Original contribution

Use of the Rapiscope vs chest auscultation for detection of accidental bronchial intubation in non-obese patients undergoing laparoscopic cholecystectomy

Tiberiu Ezri MD (Head), Vadim Khazin MD (Deputy Head), Peter Szmuk MD (Director), Benjamin Medalion MD (Attending), Pinhas Shechter MD (Attending), Israel Priel MD (Head), Mordechai Loberboim MD (Director), Avi A. Weinbroum MD (Director)

Department of Anesthesia, Edith Wolfson Medical Center, Holon 58100, Israel
Department of Cardiothoracic Surgery, Edith Wolfson Medical Center, Holon 58100, Israel
Department of Surgery, Edith Wolfson Medical Center, Holon 58100, Israel
Department of Pulmonology, Edith Wolfson Medical Center, Holon 58100, Israel
Unit of Nuclear Medicine, Edith Wolfson Medical Center, Holon 58100, Israel
Post-Anesthesia Care Unit, Tel Aviv Sourasky Medical Center, Tel Aviv, Israel
Post-Anesthesia Care Unit, University of Texas Medical School, Houston, TX, USA
Outcomes Research Institute, University of Louisville, KY, USA

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Abstract

Study Objective: Main stem bronchial intubation is not always detected by routine means and may occur more frequently during laparoscopic procedures. Tracheal tube positional changes in non-obese patients undergoing laparoscopic cholecystectomy were detected by either the Rapiscope (Cook Critical Care, Bloomington, Ind) or chest auscultation.

Design: Prospective, double-blind, crossover study.

Setting: University hospital.

Patients: Forty non-obese patients (BMI <28 kg·m⁻²), aged 18 to 80 years, American Society of Anesthesiologists risk class I-III, who underwent elective laparoscopic cholecystectomy were enrolled in this double-blind, prospective study.

Interventions: After endotracheal intubation by one anesthesiologist, two other anesthesiologists assessed the tracheal tube’s positioning by either the Rapiscope or chest auscultation; the results of one anesthesiologist’s measurement were concealed from the other.

Keywords: Bronchial intubation; Detection; Chest auscultation; Rapiscope
1. Introduction

Correct positioning of the tip of the tracheal tube is essential to avoid bronchial intubation or accidental extubation. For safe positioning, the tip of the tracheal tube should lie 2.5 to 4 cm above the carina [1] or, after chest x-ray, at the level of mid-trachea [2]. Intraoperative accidental bronchial intubation is not always detected by routine means; a flexible fiberoptic endoscope can be used as well but its use is cumbersome and costly.

In a previous study, we demonstrated that tracheal tubes move 3 times more often in obese patients undergoing laparoscopic procedures as compared with those having open surgical procedures [3]. Although the clinical criteria for determining the position of the endotracheal tube has been bronchial auscultation, that approach has an undetermined false-positive rate. Based on our earlier study [3], we assumed that the Rapiscope (Cook Critical Care, Bloomington, Ind) with the millimetric tape attached to its optical fiber would be a more precise and safe method to use, especially during procedures that involve obese patients as well as by representing a method of estimating the actual tube position.

The present study investigated the reliability of the Rapiscope vs conventional methods, such as standard chest auscultation, inspiratory pressures, ETCO₂, or SpO₂, in detecting intraoperative tracheal tube tip’s positional changes in non-obese patients undergoing laparoscopic cholecystectomy.

2. Materials and methods

The study was performed at Wolfson Medical Center. After the Institutional Ethics Committee had approved the study, all enrolled patients gave their written informed consent. Forty non-obese patients (BMI < 28 kg · m⁻²), aged 18 to 80 years, American Society of Anesthesiologists risk class I-III, who underwent laparoscopic cholecystectomy were enrolled in this double-blind, prospective study. Excluded were patients with past bronchial, upper airway, or lung surgery or with concurrent lung disease.

General anesthesia was induced with propofol 2 to 2.5 mg · kg⁻¹ and midazolam 1 mg IV; oral tracheal intubation was facilitated by rocuronium 0.6 mg · kg⁻¹. Anesthesia was maintained with N₂O:O₂ (60%:40%), isoflurane, rocuronium, and aliquots of fentanyl as deemed necessary by the attending anesthesiologist who performed the tracheal intubation and who was in charge of the anesthesia course. Patients were mechanically ventilated through a circle system in the volume mode, delivering a tidal volume of 7 mL · kg⁻¹ at a rate of 10 breaths per minute and an inspiration-to-expiration ratio of 1:2. When introducing the tracheal tube, the blue line mark sited 1 cm above the cuff was constantly placed just beyond the vocal cords; the tube was then firmly secured [4] with adhesive tape at the levels of the patient’s lips as is the standard in our institution. All the tubes (Portex, SIMS Portex Ltd, Hythe, Kent, UK) were uncut and were of ID 8 mm for males and 7 mm for females. The cuff pressure was maintained between 20 and 25 cm H₂O [5] and monitored by a manometer (Control-Inflator, VBM, Sulz am Neckar, Germany).

