RESPIRATION AND THE AIRWAY

Proficient manipulation of fibreoptic bronchoscope to carina by novices on first clinical attempt after specialized bench practice

C. Marsland1*†, P. Larsen1, R. Segal2, S. Hunter1, J. Morris2, P. Mezzavia2, A. Walpole2, B. di Luca2, K. Lee2 and W. Lim2

Department of Anaesthesia and Pain Management, Wellington Hospital, Private Bag 7902, Wellington South, Wellington, New Zealand. 2Department of Anaesthesia and Pain Management, Royal Melbourne Hospital, Victoria, Australia

*Corresponding author. E-mail: colin.marsland@paradise.net.nz

Background. Proficient manipulation of the fibreoptic bronchoscope is an important component of competent bronchoscopic airway management. We studied the duration of specialized bench training necessary to achieve this proficiency and the subsequent transfer of this psychomotor skill to human subjects.

Methods. Twenty-nine novice endoscopists undertook the training associated with a commercial non-anatomic endoscopic dexterity training system, DexterTM. Bronchoscopic driving performance was assessed after each hour of self-directed training, using a global rating scale from 1 (unskilled) to 5 (expert) with a score of 3 linked to proficiency. The scale was applied to anonymized recordings of the endoscopic view as the bronchoscope was manipulated from the mouth to the carina of an anatomic manikin. Once bench proficiency was achieved, the ability of participants to perform the skill on volunteer co-participants was assessed.

Results. Ninety-six per cent of participants achieved proficiency on the manikin within 4 h of practice. Ninety-three per cent then drove the bronchoscope proficiently from the mouth to the carina of clinical volunteers on the first attempt.

Conclusions. The endoscopic dexterity required to proficiently drive a bronchoscope in human subjects to an anatomic endpoint relevant to fibreoptic intubation is achievable after 2–4 h of specialized bench training. Training in the local environment may be more conducive to success than in time-limited workshops. Achieving a defined proficiency standard on bench models contributes to the development of basic bronchoscopic competence. This has the potential to protect patients from novice learning curves, optimize clinical education and efficiency, and assist compliance with difficult airway algorithms.

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The ability of anaesthetists to competently perform fibreoptic intubation is anticipated by the difficult airway algorithms of the major professional societies.1 2 However, uptake and performance of the technique remain variable.3–6 The typical volume–outcome relationship, in which bronchoscopic competence develops as a consequence of the performance of a large number of procedures,7 is difficult to achieve for many anaesthetists. In a study of pulmonary medicine trainees, little relationship was found between technical skill, bronchoscopy knowledge, years of training, and bronchoscopy experience.8 This suggests that endoscopic dexterity needs to be addressed as a specific educational goal, as it underpins the development of therapeutic and diagnostic bronchoscopic...
skills, and may not be acquired consistently by simple clinical exposure.

Competent performance of an awake fibreoptic intubation requires success in all cognitive and psychomotor aspects of a complex skill set. This includes application of knowledge, judicious clinical management, and proficient psychomotor performance.

For the novice, the acquisition of endoscopic dexterity may be the critical hurdle in the achievement of basic bronchoscopic competence.9 The associated difficulties have been previously described.4 9–11 Although the clinical apprenticeship model can be effective for the development of endoscopic dexterity, it does expose patients to the risks inherent in the novice learning curve. The complication rate of supervised novice bronchoscopists in respiratory medicine training halved after their first 4 months of training.12

Previous work has demonstrated the effectiveness of the endoscopic dexterity training system, DexterTM (Fig. 1) and shown a correlation between endoscopic performance on an anatomical model and subsequent performance on clinical subjects.13 However, the quality of individual performances was variable. This may have been related to personal aptitude and time spent practicing, but might also reflect the absence of a performance target. Other workers14 used a global rating scale (GRS) and checklists to assess performance of clinical fibreoptic intubation by novices after training on either a simple wooden ‘choose the hole’ box or a sophisticated bronchoscopy simulator. The novices had access to their model for up to an hour, but the mean practice time was 30 min. The outcome was the same in each group with a 50% clinical failure rate. A qualitative endpoint for bench training was not defined.

This study was designed to determine how long a period of bench training was required to achieve a proficient standard of bronchoscopic dexterity, and whether this bench proficiency transferred to the clinical environment. Descriptors of proficiency were refined to provide a method for qualitative assessment of skill performance. This information could be valuable in designing an evidence-based system of training for the development of bronchoscopic competence.

