Impedance Cardiography
Noninvasive Measurement of Hemodynamics and Thoracic Fluid Content During Endoscopic Thoracic Sympathectomy
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Abstract: Endoscopic thoracic sympathectomy (ETS) is a minimally invasive procedure for treating intractable palmar hyperhidrosis (PH). Hemodynamic changes associated with CO₂ insufflation during ETS. In the present study, we examined hemodynamic changes during general anesthesia using impedance cardiography (ICG) monitor. Seventeen adult patients (15 males) scheduled to undergo elective unilateral ETS for treatment of PH were enrolled in the study. Patients with cardiopulmonary diseases were excluded from the study. Their age and weight mean values were 26.5 ± 5 years, 71.9 ± 11.5 kg, respectively. Besides routine monitoring, impedance cardiography monitor was used to measure cardiac output (CO), cardiac index (CI), stroke volume (SV), thoracic fluid content (TFC), and systemic vascular resistance (SVR). Three phases were defined for data collection: A, prior to CO₂ insufflation; B during gas insufflation (at 10, 5, and 2 mm Hg intrathoracic pressures); and C, after gas deflation. Repeated-measures analysis of variance (ANOVA) was used for statistical analysis and post hoc Bonferroni test for multiple comparisons of the data obtained. For all comparisons, \( P < 0.05 \) was considered significant. Systemic vascular resistance significantly increased at stages B10 and 5 compared with stage A mean values (\( P < 0.05 \)). CO, CI, and SV mean values decreased significantly at stage B compared with stage A mean values. The mean values of thoracic fluid content at stages A, B10, B5, and C were 53 ± 5.30.6 ± 3.5, 31 ± 3.4, 31.6 ± 3.3, and 32.5 ± 6.84%, respectively with significant differences (\( P < 0.05 \)). Significant reductions of cardiac parameters were reported in the present study, but they were of minimal clinical significance. Of interest was the significant reduction of thoracic fluid content during CO₂ insufflation, whether it correlates to the magnitude of compression, caused by CO₂ insufflation accompanied by high systemic vascular resistance or sympathectomy procedure, yet to be further studied.

Key Words: dorsal sympathectomy, impedance cardiography, general anesthesia

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Endoscopic thoracic sympathectomy (ETS) is a minimally invasive procedure for treating intractable palmar hyperhidrosis (PH). Sympathectomy at T2-3 or T3-4 sympathetic ganglia that are involved in direct sympathetic innervation of the heart can lead to hemodynamic changes, namely, heart rate alteration. In another study, it was found that it attenuates reflex tachycardia during head-up tilt in lightly anesthetized patients with essential PH. In a similar study using echocardiography, it was found that following sympathectomy, heart rate, systemic blood pressure, and mean blood pressure were reduced, whereas left ventricular end-systolic volume index, cardiac index, and ejection fraction did not change. General anesthesia is commonly used for ETS, with 1-lung collapsed ventilation, which can be achieved either by endobronchial anesthesia or by interpleural carbon dioxide (CO₂) insufflation combined with tracheal anesthesia. General anesthesia with single-lumen tracheal intubation combined with interpleural CO₂ insufflation is our preferred technique during ETS. In a previous report on hemodynamic changes during ETS using a noninvasive cardiac output monitor, we found that although cardiac output, cardiac index, and stroke volume showed statistical significant changes, they were of marginal clinical significance. The assessment of hemodynamics using impedance cardiography (ICG) becomes an accepted and reliable method. In addition to cardiac output, cardiac index, and stroke volume, thoracic fluid content and measures of diastolic function can be determined with impedance cardiography. In the present study, we examined the hemodynamic changes during thorascopic sympathectomy under general anesthesia using impedance cardiography. To the best of our knowledge, this is the first study on the use of impedance cardiography monitor during endoscopic thoracic sympathectomy.

