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ORIGINAL ARTICLE

Achieving proficiency in rigid bronchoscopy—a study in manikins

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Abstract

Background Rigid bronchoscopy may be used to relieve acute airway obstruction following induction of anaesthesia and is a recommended option for management of the difficult airway. The ability of anaesthetists to perform rigid bronchoscopy has not been reported. We sought to explore the acquisition of procedural skill in rigid bronchoscopy by anaesthesiologists in a manikin.

Methods In a prospective interventional study, participants were asked to perform 40 rigid bronchoscopies in a TruCorp AirSim Advance airway manikin, configured to a randomised sequence of easy or difficult laryngoscopic grades to which the participants were blinded. The primary outcome was stabilisation (the attempt after which no further reduction in procedural time occurred). Dental injury and oesophageal intubation were also recorded. Forty anaesthesiologists and 40 unskilled controls (without laryngoscopic skills) participated.

Results In the easy model, stabilisation occurred at attempt 8 in the anaesthesiology group and 10 in the unskilled controls. In the difficult model, stabilisation occurred at attempt 10 in both groups. Dental injury was less common in the anaesthesiology group. The proportion of participants achieving procedural competency did not differ between groups in either the easy (35/40 vs. 30/40) or difficult model (32/40 vs. 25/40).

Conclusions This study shows that the technical skill of rigid bronchoscopy can be acquired within 10 repetitions in a manikin model. As procedural competence and complication frequency vary with the laryngoscopic grade of the model, both easy and difficult configurations should be used for training. Advanced laryngoscopic skills are not required prior to training in this technique.

Keywords Airway management · Anaesthesia · Emergency · Skill acquisition · Training

Background

Rigid bronchoscopy, in a limited number of clinical scenarios, may permit establishment of airway patency and continued oxygenation when the airway remains obstructed despite endotracheal intubation. [1–3] These cases would typically involve tracheal and bronchial obstruction due to extrinsic compression by tumours. [4] Catastrophic outcomes in such cases are well documented. The technique may also allow rapid retrieval of obstruction material from the trachea, e.g. blood clots or foreign objects and in such cases has been described in the Fourth National Audit Project by the Royal College of Anaesthesiologists as a 'potentially lifesaving' technique. [5] Rigid bronchoscopy is rarely a primary airway technique in anaesthetic practice but is a recommended alternative airway plan in certain scenarios. [4–7] It is a core skill for thoracic and otolaryngeal surgeons but is not to our knowledge considered a required competency in anaesthesiology training anywhere in the world. [8, 9] However, it is a recommended optional technique for management of the difficult airway by experts and some international societies, most notably the Australian and New Zealand College of Anaesthetists. While we can identify a number of clinical scenarios in which it might be therapeutically beneficial, these cases are indeed rare. Consequently training opportunities in such cases are extremely limited and individual experience

This data has been presented in part at the World Airway Management Meeting in Dublin in November 2015.

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likely to be sparse. [10] The ability of anaesthesiologists to perform rigid bronchoscopy has not been reported other than is isolated case reports and small series. [2, 7, 11] The purpose of this study was to assess learning curves of anaesthesiologists in acquisition of the skill of rigid bronchoscopy both in terms of procedural success and complication rates using a manikin model. An unskilled control group of non-anaesthesiologists was also used to determine whether skill with conventional laryngoscopy was advantageous in learning to perform rigid bronchoscopy. We hypothesised that subjects with prior airway skills would achieve proficiency more rapidly and cause less complications than participants with no airway skills. .

Methods

We performed this prospective interventional study in a university teaching hospital. Following ethics committee approval (Rotunda Hospital Dublin), written informed consent was obtained from all participants. Two groups were studied—anaesthesiologists and an unskilled control group of non-anaesthesiologists. Prior performance of rigid bronchoscopy was an exclusion criterion in both groups. Anaesthesiologists who had a minimum of 6-month training were recruited and included both consultants and trainees. The unskilled control group consisted of nursing staff and medical students. The study was advertised at department of anaesthesia educational seminars on the hospital campuses. These are attended by anaesthesiologists at all levels of training, as well as nursing staff work in theatre and PACU. Medical students on anaesthesiology rotation are also present at these seminars which occur on a daily basis.