The Rapiscope was inserted through the tracheal tube via a swivel connector. The Rapiscope (Fig. 1) is a battery-powered, single-fiber (1.6 mm external diameter, 70 cm long), flexible fiberscope. The single fiber is easily replaceable for which there is no chance of cross-infection among patients. The sterilization process of the replaceable fiber is similar to other fiber endoscopes. We attached a scale (in millimeters) printed on the fiber of the Rapiscope that enabled to indicate the exact distance of the tip of the tracheal tube to the carina.

In this crossover study, after intubation by one anesthesiologist, two other anesthesiologists assessed the tracheal tube’s positioning in each patient by either the Rapiscope or chest auscultation. Standard chest auscultation consisted of listening with a stethoscope to 2 breaths...
bilaterally in both the axilla and lung apex. The anesthesiologist recorded whether he heard breath sounds over the lungs and if the tube needed to be repositioned. All 3 anesthesiologists were experienced attending physicians. The order of the means of assessing the tube's position by either the Rapiscope or chest auscultation was randomized using the closed envelope method. Each of the two assessing anesthesiologists was “blinded” to the data recorded by one another. The anesthesiologist in charge of the case (the one who performed the intubation and conducted the anesthesia) changed the tracheal tube's position if one of the two blinded anesthesiologists recommended it. Bronchial intubation was defined as such when the tip of the tracheal tube was positioned beyond the carina; if this occurred, the tube was repositioned to the original (first measurement: baseline) position with the aid of the Rapiscope. Postintubation measurements were considered as “baseline” to which all subsequent measurements were compared during the procedure. The two protocol-blinded anesthesiologists performed evaluations during surgery at the following time points:

1. after intubation (~5 minutes)—baseline values in all patients;
2. Five minutes after 30° head-down positioning;
3. Five minutes after maximal abdominal insufflation (15 mm Hg);
4. Five minutes after 30° head-up position;
5. Just before (~5 minutes) extubation.

Oxyhemoglobin saturation (SpO₂), ETCO₂, and peak inspiratory pressure (PIP) values were also recorded at each time point, each recorded figure representing the average of three consecutive measurements.

2.1. Statistics

The primary end point of the study was detection of bronchial intubation by the Rapiscope vs chest auscultation in non-obese patients undergoing laparoscopic cholecystectomy. Secondary end points were detection of any other position change of the tracheal tube in the airway and detection of endobronchial intubation by other means (SpO₂, ETCO₂, and PIP) besides Rapiscope and chest auscultation.

All data were reported as mean ± SD. Analysis of variance with repeated measures was used to compare tracheal tube’s tip position, SpO₂, ETCO₂, and PIP trends at each time point. The χ² test was used to compare the number of occasions in which changes in tracheal tube position were detected by the Rapiscope and by the other clinical means. The paired t test was used to evaluate changes in SpO₂. P ≤ 0.05 indicates a statistically significant difference.

3. Results

The mean age of the cohort population was 56 ± 18 years; 22 (55%) patients were females and 18 (45%) males. The duration of the procedures was 45 ± 17 minutes. All procedures concluded without complications and patients were extubated on the table, uneventfully.

Baseline assessments (~5 minutes after intubation) via the Rapiscope and by auscultation and SpO₂, ETCO₂, and PIP showed normal tracheal positioning of the tube’s tip and normal bilateral breath sounds, with no changes in SpO₂, ETCO₂, or PIP in any patient. The Rapiscope baseline
The Rapiscope detected changes in the tracheal tube position 16 times during surgery, equally distributed between sexes, and of which, 12 involved downward movements (Table 1). Rapiscope data revealed that there was no difference in mean baseline distance of the tube’s tip to the carina between the patients who later experienced bronchial intubation and those who did not (36 ± 5 vs 39 ± 6 mm, respectively). Overall, the mean cephalad movement of the tube after table positioning to 30° head-up position was 17 ± 7 mm, whereas the mean downward movement after changing the table position to 30° head-down position was 36 ± 8 mm. The maximal abdominal inflation lead to a mean downward movement of the tube’s tip of 35 ± 7 mm.

The Rapiscope detected that the tube advanced into the right bronchus in 8 patients, half the cases after maximal abdominal insufflation, and the other half after moving the table from neutral to 30° head-down position. Chest auscultation detected bronchial intubation in 2 cases as compared with 8 by the Rapiscope (P = 0.01, Table 1).

In contrast, the values of ET\textsubscript{CO}2, SpO\textsubscript{2}, and PIP were not different from baseline values in the instances when bronchial intubation was recorded either by the Rapiscope or by auscultation.