Methods

Ethics approval for the study was obtained from both the regional branch of the National Ethics Committee in Wellington and the Ethics Committee of the Royal Melbourne Hospital. The potential for conflict of interest due to the lead author’s involvement with DexterTM was explicitly disclosed and mitigating methodology described. A study previously published by the senior authors, involving topicalization of the airways of study participants who acted as subjects for bronchoscopy,13 was fully disclosed to both ethics committees. Detail from this earlier study was included in the information packs for participants. Invitations to participate in the study and information regarding the study were posted as departmental notices and not as approaches to individual members of

Fig 1 DexterTM is an endoscopic dexterity training system designed to teach novices how to drive an endoscope. It consists of a non-anatomical model, an image chart, and maps supported by a training manual. Model configuration including image position, orientation, and level of difficulty are variable. Modules within the training manual have specific optical and mechanical learning objectives. The model itself consists of a modular series of Y pieces, image caps, and pods with different functions (portion shown in inset). The basic objective is to locate images endoscopically and record their positions and orientation on the map specific to the module being worked on. The manual, endoscopic views through the model and video of GRS scoring are freely available at http://www.dexterendoscopy.com.
scores were then used to train scorers before study commencement. Pre-recorded endoscopic passes representing standard GRS opposed to glancing contact) with mucosal surfaces. There could be no direct collisions (as opposed to glancing contact) with mucosal surfaces. Pre-recorded endoscopic passes representing standard GRS scores were then used to train scorers before study commencement. Throughout the study, all individual endoscopic passes were assigned computer-generated random numbers to ensure anonymization. Assessment of anonymized recorded endoscopic passes was performed independently by two blinded scorers. That is, scoring was performed on recorded copies of endoscopic passes after the actual event and participants could not be identified from the recordings. Clinical endoscopic passes were also timed from recorded copies to provide a quantitative basis of comparison with the other published work. The method and equipment described was used for all performance measurement.

A standard didactic teaching session based on information in the Dexter™ training manual was given to all participants after initial performance testing. The GRS was explained and video examples of different scores were shown to demonstrate the required standards. Endoscopic performance was then immediately re-tested to assess the impact of the didactic session.

Participants had open access to endoscopes and models and were instructed to follow the self-directed teaching programme contained in the Dexter™ manual. Participants were instructed to spend time on Dexter™ to gain dexterity skills and time with the anatomic manikin to practice the required anatomic task. Both models were to be used in each hour of practice starting with the early, simple modules in Dexter™. Practice was undertaken in intervals determined by individual availability and fatigue over a period of 5–10 days. Performance measurement was repeated whenever the sum of training intervals amounted to an hour of practice. When a median GRS score of 3 was achieved over three passes, participants stopped practising and a clinical bronchoscopy, as described below, was performed on awake volunteer co-participants. Clinical bronchoscopy was performed within 1 week of achieving bench proficiency.

All clinical subjects had fasted for at least 6 h for food and 2 h for clear fluids and were monitored continuously with pulse oximetry and three-lead ECG with non-invasive arterial pressure recordings at 5 min intervals. A 20 G i.v. cannula was placed in each subject, and glycopyrrolate 5 µg kg⁻¹ was given i.v. 10–20 min before airway topicalization. No i.v. sedation or analgesia was used. Topical anaesthesia to the airway was performed using lidocaine with a maximum allowable dose of 9.0 mg kg⁻¹ according to local practices. Subjects from Wellington received 2% viscous lidocaine, initially gargled and then allowed to run down the dorsum of the tongue. This was followed by 4% lidocaine aerosolized using a Mucosal Atomisation Device (MAD®, Wolfe Tory Medical Inc., Salt Lake City, UT, USA) and 2% lidocaine via an epidural catheter if required. Subjects from Melbourne received nebulized 4% lidocaine, 4% lidocaine viscous gargle, then a ‘spray as you go’ technique using 2% lidocaine via an epidural catheter. Subjects were continuously assessed regarding safety, comfort, and desire to continue.