Each participant was shown a demonstration video on the technique of rigid bronchoscopy and informed of the study endpoints and was then asked to perform rigid bronchoscopy on a manikin. The primary endpoint was the stabilisation attempt—i.e. the rigid bronchoscopy attempt after which no further improvement occurred. [12] Success was defined as the passage of the bronchoscope from the lips through the vocal cords (Fig. 1). Secondary endpoints included successful intubation within 40 s, dental damage and oesophageal intubation. Dental damage was defined as dislodgement of the front teeth of the manikin and oesophageal intubation was described as the inadvertent placement of the bronchoscope in the oesophagus. The manikin model was a TruCorpAirSim Advance (Belfast, Northern Ireland) (Fig. 1). This is a model for airway training for anaesthesiologists but can also be used for positioning of a rigid bronchoscope. The manikin contains a trachea, carina and two bronchi. It also includes an oesophagus where bronchoscope placement can be recognised. The bronchoscope was a Wolfe Rigid Bronchoscope with a light source (Knittlingen, Germany). The participant performed the procedure 40 times with the airway position of the manikin being randomised to either ‘easy’ (Cormack and Lehane grade 1) or ‘difficult’ (Cormack and Lehane grade 3) conventional laryngoscopic grade. Randomisation was performed using an online random number generation program (www.random.org). The ‘difficult’ grade was achieved by restriction of occipital movement of the manikin. Blinding was achieved by covering the manikin with a surgical drape which permitted oral access but otherwise obscured the manikin position. The ‘difficult’ and ‘easy’ settings were performed 20 times each. The participant was blinded to the easy and difficult settings on the manikin. The same randomisation sequence was used for each participant. We chose 20 repetitions based on the minimum number of rigid bronchoscopies considered for competency in other specialities. [8]

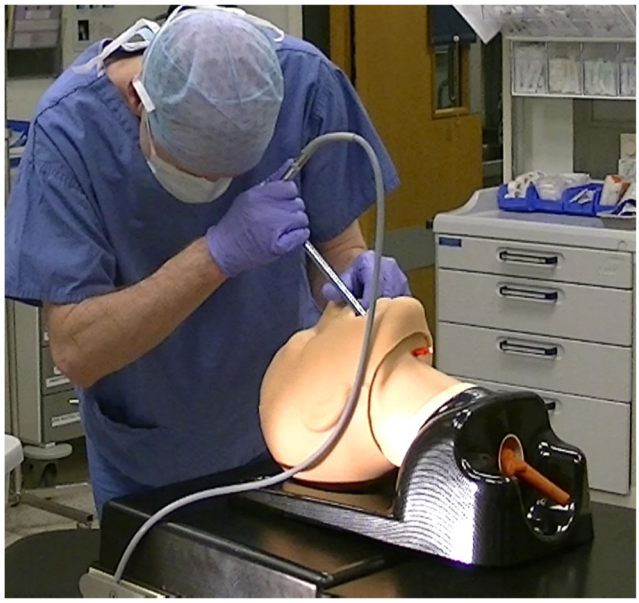

Fig. 1 Airway manikin (undraped for demonstration) with bronchoscope in final position

Data were analysed using SigmaStat (Version 2.0, Jandel Corp., San Rafael, CA). Continuous variables were analysed using repeated-measures analysis of variance. Categorical data were analysed using Fisher’s exact test and χ^2 testing with Yates correction as appropriate. Significance was considered at $P < 0.05$. Categorical data are presented as numbers and percentages. Continuous variables are presented as mean with standard deviation for parametric data or median with standard error of the mean for nonparametric data. Learning curves for procedural success were constructed using the cumulative sum method (CUSUM). [13] This is an outcome-based sequential analysis technique used to define learning curves for technical skills. It allows construction of learning curves for individuals and groups. It permits estimates of the number of cases that are required to achieve competency.

We performed the CUSUM analysis as follows. The number of procedures performed until an acceptable failure rate was reached was determined. The following variables were used: acceptable ($p_0 = 0.05$) and unacceptable ($p_1 = 0.25$)

Table 1 Participant characteristics

	Anaesthesiology $N = 40$	Controls $N = 40$
Age (years)	28.5 (5.1)	26.4 (4.0)
Gender male/female	7/13	8/12
Experience in anaesthesiology (years)	5.4 (3.8)	–

Data are mean (SD)

failure rates, the probability of type I ($\alpha = 0.05$) and type II errors ($\beta = 0.1$). The proportion of participants who crossed the lower decision limit (h0) was determined and compared within and between groups. The calculations used were as previously described and were as follows. [13, 14]

