant changes in PSV, PI, RI, or flow volume of the normal and diseased sides during repeated measures ($P > 0.05$). For EDV, there was no significant change in the diseased side during repeated measures ($P = 0.344$). In the normal side, a significant change was observed in the EDVs measured in the supine and decubitus positions and during OLV ($P = 0.044$), but in terms of contrasts within subjects there was no significant difference between any pairs in the groups (in all pairs $P > 0.05$). In addition, there was no significant difference between the diseased and normal sides for any of the flow parameters measured in the supine ($P > 0.05$) or lateral decubitus positions before ($P > 0.05$) or during ($P > 0.05$) OLV. Moreover, no significant change was determined in the blood flow parameters of diseased or normal sides in relation to OLV duration ($P > 0.05$ for all parameters).

## Discussion

Thoracic surgery is being used increasingly worldwide. Many studies on the complications of pulmonary resections have been performed in recent

Table.

| Doppler parameters | | Supine | Lateral decubitus | OLV 1 | P-value |
|---|---|---|---|---|---|
| PSV | Diseased side* | 107 ± 44 | 103 ± 44 | 101 ± 54 | 0.890 |
| | Normal side* | 106 ± 39 | 89 ± 37 | 100 ± 62 | 0.099 |
| | P-value | 0.916 | 0.197 | 0.964 | |
| EDV | Diseased side* | 29 ± 13 | 28 ± 14 | 24 ± 15 | 0.344 |
| | Normal side* | 27 ± 9 | 23 ± 12 | 27 ± 13 | 0.044 |
| | P-value | 0.577 | 0.156 | 0.657 | |
| PI | Diseased side* | 1.75 ± 0.61 | 1.87 ± 0.93 | 1.85 ± 0.53 | 0.789 |
| | Normal side* | 1.66 ± 0.37 | 1.83 ± 0.67 | 1.81 ± 0.51 | 0.321 |
| | P-value | 0.471 | 0.832 | 0.772 | |
| RI | Diseased side* | 0.72 ± 0.06 | 0.72 ± 0.07 | 0.75 ± 0.07 | 0.262 |
| | Normal side* | 0.73 ± 0.07 | 0.74 ± 0.08 | 0.75 ± 0.07 | 0.463 |
| | P-value | 0.707 | 0.511 | 0.696 | |
| Volume | Diseased side* | 677 ± 218 | 669 ± 205 | 525 ± 224 | 0.327 |
| | Normal side* | 633 ± 169 | 528 ± 199 | 411 ± 134 | 0.677 |
| | P-value | 0.765 | 0.139 | 0.870 | |

OLV: one-lung ventilation, PSV: peak systolic velocity, EDV: end diastolic velocity,
PI: pulsatility index, RI: resistive index.
*All values are given as mean ± standard deviation.
Note: Approximately 80% of the blood flowing from the CCA goes through the ICA.

years (1–4). Pre- and postoperative complications associated with the anesthesia technique employed or the operation itself are often encountered in thoracic surgery and new research aimed at preventing such complications is being carried out.

OLV is required for a number of thoracic procedures, such as lung, esophageal, aortic, or mediastinal surgery. It is now used for almost all thoracic operations involving the lung or in which the collapse of the lung improves access to the operation field (1). Some studies have reported OLV-associated pathophysiological effects and complications (1–6).

Hypoxemia during OLV may compromise the safety of the patient and is a challenge for the anesthesiologist and the surgeon (1). Many studies have suggested multiple risk factors related to the etiology of lung injury during OLV. Some animal studies showed that OLV causes biochemical and histopathological injury in the lungs, liver, and ileum and that this damage increases with the duration of occlusion (2,3). In their experimental study, Yuluğ et al. showed that OLV causes tissue damage in the liver and ileum and that this increases with occlusion duration (3). In another experimental study, Tekinbas et al. reported biochemical and histopathological injury in collapsed and contralateral lungs in OLV, and that this injury again increases with occlusion duration (2).

Gong et al. measured left upper pulmonary vein (LUPV) flow using a transesophageal echocardiography probe in right OLV patients. LUPV was measured every 5 min over the 30-min OLV period. They determined a 60% reduction in regional pulmonary blood flow over 30 min (7).

Carotid doppler US has been widely used to evaluate the effect of cardiovascular surgery on circulatory function (8–11). It constitutes an important diagnostic tool for demonstrating complications, especially after carotid artery and aortic arch. Doppler US has also been used for pulmonary blood flow in experimental studies (12).

Some recent studies have evaluated the carotid doppler US in chronic obstructive pulmonary disease (COPD). Albayrak et al. measured CBF in COPD patients using carotid doppler US (13). They reported that CBF was significantly higher in COPD patients compared to the control group.

The increase in CBF was associated with hypoxemia. Hypercapnia may cause dilatation in cranial arteries and veins, resulting in increased CBF (14,15). Another study on COPD patients showed that oxygen replacement therapy reduces CBF hypoxemia during OLV, which may affect the safety of the patient and is a challenge for the anesthesiologist and the surgeon (16,17).

There are no studies in the literature of the effect of OLV on CBF. We used doppler US to quantify CBF in our patients, which is a practical, noninvasive, economical, and repeatable test that can be performed bedside.

CBF is affected by various neuronal and chemical events. For example, in the same way that oxygen or carbon dioxide pressure in the blood affects CBF, it is also influenced by pressure variations inside the head and by blood viscosity. All these factors are affected by OLV. When average arterial pressure declines or pressure inside the head rises, there is a decrease in cerebral perfusion pressure. In addition, cerebrovascular pressure falls with expansion of precapillary vessel diameters and CBF remains stable. When cerebral perfusion rises, vessel diameters narrow, resistance increases, and CBF remains stable. This mechanism, which permits CBF to remain stable so long as systemic mean arterial pressure remains between 60 and 100 mmHg, is known as autoregulation. When mean arterial pressure falls below 60 mmHg the expansion capacities of the precapillary vessels are exceeded. The vessels cannot expand any further, and cerebral perfusion pressure and associated CBF also decrease. OLV can have a direct effect on these factors impacting CBF. For example, hypoxemia is common during anesthesia with OLV (4). During OLV, although only one lung is ventilated, both lungs are perfused. Perfusion of the collapsed, nonventilated lung inevitably leads to transpulmonary shunting, to impairment of oxygenation, and occasionally to hypoxemia.

We investigated the effect of OLV, and the duration thereof, on carotid blood flow. Patients with signs of carotid artery disease and/or cerebrovascular disease were excluded. Carotid blood flows were measured bilaterally at 3 to 4 different times during surgery. Approximately 80% of the blood flowing from the CCA goes through the internal carotid artery (ICA). We thought this ratio was good enough for our purposes, but it needs further investigation. There was no statistically significant difference between the flow parameters of diseased and normal sides and no significant change in any of the flow parameters related to the decubitus position, or OLV and the duration thereof.

OLV was well tolerated by these patients. No problems occurred during operation with the oxygen and carbon dioxide levels. Oxygen and carbon dioxide levels were within normal limits.

OLV appears to be reliable in terms of cerebral blood flow. In our study, measurements were taken from the CCA, and these were confirmed by measurements from the ICA. However, considering the patient was intubated and placed in the decubitus position during thoracotomy, the ICA was localized and any measurements taken from it would not be effective. Further studies with a wider patient group and use of various biochemical parameters are now needed to clarify the effect of OLV on cranial perfusion.

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