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ORIGINAL ARTICLE

Trainee impact on advanced diagnostic bronchoscopy: An analysis of 607 consecutive procedures in an interventional pulmonary practice

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ABSTRACT

Background and objective: **Complications during advanced diagnostic bronchoscopy are rare and include: pneumothorax, bleeding, mediastinitis and lymphadenitis. Increased complications have been demonstrated in patients undergoing routine bronchoscopy procedures performed by trainees. This study aimed to determine the impact of trainees during advanced diagnostic bronchoscopy on procedure time, sedation use and complications.**

Methods: **A retrospective review of a quality improvement database including consecutive pulmonary procedures performed by an interventional pulmonologist (D.R.S.) at the University of Calgary, from 1 July 2007 to 1 April 2011.**

Results: **Six hundred seven (55.2%) of the 1100 procedures involved an advanced diagnostic procedure defined as: endobronchial ultrasound-guided transbronchial needle aspiration (EBUS-TBNA), electromagnetic navigation bronchoscopy (ENB) and/or peripheral EBUS. A trainee participated in 512 (84.3%) procedures. A complication occurred in 25 patients (4.1%), with a trend towards increased complication rates in the trainee group (4.7% vs 1.1%, difference 3.6%, $P = 0.076$). Significant differences were seen when a trainee participated versus when no trainee participated for procedure length (58.32 min vs 37.69 min, difference 20.63 min (95% confidence interval: 19.07–22.19), $P = 0.001$) and for the dose of propofol (178.3 mg vs 137.1 mg, difference 41.2 mg (95% confidence interval: 19.81–63.38), $P = 0.002$).**

Conclusions: **In an academic interventional pulmonology practice utilizing the apprenticeship model, trainee participation in advanced diagnostic bronchoscopy increased procedure time, increased the amount of sedation used and resulted in a trend to increased complications. Attempts to modify trainee procedural training to reduce the burden of procedural learning for patients are warranted.**

SUMMARY AT A GLANCE

Trainees can negatively impact advanced bronchoscopy.

Key words: bronchoscopy, complication, education, endobronchial ultrasound, simulation.

Abbreviations: EBUS-TBNA, endobronchial ultrasound-guided transbronchial needle aspiration; ENB, electromagnetic navigational bronchoscopy.

INTRODUCTION

Recent advances in diagnostic bronchoscopy techniques have lead to the widespread use of techniques such as endobronchial ultrasound-guided transbronchial needle aspiration (EBUS-TBNA), electromagnetic navigation bronchoscopy (ENB) and peripheral EBUS. EBUS-TBNA is a revolutionary technique used to accurately biopsy intrathoracic structures in real time using ultrasound guidance during bronchoscopy.[1,2] EBUS-TBNA is generally considered to be a safe procedure;[3] however, complications associated with EBUS-TBNA include: fever, pneumonia, bleeding, pneumothorax, haemopneumomediastinum and infections including pericarditis and lymphadenitis.[4–8] Myocardial infarction, congestive heart failure, arrhythmia, respiratory failure and

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even death have been reported with flexible bronchoscopy;[9–19] however, only recently have serious complications such as respiratory failure and death been reported with EBUS-TBNA.[20] ENB and peripheral EBUS use advanced imaging techniques to locate and biopsy peripheral lung lesions, and the most common complication associated with both techniques is pneumothorax.[21]

Procedural skill training is vital to patient care, and teaching these skills to trainees is necessary to provide an adequate pool of trained physicians to meet the demand for specialized procedures. Some experts in pulmonary procedural training have proposed that training using patient care experiences (see-one, do-one, teach-one methods using practice on patients, also known as the apprenticeship model) can result in increased erroneous diagnoses, increased patient discomfort and increased risk for procedure-related morbidity.[22,23] Patients undergoing bronchoscopy performed by trainees learning via the apprenticeship model of learning have been demonstrated to have an increase in complications rates.[24]

There are currently no published studies investigating the impact of trainees on the performance and rate of complications in advanced diagnostic bronchoscopy. The aim of this study is to determine whether the participation of trainees during advanced diagnostic bronchoscopy procedures leads to increased procedure time, increased sedation use and increased complications.

METHODS

A retrospective analysis of a quality improvement database was performed from all consecutive pulmonary procedures performed by an interventional pulmonologist (D.R.S.) at the University of Calgary, collected from 1 July 2007 to 1 April 2011. Prior to the start of this study, D.R.S. had completed 800 flexible bronchoscopy procedures and 400 EBUS-TBNA procedures.