Two to four passes from the mouth to the carina were performed on each clinical subject. Oral conduits, such as intubating oropharyngeal airways, were not used. Subjects

| Table 1 Five-point GRS of fibreoptic bronchoscope manipulation ability |
|-------------------------|----------------|----------------|----------------|----------------|
|                        | 1 Unskilled    | 2 Proficient   | 4 Expert       |
| View of central        | Frequently     | Loses view of central airway no more than once | Maintains central airway in centre of field of view |
| central airway         | loses view of central airway | | |
| Mucosal contact        | Frequent or hard collisions | No collisions, infrequent glancing contact with mucosa | No mucosal contact |
|                        | with mucosa    | | |
| Progress               | Hesitant, jerky, or inaccurate attempts to progress | General progression, occasional hesitancy. Some inaccuracy with initial movement | Progresses smoothly and accurately between sequential landmarks |
|                        | | | |
| Orientation            | Image not oriented | Image usually oriented | Maintains orientation | |
were then monitored for 1 h, observed for 3 h, and driven home. Blood samples for lidocaine levels were drawn 30, 60 min, and then at 2, 3, and 4 h from the start of bronchoscopy. Samples were promptly spun down and the plasma frozen for batch lidocaine assay. Clinical subjects were asked to record the presence of any side-effects they experienced after lidocaine topicalization at hourly intervals for 6 h and then overnight. They also recorded on 0–10 cm visual analogue scales (0, terrible; 5, tolerable; 10, enjoyable) their subjective experience of being topicalized and bronchoscoped.

The quality of the bronchoscopic passes from the mouth to the carina of clinical subjects was subsequently assessed by applying the GRS to anonymized recordings of the endoscopic view as previously described.

**Statistical methods**

Ordinal data that are not normally distributed, for example, GRS scores and previous bronchoscopy experience, are presented as median (IQR). The GRS scores before and after initial didactic teaching were compared using the Wilcoxon signed-rank test. Reliability of the two independent scorers was determined by calculation of Cohen’s κ, where values from 0.41 to 0.6 are associated with moderate agreement, 0.61 to 0.8 with substantial agreement, and 0.81 to 1.00 with almost complete agreement between the two scores.19,20 Plasma lidocaine levels were normally distributed, and are presented as mean (SD). All statistics were calculated using SPSS (SPSS Version 17, SPSS, Chicago, IL, USA).

**Results**

Thirty-seven participants were enrolled in the study. Eight were subsequently excluded on the basis of either pre-existing proficiency on baseline testing (five of eight) or failing to attend practice sessions after the didactic teaching (three of eight). The final study number was 29. Twenty-one (71%) participants had previously attempted fibreoptic intubations with a median (IQR) number of 4 (0.75, 5) per participant. Thirteen of these had undergone no training before attempting clinical fibreoptic intubation. The median of the individual scores on baseline GRS testing was 2 (2, 2), and there was a small, but statistically significant (P<0.001), improvement in scores after didactic teaching to 2 (2, 2.5).

The cumulative achievement of proficient (GRS 3) bronchoscopic manipulation from the mouth to the carina in the anatomic model is shown against hours of practice in Figure 2. One subject had not achieved a GRS score of 3 within 4 h of practice but went on to achieve that standard by 5 h. The percentage of participants achieving a GRS score of 3 after each hour of practice is shown in Figure 3. There was no difference in practice time needed to achieve proficiency between participants with some previous exposure to bronchoscopy and those with none.

GRS scores on subsequent clinical bronchoscopy in awake volunteers are shown in Figure 4. A GRS score of 3 or better was achieved by 93% (27/29) of participants. Mean time from the mouth to the carina was 57 (14) s. Two subjects achieved clinical GRS scores of 2. The first had a time from the mouth to the carina of 45 s, but collided with the oral mucosa during the attempt. The second had a time from the mouth to the carina of 82 s, and while there were no collisions or loss of central airway view, neither scorer considered that the GRS 3 requirement for ‘general progression’ rather than ‘general hesitancy’ was adequately met (Table 1).
A mean dose of applied lidocaine was 7.9 (range 6.3–9.0) mg kg\(^{-1}\) adequately anaesthetized within the study dose range. The bronchoscopy. One participant’s airway could not be adequately, the median (range) subjective response to being topi- calized was 5.0 (3–6.5) and to being bronchoscoped was 6.0 (4–10).

Side-effects attributable to lidocaine such as early dis- inhibition, light-headedness, impaired concentration and co-ordination, and latterly fatigue and ‘mild flu-like’ or ‘hangover-like’ symptoms were variably present. There was no association between dose in mg kg\(^{-1}\) and the presence, absence, or intensity of side-effects. On 0–10 cm visual analogue scales (0, terrible; 5, tolerable; 10, enjoyable), the median (range) subjective response to being topicalized was 5.0 (3–6.5) and to being bronchoscoped was 6.0 (4–10).

