Surgical Endoscopy (2019) 33:3287–3290
https://doi.org/10.1007/s00464-018-06614-9

Single lumen endotracheal intubation with carbon dioxide insufflation for lung isolation in thoracic surgery

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Received: 17 October 2018 / Accepted: 23 November 2018 / Published online: 3 December 2018

Abstract

Introduction Double lumen tube (DLT) intubation is used for lung isolation but is not without disadvantages including increased intubation time, anesthesia expertise, risk of airway trauma, and costs over single lumen tube (SLT) intubation. SLT intubation with CO_2 insufflation can be used as an alternative for lung isolation. We reviewed our experience with this technique during thoracoscopic surgery.

Methods We performed a retrospective review of a prospectively maintained IRB-approved database from 2009 to 2018. Operations were performed with CO_2 insufflation up to 15 mmHg. Indications for surgery, operative details, intraoperative complications, pathology, and postoperative complications were reviewed.

Results We identified 123 patients (70 females [57%]) with a median age of 40 years (range 16–80 years) and a median BMI of 26.2 kg/m^2 (range 15–59 kg/m^2) that underwent minimally invasive thoracoscopic procedures with this technique. Procedures included: mediastinal mass resection or biopsy (41%), sympathectomy (37%), wedge resection (10%), first rib resection (6%), diaphragm plication (2%), segmentectomy (2%), decortication (2%), pleural biopsy (2%), and pericardial cyst resection (1%). Median operative time was 90 min (range 25–584 min) and median intraoperative blood loss was 10 mL (range 2–200 mL). Intraoperative hemodynamic parameters were obtained at procedure start, 1 h after CO_2 insufflation, and at procedure completion: we observed significant changes in heart rate and systolic blood pressure ($P = 0.027$ and $P < 0.001$, respectively) although clinically inconsequential. Mean end-tidal CO_2 1 h after insufflation was 36.6 ± 4.5 mmHg. There were no intraoperative complications and no conversions to a DLT. Median length of stay was 1 day (range 0–14 days). Five complications (4%) were observed and no mortalities.

Conclusions SLT intubation and CO_2 insufflation is a feasible and safe alternative to DLT intubation for lung isolation. This can be a useful strategy to accomplish lung isolation for some thoracoscopic procedures, in particular when expertise for DLT placement is unavailable.

Keywords Single-lumen tube intubation · Carbon dioxide insufflation · Thoracic surgery · Minimally invasive thoracic surgery

Over the last decade minimally invasive approaches have been increasingly utilized for complex thoracic procedures without compromising outcomes. Successful minimally invasive thoracic procedures mandate lung isolation typically achieved with double lumen tube (DLT) intubation. DLT intubation allows excellent exposure and visualization, facilitating successful completion of the procedure. This technique is not without its disadvantages, however. DLT intubation requires expert placement and confirmatory bronchoscopy, resulting in increased intubation time and costs for the institution [1, 2]. Additionally, DLT intubation is associated with airway trauma [3, 4].

Two-lung ventilation with single lumen tube (SLT) intubation can be used as an alternative to DLT intubation in thoracoscopic surgery. Cerfolio and colleagues described the feasibility of SLT intubation and thoracoscopy in the completion of pleural biopsies, drainage of pleural effusions, and talc pleurodesis [1]. Furthermore, insufflation of

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the thoracic cavity with carbon dioxide (CO_2) to improve exposure has been primarily reported in the context of thoracoscopic sympathectomies [5, 6]. Use of SLT intubation and CO_2 insufflation for lung isolation has been shown to be safe for thoracoscopic wedge resections [7]. However, use of this technique in a wide variety of thoracoscopic procedures is lacking in the literature. We reviewed a single surgeon's experience with SLT intubation and CO_2 insufflation in a variety of minimally invasive thoracic procedures.

Methods

A retrospective review was performed of a prospectively maintained database of minimally invasive thoracic procedures. From 2009 to 2018, one surgeon (MBM) performed 123 thoracoscopic cases using SLT intubation and CO_2 insufflation without lung isolation. CO_2 insufflation was used up to 15 mmHg. Indications for surgery, operative details, intraoperative complications, pathology, and postoperative complications were reviewed. An ANOVA was used to determine statistical significance. A P value of <0.05 was considered significant. This study was approved by the Institutional Review Board.

Results

A total of 123 patients underwent minimally invasive thoracoscopic procedure with SLT intubation and CO_2 insufflation. Patient characteristics and surgical indications are presented in Table 1. Median age was 40 years (range 16–80 years). The median BMI was 26.15 kg/m^2 (range 15–59 kg/m^2). The most common comorbidities included hypertension (28 of 123 [22.8%]), diabetes (10 of 123 [8.1%]), and asthma (9 of 123 [7.3%]). The majority of patients did not have a smoking history (80 of 123 [65%]) and 48% (59 of 123) were ASA class II. The most common indications for surgery included hyperhidrosis (36.6%), anterior mediastinal mass/lymphadenopathy (26%), and myasthenia gravis (13.8%). Procedures performed with this technique are described in Table 2. The most common procedures included mediastinal mass excision/biopsy (50 of 123 [40.7%]), sympathectomy (46 of 123 [37.4%]), and wedge resection (12 of 123 [9.8%]).