$$a = \ln[(1-\beta)/\alpha]$$

$$b = \ln[(1-\alpha)/\beta]$$

$$P = \ln(p_1/p_0)$$

$$Q = \ln[(1-p_0)/(1-p_1)]$$

$$S = Q/(P+Q)$$

$$h_0 = -b/(P+Q)$$

$$h_1 = a/(P+Q)$$

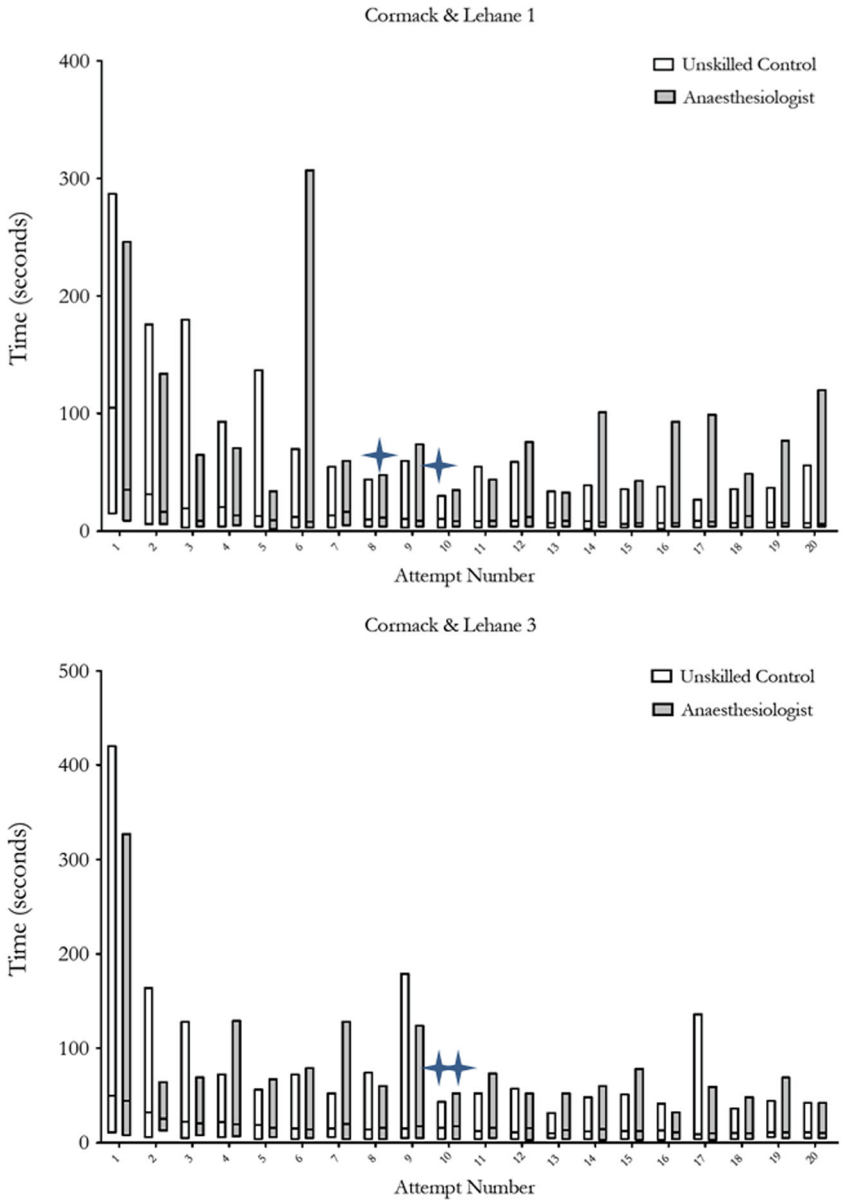

Fig. 2 **a** Time to successful tracheal access in easy configuration. Data are median, IQR. **a** *indicates attempt at which stabilisation occurred. **b** Time to successful tracheal access in difficult configuration. Data are median, IQR. **a** *indicates attempt at which stabilisation occurred

Acceptable failure rate $p0 = [(h_0(1-\alpha)-\alpha h_1)/(s-p_0)]$

Unacceptable failure rate $p1 = \left[\left(h_1(1-\beta)-\beta h_0/\left(p_1-s\right)\right]\right.$

α = probability of type I error

β = probability of type II error

Sample size was based on pilot data in which procedural success within 10 repetitions was assessed. This yielded success rates of 80% for anaesthesiologists and 35% for unskilled controls and projected a minimum sample size of 36 per group. An extra 10% ($n = 4$) were added to allow for drop outs.