All consecutive patients undergoing an interventional pulmonary procedure during the study period were entered into a quality improvement database. The majority of data points were entered into an SPSS file at the time of the procedure (SPSS software package, version 19.0; SPSS, Inc., Chicago, IL, USA), including any early complications. At 6–8 weeks following each procedure, the charts were reviewed, including follow-up visit notes for bronchoscopy results and additional notes from the referring physician or cancer centre. Procedure results and any additional complications were then entered into the database. The study was approved by the Calgary Health Research Ethics Board (Ethics ID: E-23801).

Bronchoscopy procedures were performed in a dedicated bronchoscopy suite utilizing a 1T-160 or P-160 Olympus video bronchoscope (Olympus Canada, Markham, ON, Canada) for the airway examination and a BF-UC160F-OL8 (EBUS bronchoscope; Olympus Canada) for the EBUS-TBNA procedure. Additional diagnostic or therapeutic techniques such as transbronchial biopsy, peripheral EBUS (UM-S20-20R, Olympus Canada), ENB (superDimension, Inc., Minneapolis, MN, USA) and electrocautery were also used in some patients. Moderate sedation was performed using intravenous midazolam and propofol, with lidocaine used for topicalization of the airway. The bronchoscopy suite is staffed by two respiratory therapists, in addition to the bronchoscopist and any trainees assisting with the procedure. All patients undergoing transbronchial biopsies, ENB and peripheral EBUS had a chest radiograph and/or bedside ultrasound with confirmation of the sliding pleura sign within 2-h post-procedure. Any patient with no sliding pleura sign underwent a chest radiograph to confirm the presence of a pneumothorax. Fluoroscopy was not used in this study. Major bleeding was defined as >5 mL and/or requiring interruption of the procedure and/or any specific intervention such as topical iced saline/epinephrine application. Lymphadenitis was defined as fever (temperature >38.5°C) and feeling unwell 24–48 h post-EBUS-TBNA procedure, with an absence of new infiltrates on chest radiograph, requiring (and resolving) with broad-spectrum antibiotic therapy.

A trainee was defined as any physician in training who participated in the entire bronchoscopy procedure as the primary operator for the purposes of learning bronchoscopy. The trainees included interventional pulmonary fellows, pulmonary fellows, thoracic surgery fellows and critical care fellows. All trainees participated in all aspects of the procedures, including EBUS-TBNA, ENB, peripheral EBUS and any biopsy techniques employed (i.e. when a trainee participated in the procedure, they also performed the biopsies including the transbronchial biopsies, EBUS-TBNA, ENB and peripheral EBUS biopsies). All trainees were trained via the apprenticeship model, meaning that they learned by practising on patients. At the time of this study, there was no formal simulation-based bronchoscopy training available to the trainees.

A procedure was considered diagnostic if any of the specimens obtained demonstrated a specific diagnosis. A finding of normal lymphocytes was considered diagnostic if confirmed by further testing (i.e. mediastinoscopy or serial imaging revealing adenopathy resolution). Procedures were also considered diagnostic if lymphoma was found on cytology and/or flow cytometry; whether or not treatment was started based on this result, or if excisional biopsy was performed as recommended by haematology for confirmation.

Statistical analysis

Three metrics were selected *a priori* as most relevant to the assessment of the effect of trainee participation in procedures: total procedure time, total sedation used and total complications. In addition, procedural diagnostic rate was also compared. The results were analysed between groups with a standard *t*-test or chi-square as appropriate. Comparison of procedure length according to the procedure subtypes was performed with analysis of variance. Regression analysis was used to model trainee presence, procedure subtype, inpatient versus outpatient status, age,

gender, malignant diagnosis and use of clopidogrel on the main outcome measures of procedure time (linear model) and occurrence of complications (binary logistic model).

RESULTS

One thousand one hundred consecutive patients undergoing pulmonary procedures performed from 1 July 2007 to 1 April 2011 were entered into the database. Of these, 967 (87.9%) were flexible bronchoscopies and 607 (55.2%) involved advanced bronchoscopy techniques defined as: EBUS-TBNA, ENB, peripheral EBUS or a combination thereof.

Of the 607 advanced diagnostic procedures, a trainee participated in 512 (84.3%) of the procedures. The majority of procedures were performed on an outpatient basis (81.5%). The mean age was 62.9 (standard deviation ±14.2) and 312 (51.4%) were male. All procedures were done in the bronchoscopy suite with moderate sedation. A complication occurred in 25 patients (4.1%). No deaths occurred.