Surgical approaches included VATS (113 of 123 [91.9%]) and robotic (10 of 123 [8.1%]). Intraoperative parameters were collected from the anesthesia records and reported in Table 3. Intraoperative vitals were collected at the start of the procedure, 1 h after CO_2 insufflation, and at the completion of the procedure. There was a significant difference in mean heart rate during the case (76.1 ± 15.6 beats per minute [bpm] vs. 76.3 ± 14.5 bpm vs. 80.7 ± 14.8 bpm; $P=0.027$). Additionally, there was a significant difference in mean systolic blood pressure (111.5 ± 18.2 mmHg vs. 113.1 ± 17.2 mmHg vs. 121.9 ± 19.9 mmHg; $P<0.001$). There was no significant difference in mean diastolic

Table 1 Patient characteristics

Characteristics	*N* (%)
Gender	
Female	70 (56.9)
Male	53 (43.1)
Age (years), median (range)	40 (16–80)
BMI (kg/m^2), median (range)	26.15 (15–59)
Comorbidities	
Hypertension	28 (22.8)
Diabetes	10 (8.1)
Asthma	9 (7.3)
History of pulmonary embolism	5 (4.1)
Coronary artery disease	3 (2.4)
COPD	3 (2.4)
History of stroke	2 (1.6)
Smoking history	
Never smoker	80 (65.0)
Current smoker	10 (8.1)
Former smoker	33 (26.8)
ASA classification	
I	20 (16.3)
II	59 (48.0)
III	42 (34.1)
IV	2 (1.6)
Indication for surgery	
Hyperhidrosis	45 (36.6)
Anterior mediastinal mass/lymphadenopathy	32 (26.0)
Myasthenia gravis	17 (13.8)
Pulmonary nodule	11 (8.9)
Thoracic outlet syndrome	8 (6.5)
Other	11 (8.9)

Table 2 Cases performed with single lumen endotracheal tube and carbon dioxide insufflation

Case ($N=123$)	*N* (%)
Mediastinal mass resection/biopsy	50 (40.7)
Sympathectomy	46 (37.4)
Wedge resection	12 (9.8)
First rib resection	7 (5.7)
Diaphragm plication	2 (1.6)
Segmentectomy	2 (1.6)
Decortication	2 (1.6)
Pleural biopsy	2 (1.6)
Pericardial cyst resection	1 (0.8)

Table 3 Intraoperative parameters

Parameter	Procedure start	1 h after CO_2 insufflation	Procedure completion	*P* value
FiO_2	–	70.2 ± 19.8	–	–
SaO_2 (%)	–	98.8 ± 2.2	–	–
$ETCO_2$ (mmHg)	–	36.6 ± 4.5	–	–
Heart rate (bpm)	76.1 ± 15.6	76.3 ± 14.5	80.7 ± 14.8	0.027
SBP (mmHg)	111.5 ± 18.2	113.1 ± 17.2	121.9 ± 19.9	< 0.001
DBP (mmHg)	60.9 ± 10.4	62.5 ± 10.4	63.5 ± 11.0	0.175

Values are mean ± SD

FiO_2 fraction of inspired oxygen, *SaO_2* oxygen saturation, *$ETCO_2$* end-tidal CO_2, *SBP* systolic blood pressure, *DBP* diastolic blood pressure

Table 4 Operative outcomes

Parameter	*N* (%)
Intraoperative blood loss (mL), median (range)	10 (2–200)
Operative time (min), median (range)	90 (25–584)
Hospital stay (days), median (range)	1 (0–14)
Pathology	
Benign	49 (39.8)
Malignant histology	10 (8.1)
Metastatic cancer	10 (8.1)
N/A	54 (43.9)
30-Day re-admission	1 (0.8)
90-Day complications	5 (4.1)
Pneumothorax	2 (1.6)
Re-intubation	1 (0.8)
Air leak	1 (0.8)
Pleural effusion	1 (0.8)
90-Day mortality	0

blood pressure (60.9 ± 10.4 mmHg vs. 62.5 ± 10.4 mmHg vs. 63.5 ± 11.0 mmHg; $P = 0.175$). Finally, 1 h after CO_2 insufflation mean FiO_2 was 70.2 ± 19.8, mean SaO_2 was 98.8 ± 2.2%, and mean $ETCO_2$ was 36.6 ± 4.5 mmHg. There were no adverse intraoperative events. No cases were converted to thoracotomy and no cases required conversion to a DLT.