There were 4 additional events of tracheal tube downward movements (not related to changes in table position or abdominal inflation with gas), which were detected before extubation, albeit not entering the bronchus, and 4 events that involved cephalad migrations of the tracheal tube’s tip, which occurred after the changes to head-up position. In all these cases, only the Rapiscope was used to identify tracheal tube position changes.

4. Discussion

In this prospective, controlled, double-blind study, the Rapiscope precisely assessed the position of the tube’s tip in all patients under all conditions. It enabled the identification of 4 events where the tip moved endobronchially after maximal abdominal insufflation and 4 cases after the table position was changed from a neutral to a 30° head-down position. In 16 cases, the Rapiscope visualized downward or cephalad migration of the tube position endotracheally. In comparison, chest auscultation detected bronchial intubation in only two cases, leading to the conclusion that the Rapiscope seems especially useful during procedures in which tracheal tube movements are likely.

Changes in the operating table position and abdominal gas insufflation during laparoscopy [6,7] as well as flexion of the head [8] might cause tracheal tube movement into the bronchial main stem. In obese patients, laparoscopic procedures increase the likelihood for bronchial intubation when compared with open abdominal surgeries [3]. The true incidence of accidental bronchial intubation has not been established. Accidental bronchial intubation reportedly occurred in 2.4% of patients in one pediatric ICU population [9]. In the Australian Incidence Monitoring study, accidental bronchial intubation was recorded in 154 (3.7%) of 3947 incidents [10]. In this latter study, one third of the affected cases were associated with head or neck surgery and with possible flexion of the patient’s head. Noteworthy, taping the endotracheal tube at a predetermined distance did not guarantee the avoidance of the tube migration or endobronchial intubation [11].

With the Rapiscope, we show in the present study that bronchial intubation could also happen in non-obese patients undergoing laparoscopic surgery: 4 of our patients reinforced earlier reports that head-down position might be associated with an increased risk of bronchial intubation [6] due to a cephalad movement of the lungs, which pushes the bronchi toward the tip of the tracheal tube. As what happened with the 4 other cases of bronchial intubation, additional movement of the mediastinum might be caused by the abdominal gas inflation [7,11,12]. This may be further exaggerated in obese patients [3,13]. The range of the change in the tracheal tube tip’s position may also depend upon the method of taping of the tracheal tube [2]. Females might present a higher incidence of migration than

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### Table 1  Characteristics of endotracheal tube movements (n = 16); endobronchial intubations (n = 8) detected by the Rapiscope vs chest auscultation and changes by other clinical means

<table>
<thead>
<tr>
<th>Modes of assessment →</th>
<th>Rapiscope</th>
<th>Chest auscultation</th>
<th>SpO\textsubscript{2} (%)</th>
<th>ET\textsubscript{CO}2 (mm Hg)</th>
<th>PIP (cm H\textsubscript{2}O)</th>
<th>P (\textit{χ}\textsuperscript{2} test)\textsuperscript{a}</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline (after intubation)</td>
<td>–</td>
<td>–</td>
<td>98 ± 2</td>
<td>38 ± 4</td>
<td>22 ± 3</td>
<td>–</td>
</tr>
<tr>
<td>30° Head-down position</td>
<td>4</td>
<td>1</td>
<td>97 ± 2</td>
<td>35 ± 3</td>
<td>24 ± 3</td>
<td>0.22</td>
</tr>
<tr>
<td>Maximal insufflation</td>
<td>4</td>
<td>1</td>
<td>97 ± 3</td>
<td>37 ± 3</td>
<td>26 ± 2</td>
<td>0.22</td>
</tr>
<tr>
<td>30° Head-up position</td>
<td>4</td>
<td>0</td>
<td>98 ± 2</td>
<td>37 ± 2</td>
<td>24 ± 4</td>
<td>0.07</td>
</tr>
<tr>
<td>Before extubation</td>
<td>4</td>
<td>0</td>
<td>98 ± 2</td>
<td>35 ± 3</td>
<td>23 ± 3</td>
<td>0.07</td>
</tr>
<tr>
<td>Bronchial intubation</td>
<td>8</td>
<td>2</td>
<td>97 ± 2</td>
<td>36 ± 4</td>
<td>24 ± 3</td>
<td>0.01</td>
</tr>
<tr>
<td>(P) (ANOVA)</td>
<td>–</td>
<td>–</td>
<td>0.5</td>
<td>0.3</td>
<td>0.5</td>
<td>–</td>
</tr>
</tbody>
</table>

Values are expressed as absolute numbers or as mean ± SD. SpO\textsubscript{2} indicates pulse-derived arterial blood saturation; ET\textsubscript{CO}2, end-tidal carbon dioxide; PIP, peak inspiratory pressure; ANOVA, analysis of variance.