Patient demographics and procedural details of procedures when a trainee participated in the procedure versus when no trainee participated can be seen in Table 1. The main results are listed in Table 2. Significant differences were seen when a trainee participated in the procedure versus when no trainee participated for procedure length (58.32 min vs 37.69 min, difference 20.63 min (95% confidence interval: 19.07–22.19), $P = 0.001$) and for the dose of propofol used (178.28 mg vs 137.11 mg, difference 41.17 mg (95% confidence interval: 19.81–63.38), $P = 0.002$). The dose of midazolam used was higher when a trainee participated in the procedure, but did not reach statistical significance (7.19 mg vs 6.68 mg, difference 0.51 mg (95% confidence interval: 0.04–1.06), $P = 0.070$).

A trend towards more complications was seen in the trainee group (24/512 (4.7%) vs 1/95 (1.1%), difference 3.6%, $P = 0.076$). Complication details are listed in Table 3. There were no significant differences in the number of complications in inpatients versus outpatients (5.4% vs 3.8%, $P = 0.3$). When transbronchial biopsy, ENB and/or peripheral EBUS were

Table 1 Patient demographics and procedure details

Characteristic	No trainee ($n = 95$)	Trainee ($n = 512$)
Female gender (%)	45 (47.4%)	250 (48.8%)
Mean age (±SD)	65.48 (12.97)	62.43 (14.33)
Inpatient	22 (23.2%)	90 (17.6%)
Patient taking clopidogrel (75 mg daily)†	2 (2.1%)	9 (1.8%)
Mean number of EBUS-TBNA samples taken per procedure (±SD)‡	4.69 (1.34)	4.42 (1.23)
EBUS-TBNA alone	64 (67.4%)	346 (67.6%)
EBUS-TBNA plus transbronchial biopsy	10 (10.5%)	30 (5.9%)
EBUS-TBNA plus peripheral EBUS	13 (13.7%)	86 (16.7%)
EBUS-TBNA plus ENB	3 (3.2%)	31 (6.1%)
EBUS-TBNA and electrocautery§	5 (5.3%)	19 (3.7%)

All comparisons are non-significant ($P > 0.05$).

† EBUS-TBNA only (no transbronchial biopsies, ENB or peripheral EBUS) was performed on patients taking clopidogrel[3].

‡ Not including samples taken from other techniques i.e. ENB.

§ Refers to the diagnostic use of electrocautery biopsy forceps to biopsy friable endobronchial tumour.

EBUS-TBNA, endobronchial ultrasound-guided transbronchial needle aspiration; ENB, electromagnetic navigation bronchoscopy; SD, standard deviation.

Table 2 Main results

Characteristic	No trainee ($n = 95$)	Trainee ($n = 512$)	Difference, *P*-value
Mean total procedure time in minutes* (±SD)	37.69 (9.03)	58.32 (6.70)	20.63 (95% CI: 19.07–22.19), $P = 0.001$
Mean propofol used* (mg) (±SD)	137.11 (93.14)	178.28 (108.53)	41.17 (95% CI: 19.81–63.38), $P = 0.002$
Mean midazolam used (mg) (±SD)	6.68 (2.48)	7.19 (2.50)	0.51 (95% CI: 0.04–1.06), $P = 0.070$
Total complications	1 (1.1%)	24 (4.7%)	3.6%, $P = 0.076$
Procedural diagnostic rate†	96.8%	91.6%	5.2%, $P = 0.099$
Final diagnosis = malignant‡	66 (69.5%)	311 (61.1%)	8.4%, $P = 0.075$

* $P < 0.05$ *t*-test.

† Considered diagnostic if lymphoma was found on cytology or flow cytometry (even if excisional biopsy recommended by haematology for confirmation).

‡ Three patients (0.5%) = diagnosis unknown.

CI, confidence interval; SD, standard deviation.

Table 3 Complication details

Complication	No trainee ($n = 95$)	Trainee ($n = 512$)
Pneumothorax†	0 (0%)	11 (2.2%)
Pneumothorax requiring chest tube	0 (0%)	7 (1.4%)
Congestive heart failure	1 (1.1%)	3 (0.6%)
Myocardial infarction	0 (0%)	1 (0.2%)
Post-bronchoscopy pneumonia	0 (0%)	4 (0.8%)
Hospital admission for COPD exacerbation	0 (0%)	1 (0.2%)
Major bleeding‡	0 (0%)	1 (0.2%)
Lymphadenitis§	0 (0%)	3 (0.6%)
Total complications	1 (1.1%)	24 (4.7%)

All comparisons are non-significant ($P > 0.05$).