PATIENTS AND METHODS
After written informed consent for surgery and research was obtained and hospital ethics committee approval, 17 adult patients (15 males) scheduled to undergo elective unilateral ETS (10 right side and 7 left side procedure) for treatment of PH were enrolled in the study. All procedures were performed by the same surgeon who used a 3-insertion technique and clip application. Patients with cardiopulmonary disease were excluded from the study. The physical status of the patients was determined according to the American Society of Anesthesiologists (ASA) classification I or II. Preoperative chest x-ray...
was taken for all patients to exclude any lung pathology. Premedication for all patients was achieved with oral 2 mg lorazepam 2 hours preoperatively. Their age, height, and weight mean values were 26.5 ± 5 years, 166.4 ± 6.8 cm, and 71.9 ± 11.5 kg, respectively.

Intraoperative monitoring consisted of electrocardiogram (ECG) lead II, heart rate, arterial oxygen saturation (SpO₂) measured by pulse oximeter, blood pressure measured by a noninvasive automated method, end-tidal CO₂ (EtCO₂), and body temperature by the rectal route (Hewlett Packard, Sarino, Italy). Induction of anesthesia was achieved with 0.1 μg/kg sufentanil and 3 mg/kg propofol followed by 0.1 mg/kg cisatracurium to facilitate single-lumen tracheal intubation. The patients' lungs were ventilated with 50% oxygen (O₂) in nitrous oxide (N₂O) and 1 MAC sevoflurane using an anesthesia delivery unit (Datex Ohmeda type A Elec, Promma, Sweden) with a tidal volume of 10 ml/kg, respiratory rate of 10 breaths/min, and inspiration time of 33% of respiratory cycle time including a 10% end-inspiratory pause for both 2-lung and 1-lung ventilation. Incremental doses of sufentanil and cisatracurium were given when required. Patients were positioned supine, with 30 degrees higher tilt of the ipsilateral thorax. A Veress needle was inserted into the pleural space through a small incision in the third or fourth intercostal space of the operated side, and CO₂ was insufflated at a rate of 0.5–1 L/min and intrathoracic pressure of 10 mm Hg to achieve lung collapse. Then the pressure was reduced and maintained at 5 and later 2 mm Hg throughout the rest of the procedure. At the end of surgery, a silastic chest tube was inserted, connected to an underwater seal system and the lung allowed to expand fully with positive pressure ventilation, then the tube was removed. Upon completion of surgery, 1.2 mg atropine and 2.5 mg neostigmine were given intravenously and the trachea was extubated. The patients then were sent to the recovery room and later to the ward after chest x-ray examination to rule out pneumothorax.

Impedance cardiography monitor (Cardio Dynamics International Corporation, Bioz ICG, model 4110, California) was used for measuring thoracic fluid content, acceleration index (ACI: index of contractility) and heart rate. It calculates cardiac output, cardiac index, and stroke volume. It employs a tetrapolar lead system with paired inner electrodes placed on either side in the supracavicular fossa just above the level of the suprasternal notch and along the mid-axillary line at the level of the xiphoid. The outer electrodes are placed 6 cm cephalad and caudal, respectively. The software program used a modification of the Sramek-Bernstein equation based on empirical corrections for body habitus. A single measurement of impedance cardiac output was made once each minute from all cardiac cycles over an 8-second interval, by computing beat-by-beat stroke volume and multiplying by heart rate. For statistical analysis, 3 phases were defined: A, prior to CO₂ insufflation; B, during gas insufflation (at 10, 5, and 2 mm Hg, intrathoracic pressures); and C, after gas deflation. Statistical analyses were performed using a computer program (SPSS version 11.0 for Windows; SPSS Inc., Chicago, IL). The results were expressed as mean ± SD. Repeated-measures ANOVA was used for analysis of differences in the data before, during, and after lung collapse, and post hoc Bonferroni test for multiple comparisons of the data obtained. For all comparisons, P < 0.05 was considered significant.