Operative outcomes are described in Table 4. Median operative time was 90 min (range 25–584 min) and median intraoperative blood loss was 10 mL (range 2–200 mL). Median length of hospital stay was 1 day (range 0–14 days). There was one (0.8%) 30-day re-admission. There was 1 (0.8%) minor complication (Grade < IIIa) and 4 (3.2%) major complications (Grade ≥ IIIa). Complications included pneumothorax requiring chest tube placement (2 of 123 [1.6%]), re-intubation (1 of 123 [0.8%]), air leak (1 of 123 [0.8%]), and pleural effusion requiring chest tube placement (1 of 123 [0.8%]). There were no mortalities. Median follow-up was 20 days (range 2 days to 5 years).

Discussion

The use of minimally invasive approaches for a variety of complex thoracic procedures has significantly increased in the last decade. This shift away from thoracotomy has improved patient outcomes and is well documented. Traditionally, minimally invasive thoracic surgery is performed with single-lung ventilation allowing the non-operative lung to be ventilated throughout the case. Intubation with a DLT enables single-lung ventilation and offers excellent visualization of the operative field. However, placement of a DLT has its inherent disadvantages such as the risk of tracheobronchial trauma and vocal cord injury [2]. Additionally, placement of a DLT may not be feasible in all patients. Patients with prior head and neck surgery or radiation, morbidly obese, or those with congenital anomalies may not be ideal candidates for this technique. Placement of a DLT requires expertise and a fiberoptic bronchoscope must be readily available for confirmation of correct placement. These additional steps result in increased total operating room time and costs (both, as a result of increased operating room time and DLT use) to the institution [7].

SLT intubation and CO_2 insufflation for lung isolation is an alternative to DLT intubation for minimally invasive thoracic surgery. SLT intubation and CO_2 insufflation have been previously described in thoracoscopic sympathectomies [5, 6]. Sancheti and colleagues have also described the safety of this technique during thoracoscopic wedge resections compared to DLT intubation. The authors found a significant decrease in operating room time, time to incision, and operative time with SLT intubation and CO_2 insufflation compared to DLT intubation. They did not report any intraoperative hemodynamic compromise or complications in their series of 65 patients [7].

The literature is lacking, however, with regard to the use of SLT intubation and CO_2 insufflation in a wide variety of thoracic procedures. At our institution, we employed this technique during a variety of minimally invasive thoracic procedures to resolve some of the abovementioned

disadvantages with DLT intubation. SLT intubation with CO_2 insufflation provides an excellent working space by enabling collapse of the lung and diaphragm away from the operative field. In this series, 123 patients had various comorbidities; median BMI was 26.15 kg/m^2 (range 15–59 kg/m^2) and underwent a variety of thoracoscopic procedures with this technique. Although we initially began using SLT intubation with CO_2 insufflation for thoracoscopic sympathectomies, we broadened its use in other procedures when we observed an improvement in operative time, increased efficiency with rapid lung collapse, safety, and rapid postoperative recovery. We have found this technique especially useful in patients with respiratory failure who cannot tolerate single-lung ventilation.

However, routine use of this technique has been slow to adopt as a result of several theoretical disadvantages. One of the concerns with this technique is the theoretical risk of hemodynamic compromise with the creation of a tension pneumothorax by CO_2 insufflation. However, some have demonstrated the lack of deleterious effects on patients' hemodynamics with low-pressure insufflation [7–9]. In our series, we did not observe clinically relevant changes in intraoperative vitals with the use of CO_2 insufflation up to 15 mmHg. The risk of acidosis with CO_2 insufflation is another concern [10, 11]. However, mean intraoperative $ETCO_2$ in this series was 36.6 ± 4.5 mmHg after 1 h of CO_2 insufflation up to 15 mmHg. This was still within the acceptable range of permissive hypercapnia and no patient required interruption of CO_2 insufflation. Furthermore, in this series, we did not observe intraoperative complications and no cases were converted to a DLT.

Five patients (4%) suffered 90-day complications. One patient with no significant medical history underwent an uncomplicated VATS thymectomy and required postoperative re-intubation for respiratory failure. She was extubated on postoperative day 1 and discharged home on postoperative day 5. Two patients had a postoperative pneumothorax requiring IR-guided chest tube placement. One patient was re-admitted with a pleural effusion requiring IR-guided chest tube placement. The fifth patient had a persistent air leak managed conservatively. There were no re-operations or mortalities in this series.

This study has several limitations. First, all procedures described were performed by one surgeon at a single institution. Second, patients described in this series were relatively young and had few significant comorbidities suggesting careful preoperative patient selection. Additionally, this is a retrospective study with its inherent limitations. Further multi-institutional studies must be performed to evaluate the feasibility and applicability of this technique in increasingly complex thoracic procedures.

SLT intubation and CO_2 insufflation is a useful strategy to accomplish lung isolation for a variety of thoracoscopic procedures, in particular when expertise for DLT placement is unavailable. In this series, we did not observe intraoperative complications or hemodynamic compromise with the use of this technique. SLT intubation and CO_2 insufflation is a feasible, efficient, and safe alternative to DLT intubation for lung isolation.

Compliance with ethical standards

Disclosures Raul Caso, Colleen Hamm Kelly, M. Blair Marshall declare that they have no conflicts of interest or financial ties to disclose.

Informed consent Written consent was not required as this was not an experimental study.

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