† The majority of the pneumothoracies were related to electromagnetic navigation bronchoscopy (1 pneumothorax), transbronchial biopsy (5 pneumothoracies) and peripheral EBUS (3 pneumothoracies), although there was one patient who had a pneumothorax requiring a chest tube related to EBUS-TBNA biopsy of a 10R lymph node (no transbronchial biopsies were performed). One pneumothorax not requiring a chest tube was thought to be related to a bronchoalveolar lavage (although EBUS-TBNA was used during that procedure, no enlarged lymph nodes were found and no EBUS-TBNA sampling was performed).

‡ Bleeding was caused by trauma to endobronchial tumour by the EBUS-TBNA bronchoscope (not the needle) and required electrocautery and cold saline for bleeding control.

§ Two patients had positive cultures from lymph node sample cultures (oropharyngeal organisms) and one patient had serial computed tomography imaging documenting rapid enlargement of a sampled lymph node post-procedure.

COPD, chronic obstructive pulmonary disease; EBUS-TBNA, endobronchial ultrasound-guided transbronchial needle aspiration.

performed, there were significantly more complications versus EBUS-TBNA without these additional techniques (12/173 (6.9%) vs 13/434 (3.0%), $P = 0.027$), although patients involving these techniques were equally distributed between the two groups.

There were no significant differences seen in the number of complications between the different subgroups of trainees involved in the study (IP fellow 9/290 (3.1%), pulmonary fellow 6/73 (8.2%), critical care fellow 1/7 (14.2%), thoracic surgery fellow 1/13 (7.7%)) and when both an interventional pulmonology fellow and pulmonary fellow participated in the procedure 7/133 (5.3%), $P = 0.361$). A linear regression model (analysis of variance, $P < 0.001$, $R^2 = 0.543$) noted that trainee presence was the most important predictor of procedure length (coefficient 20.6, $P < 0.001$), with procedure subtype (coefficient 0.6, $P = 0.03$) and gender (coefficient −1.2, $P = 0.04$) having a significant impact as well.

Overall, a diagnosis was obtained from the procedure results in 564 (92.9%) of patients. In 377 (62.4%) patients, the final diagnosis (including any subsequent tests) was malignant, while in three patients (0.5%), no final diagnosis was ever obtained. No significant differences were seen when a trainee was present versus when no trainee was present for procedure diagnostic rate (91.6% vs 96.8%, difference 5.2%, $P = 0.099$).

DISCUSSION

This study provides evidence that in an academic interventional pulmonology practice using the apprenticeship model of procedural education, trainee participation in advanced diagnostic bronchoscopy increases procedure time, increases the amount of sedation required and may increase complications.

Other studies have demonstrated the potential negative impact of trainees on procedural and patient outcomes. A retrospective study performed by Ouellette in an academic pulmonary practice in the United States revealed increased complication rates in bronchoscopy procedures performed by novice bronchoscopists.[24] In this study, novice bronchoscopists in their first trimester of training had a complication rate of 3.1% that was significantly higher than the rate of 1.6% seen with the senior trainees. Similar to our study, the most common complication was pneumothorax.

The complication rate of 3.1% in the novice bronchoscopists in the Ouellette study is comparable with the 4.7% complication rate seen in the trainee group in our study.[24] The complication rate in the more senior trainees in the study was 1.6%, lower than the 4.7% seen in our study. This difference may be explained by the more invasive/interventional nature of the bronchoscopies performed in our study as well as the differences in the definitions of 'complications' between studies. Our study utilized a broader complication definition, including some less serious complications in the total complication rates versus only 'serious complications' being reported in the Ouellette study.[24]

The complication rates seen in our study are consistent with other previously reported complication rates in flexible bronchoscopy and EBUS-TBNA.[4–19] Overall complication rates from flexible bronchoscopy have been reported from 0.5% to 11%, with serious complications reported from 0.8% to 5%, and mortality rates being reported from 0% to 0.17%.[9–19] There were no deaths in our study.