RESULTS

There was no significant difference in heart rate and mean arterial blood pressure (MAP) during stages A, B10, and C (P > 0.05) (Figs. 1 and 2). The mean values of acceleration index at stages A, B, and C were, respectively, 123.5 ± 30, 91 ± 28, and 108.8 ± 48/100 s with nonsignificant differences (P > 0.05). The mean values of thoracic fluid content at stages A, B10, 5, 2, and C were, respectively, 33 ± 5, 30.6 ± 3.5, 31 ± 3.4, 31.6 ± 3.3, and 32.5 ± 6.8/kΩ, with significant differences (P < 0.05) (Fig. 3). The mean values of cardiac output at stages A, B10, 5, 2 and C were, respectively, 5.7 ± 1, 4.5 ± 1, 4.8 ± 1, 5.4 ± 0.9, and 5.9 ± 1.1 L/min with significant differences at B10 and 5 compared with stage A (P < 0.05). Cardiac index mean values at stages A, B10, 5, 2 and C were, respectively, 3.2 ± 0.4, 2.6 ± 0.3, 2.7 ± 0.4, 3.1 ± 0.3, and 3.3 ± 0.6, with significant differences at B10 and 5 compared with stage A mean value (P < 0.05) (Fig. 4). Systemic vascular resistance mean values showed significantly high values at stages B10 and 5 compared with stage A mean values (Fig. 5). The mean values of stroke volume at stages A, B10, 5, 2, and C were, respectively, 74.8 ± 19.5, 60.8 ± 16, 65.3 ± 17, 66.4 ± 10.6, and 64.3 ± 16.7 ml/beat, with significant differences at stage B compared with stage A (P < 0.05) (Fig. 6).

DISCUSSION

In this study, we examined the hemodynamic changes during endoscopic thoracic sympathectomy using impedance cardiography monitor. Evaluation of the hemodynamic response to CO₂ insufflation during ETS has been studied in several reports before. CO₂ insufflation into the pleural space during 1-lung anesthesia for thoracoscopic surgery is used in some centers to improve surgical access, even though this practice has been associated with well-described cardiovascular compromise. Recently, a case was reported of 35-year-old woman undergoing thoracoscopic left dorsal

![Heart Rate](image-url)
sympathectomy for hyperhidrosis who experienced bradycardia and hypotension during gas insufflation that resolved promptly with the release of the gas. In a previous study using noninvasive cardiac output monitoring, we found that compared with a left-sided sympathectomy procedure, direct compression during CO2 against the vena cava and right atrium and ventricle during right-sided ETS caused reduction of cardiac output, cardiac index, and stroke volume. In the present report, we could not study the differential effects of CO2 insufflation due to smaller sample size in both groups. In another study, we concluded that tracheal anesthesia with and intrathoracic CO2 insufflation of pressure <6 mm Hg provided optimal operating conditions, adequate oxygenation, and perfect hemodynamic stability. Bioimpedance relies on the proportion of change in the conduction of alternating current applied across the thorax as a function of blood volume in the heart and great vessels. Stroke volume, cardiac output, thoracic fluid content, and measures of diastolic function and systemic vascular resistance can be determined with bioimpedance. Impedance cardiography is an accepted method for safe, reliable, and reproducible assessment of hemodynamics in patients with cardiac disease. Thoracic fluid content is a specific parameter measured by impedance cardiography monitor. It represents total fluid volume in the chest, composed of both intravascular and extravascular fluid. Thoracic fluid content is calculated as the inverse of the baseline impedance measurement. Baseline impedance is directly proportional to the amount of conductive material (ie, blood, lung water) in the chest. In the present study, thoracic fluid content has significantly reduced during intrathoracic CO2 insufflation at different pressures, which may reflect the extent of pressure exerted by CO2 gas. Also we have demonstrated a significant increase in systemic vascular resistance with high pressure values of CO2 insufflation. Whether high systemic vascular resistance has led to reduction of thoracic fluid content has yet to be further studied. In a recently published study on morbidity obese patients who underwent laparoscopic gastric band surgery, we have demonstrated high systemic vascular resistance values during CO2 insufflation that continued to be significantly high during the recovery period. In the present study, we have demonstrated significant reduction of cardiac output, cardiac index, and stroke volume during CO2 insufflation which is in accordance to previous published reports.

In conclusion, although during ETS significant changes in hemodynamic parameters were found in the present study, they were of minimal clinical significance. Of interest was the significant reduction of thoracic fluid content during CO2 insufflation, whether it correlates with the magnitude of compression and with subsequent hemodynamic changes caused by CO2 insufflation, namely, an increase in systemic vascular resistance or caused by the sympathectomy procedure itself, is still to be studied.
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REFERENCES