Discussion

The importance of procedural competence in an essential skill is self-evident. Although competence may be readily recognized, a practical definition can be elusive.\(^{21}\) Success in terms of reaching an endpoint within a certain time frame\(^{22}\) or performing an arbitrary number of procedures\(^{21}\) is not evidence of competence. Psychomotor proficiency is an important component of bronchoscopic competence. We have demonstrated that the majority of novice bron- choscopists can proficiently manipulate a bronchoscope from the mouth to the carina of an anatomic manikin in 2–4 h of bench practice using Dexter\textsuperscript{TM}. This proficiency transfers to clinical subjects in most cases.

The substantial inter-rater reliability between the principle scorers suggests that the GRS criteria developed provide a robust and transferable concept of proficient endoscopic performance. The qualitative performance target was defined by descriptors of proficiency rather than expertise (Table 1). The choice of descriptors may be considered arbitrary to some extent, but the robust application of the scale to both the bench and the clinical environment helps ensure the validity of the observed skill transference. The proficiency target provided a relevant and achievable endpoint for bench training and clinical performance, and reduced the impact of individual aptitude upon training success.

Our findings suggest that bronchoscopic dexterity may be best developed in the local environment. Participants needed a total of 2–4 h of practice to gain proficiency. Their practice sessions, typically lasted 20–30 min, by observation, before the onset of fatigue. Distributed practice, where practice intervals are separated by periods of rest, is recognized to be more effective than massed practice, not only for skill acquisition but for clinical transference and skill retention.\(^{23}^{24}\) Short periods of intermittent practice over a period of 5–10 days are achievable and effective locally, but can be logistically difficult in the typical workshop environment. If training is limited to sporadic clinical opportunities or massed practice within time-limited workshops, then individual aptitude may heavily influence training success. We measured clinical skill transfer within a week of bench training. Skill retention after longer intervals warrants further study.

The use of study participants as clinical volunteers for bronchoscopy has been previously described.\(^{13}^{25}\) The experience is well tolerated and highly valued by most participants. We consider the practice as described here to be safe, but it cannot be considered entirely benign and is logis- tically challenging. Side-effects related to lidocaine topicalization in non-sedated volunteers have been previously reported\(^{13}^{18}^{26}\) and were again evident. Complications related to minor airway trauma and infection in a large series of airway course participants have been reported.\(^{26}\) These risks coupled with the availability of effective, clinically transferable bench training need to be weighed against the benefit of the experience as perceived by volunteers.
A potential weakness of this study relates to the clinical endpoint. Reaching the carina of an anatomically normal clinical subject is a relevant endpoint for fibreoptic intubation of the anatomically difficult airway but not necessarily the pathologically difficult airway. The distinction lies in the need for fine control of oblique movement in the latter situation. The Dexter™ training system emphasizes the importance of handle rotation co-ordinated with insertion cord tip flexion, to control oblique movement of the bronchoscope. These skills are practiced repeatedly in different ways in the model. Participants also had access to manikin bronchial trees to practice these skills in an anatomical setting. A proficient score, from the mouth to the carina of clinical subjects, required midline positioning, control of tip flexion, and smooth advancement. Control of oblique movement was occasionally required to move into a lateral airspace if the soft palate and dorsum of the tongue were opposed in the midline. We did not consider it ethical to have participants exploring the bronchial trees of clinical volunteers to demonstrate clinical proficiency in the oblique movement, nor was it appropriate or practical to obtain patients with difficult airways for this purpose. Demonstration of clinical transfer of bench proficiency to patients in bronchoscopy clinics is an area of future interest.

Part-task trainers can be a safe and efficient means of developing clinically transferable psychomotor skills but have limitations. The fixed open airspace of an anatomic model does not reflect the dynamic or pathological clinical situation. Clinical context and experience are necessary for the development of competence in fibreoptic intubation and the wider set of bronchoscopic skills. Assessment of this competence might involve qualitative performance measurement as described and also checklists for skills such as equipment preparation, patient management, and successful navigation to specific endpoints in the bronchial tree. Validated web-based tools for bronchoscopy education and assessment are available.

We have described a method of bench training and a means of performance measurement that together provide a route to clinical proficiency in the basic skills of driving a bronchoscope to the carina. This information could be valuable in designing an evidence-based system of training for the development of basic bronchoscopic competence. A proficient standard of endoscopic dexterity achieved before entering the clinical environment has the potential to help protect patients from novice learning curves, maximize the training benefit of clinical opportunities, improve operating theatre and bronchoscopy clinic efficiency, and assist compliance with the bronchoscopic component of difficult airway algorithms.

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