The mean total procedure time in this study is longer than in some previous reports of EBUS-TBNA;[1,2,25–27] however, these studies did not include the use of additional techniques such as peripheral EBUS, electrocautery and ENB. The mean number of

Table 4 Complication details: endobronchial ultrasound-guided transbronchial needle aspiration only

Complication	No trainee ($n = 64$)	Trainee ($n = 346$)
Pneumothorax	0 (0%)	2 (0.6%)
Pneumothorax requiring chest tube	0 (0%)	1 (0.3%)
Congestive heart failure	1 (1.6%)	2 (0.6%)
Myocardial infarction	0 (0%)	1 (0.3%)
Post-bronchoscopy pneumonia	0 (0%)	2 (0.6%)
Hospital admission for COPD exacerbation	0 (0%)	1 (0.3%)
Major bleeding	0 (0%)	1 (0.3%)
Lymphadenitis	0 (0%)	3 (0.9%)
Total complications	1 (1.6%)	12 (3.5%)

All comparisons are non-significant ($P > 0.05$).
COPD, chronic obstructive pulmonary disease.

EBUS-TBNA samples taken per procedure in this study is also higher than many EBUS-TBNA studies reported in the literature,[1,25–27] likely contributing to longer procedure times in both study groups. Similar to previous studies, our study showed a low rate of complications related to EBUS-TBNA (Table 4). Although some of the complications seen have been reported to be specific to EBUS-TBNA (i.e. pneumothorax and lymphadenitis), many of the complications in the EBUS-TBNA-only group were arguably related to the bronchoscopy procedure itself (i.e. congestive heart failure, myocardial infarction, post-bronchoscopy pneumonia, chronic obstructive pulmonary disease exacerbation) and may have been directly related to the increased procedure time and sedation requirements seen in the trainee group.

Although the data were obtained from a prospectively collected quality assurance database, the retrospective analysis of the study has limitations. Patients were not randomized to each group, so that even though we found no differences between groups in terms of age, gender, inpatients status, use of clopidogrel, prevalence of malignancy and number of additional procedures performed, there may have been differences between groups not apparent in our analysis. This study evaluated the procedures performed in the practice of a single interventional pulmonologist, and as such, the results may not be applicable to all bronchoscopists. Differences in teaching technique may affect the variables measured such as sedation used and procedure time, possibly even the complications noted. Repeating this study in a prospective, randomized fashion with multiple bronchoscopists and a larger sample size would be ideal.

All trainees in this study learned bronchoscopy by practising on patients (the apprenticeship model) without the benefit of alternative teaching methods such as a simulation-based training curriculum. The use of computer bronchoscopy simulators to measure bronchoscopy skills has been validated.[28,29] Additional studies have shown the bronchoscopy simulator to be a useful tool for enhancing learning,[22,30–32] with demonstration of effective skill transfer from the simulator to reality.[28,33] Use of inanimate and animal models for learning EBUS[34] as well as the use of simulation-based curricula for other medical procedures have also been shown to be effective.[35] Simulation allows for the standardization of the process of learning, allowing high stakes scenarios, such as advanced bronchoscopy procedures, to be simulated and repeated as needed in a controlled environment with no risk to patients. Because it has been shown that the use of bronchoscopy simulation speeds the acquisition of bronchoscopy skills and improves trainee procedural speed and efficiency,[32,36] it will be interesting to see if future studies demonstrate improved patient and procedural outcomes following the introduction of these alternative education tools in pulmonary procedures, as has already been demonstrated in central venous catheter insertion procedures[37] and for laparoscopic surgery procedures.[38]

It should be pointed out that the apprenticeship model may not be ideal for the learners either. Learning flexible bronchoscopy by practising on patients has been associated with increased learner anxiety and can introduce significant variability into the learning experience.[22,23] There is increasing evidence that learning medical procedures in a high-stress patient care environment can lead to excessive learner activation, resulting in decreased learning retention.[39] The evidence continues to mount for the use of simulation-based curricula in procedural education and against the traditional use of patients as the primary subjects for trainees to learn and practise medical and surgical procedures.[37–39]

In summary, this study demonstrates that in an academic interventional pulmonology practice utilizing the apprenticeship model for bronchoscopy education, trainee participation in advanced diagnostic bronchoscopy increases procedure time, increases the amount of sedation used and results in a trend to increased complications. Given these results and the other disadvantages of the apprenticeship model of learning flexible bronchoscopy and advanced bronchoscopic techniques, attempts to modify trainee procedural training in order to reduce the burden of procedural learning on patients are warranted.

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