\(\textsuperscript{a}\) Statistical comparisons between the Rapiscope-originated and the chest auscultation–originated data.
males, for unexplained reasons [14]. This latter suggestion was not reconfirmed in our study.

The classical clinical means to establish a correct tracheal tube position is to pass the tube’s cuff 1 cm below the vocal cords [15]; this, however, may not guarantee that the same position will be maintained throughout the procedure. Other non–fail-safe methods for tracheal tube position assessment include chest auscultation, use of fix tube lengths (ie, 21 cm in females and 23 cm in males) [16], various tube length formulae, palpation of the tube’s cuff at the suprasternal notch [17], or the use of a lighted stylet inserted through the endotracheal tube [18].

Brunel et al [19] had previously demonstrated that chest auscultation might miss bronchial migration of the tracheal tube. In our study, 8 cases of bronchial intubation were detected by the Rapiscope, compared with only 2 by auscultation of the lungs and none by changes in SpO2, ETCO2, or PIP values.

In the report of McCoy et al [10], capnography remained normal or unremarkable during 88.5% of endobronchial intubation cases. The authors concluded that capnography is a nonsensitive diagnostic tool for detecting accidental bronchial intubation. The ETCO2 can increase, decrease, or remain unaltered, depending on the circumstances.

There are several explanations for the lack of change in PIP with accidental bronchial intubation. Firstly, the left lung was not in total collapse during surgery. Total collapse needs time to establish, especially when the left lung is still partially ventilated through the proximal (upper) part of the bevel of the tube in cases when only the tip of the tracheal tube is positioned in the main bronchus. Furthermore, our patients were relatively young and non-obese and presumably had normal lung compliances. In addition, breath sounds from the left side of the chest would not change or disappear until the tip enters the right mainstem bronchus, 1.5 to 3.2 cm for the Magill tube and 2.0 to 3.2 cm for the Murphy tube; the latter type of tube was used in the present study. These results further support our suspicion of the unreliability of the auscultation of bilateral breath sounds for confirming proper placement of the endotracheal tube [20]. Nevertheless, although the above-mentioned parameters did not change, endobronchial intubation is clinically dangerous and must be quickly recognized and corrected because the lung’s lobules become progressively hypoventilated and shrink and microatelectasis increases, all of which lead to hypoxemia and hemodynamic changes.

Although the chest x-ray is an accurate method, it is not always readily feasible or available in the operating theater. It is usually reserved to cases where blood desaturation and/or unexplained increase in peak inspiratory pressures are encountered. Fiberoptic bronchoscopy is a fail-safe method for real-time assessment of the endotracheal tube tip’s position within the trachea [8]. However, it is much more expensive than the Rapiscope (in Israel, it costs approximately £10000 per unit as compared with £300); thus, 33 operating rooms could be equipped with Rapisces for the cost of a single bronchoscope. In addition, because the fiber is replaceable, the use of the Rapiscope in a second patient can take place without delay. Owing to its chargeable battery, it does not require an external light source.

Our study demonstrated that changes in the tracheal tube tip’s position in non-obese patients undergoing laparoscopic surgery can be detected easily in the operating room by using the Rapiscope. We compared the reliability of chest auscultation, pulse oximetry, capnography, and peak inspiratory pressure with the effectiveness of the Rapiscope in detecting bronchial intubation and found the latter superior, not mentioning the usefulness in detecting nonendobronchial movements of the tracheal tube as well (ie, it may also detect accidental extubation). The Rapiscope was previously used for the detection of the tracheal tube’s tip position in both pediatric and adult intensive care patients and was found clinically useful and superior to chest auscultation [21,22], thus supporting our results. A recent study [23] also reported the usefulness of the Rapiscope in quickly diagnosing esophageal intubation. The use of a millimeter scale band printed on the fiber enhances the accuracy of the Rapiscope. This is one of the original ideas of our study. Furthermore, its intraoperative use was only once reported in our previous study [3] demonstrating that the tracheal tube moves more often in obese patients undergoing laparoscopic as compared with open abdominal procedures. Although the current study reconfirmed the high incidence of tube movements in laparoscopic procedures, it further emphasizes the occurrence of a surprisingly high incidence of accidental bronchial intubation even in non-obese patients.

As is the case with other endoscopic techniques [24], the use of the Rapiscope bears some limitations. One limitation is its relative ineffectiveness in the presence of blood and abundant secretions in the airways because suction cannot be done. Fogging also limits its use. Furthermore, the lack of a “lever” that can manipulate its tip in various directions might limit its access to the larynx in patients with difficult or abnormal airway anatomy, when used without a tracheal tube in place.

In conclusion, the Rapiscope was able to detect significantly more endobronchial intubations, as opposed to chest auscultation. It also detected minute movements of the tracheal tube within the trachea. The Rapiscope may become a routine means for the detection of the correct position of the endotracheal tube during such laparoscopic procedures.

References