Results

Forty anaesthesiologists and 40 unskilled controls participated (Table 1). In the 'easy' model, stabilisation occurred at attempt 8 in the anaesthesiology group and 10 in unskilled controls (Fig. 2). In the 'difficult' model, stabilisation occurred at attempt 10 in the anaesthesiology group and 10 in unskilled controls (Fig. 2). The anaesthesiology group achieved successful intubation more quickly than the unskilled control group at the first attempt in the 'easy' model, but there were no differences between groups at any other time. In the 'difficult' model, there were no differences between groups at any other time. The time taken to intubate the model was greater in the 'difficult' than the 'easy' model in both groups. The anaesthesiology group first achieved 100% intubation success within 40 s at attempts 7 and 16 in the 'easy' and 'difficult' models, respectively, while the unskilled controls achieved 100% in the 'easy' model only at attempt 10 (Fig. 3). The highest incidence of dental injury was seen in both groups during the first five intubation attempts and was higher in unskilled controls (Fig. 4). In both groups, dental injury was more common in the 'difficult' model (Fig. 4). In both the anaesthesiology group and unskilled controls, oesophageal intubation occurred most frequently in the first five intubation attempts and did not differ thereafter (Fig. 4). There were no differences in the frequency of oesophageal intubation between the groups at any time. In the both groups, oesophageal intubation was more common in the 'difficult' than 'easy' model (Fig. 4). There was no difference between the groups in

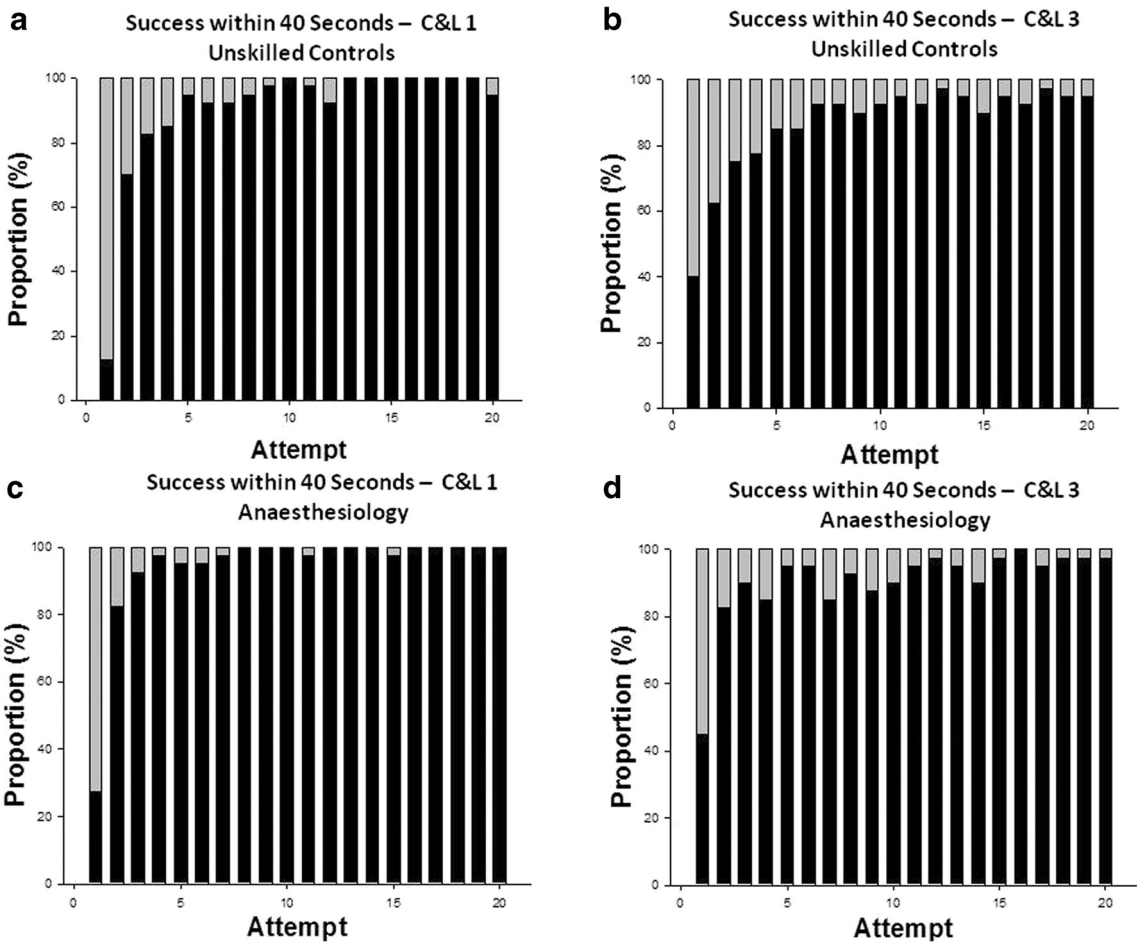

Fig. 3 Proportion of attempts successful within 40 s. **a** Easy airway grade–controls. **b** Difficult airway grade–controls. **c** Easy airway grade–anaesthesiologists. **d** Difficult airway grade–anaesthesiologists. C&L: Cormack and Lehane Grade

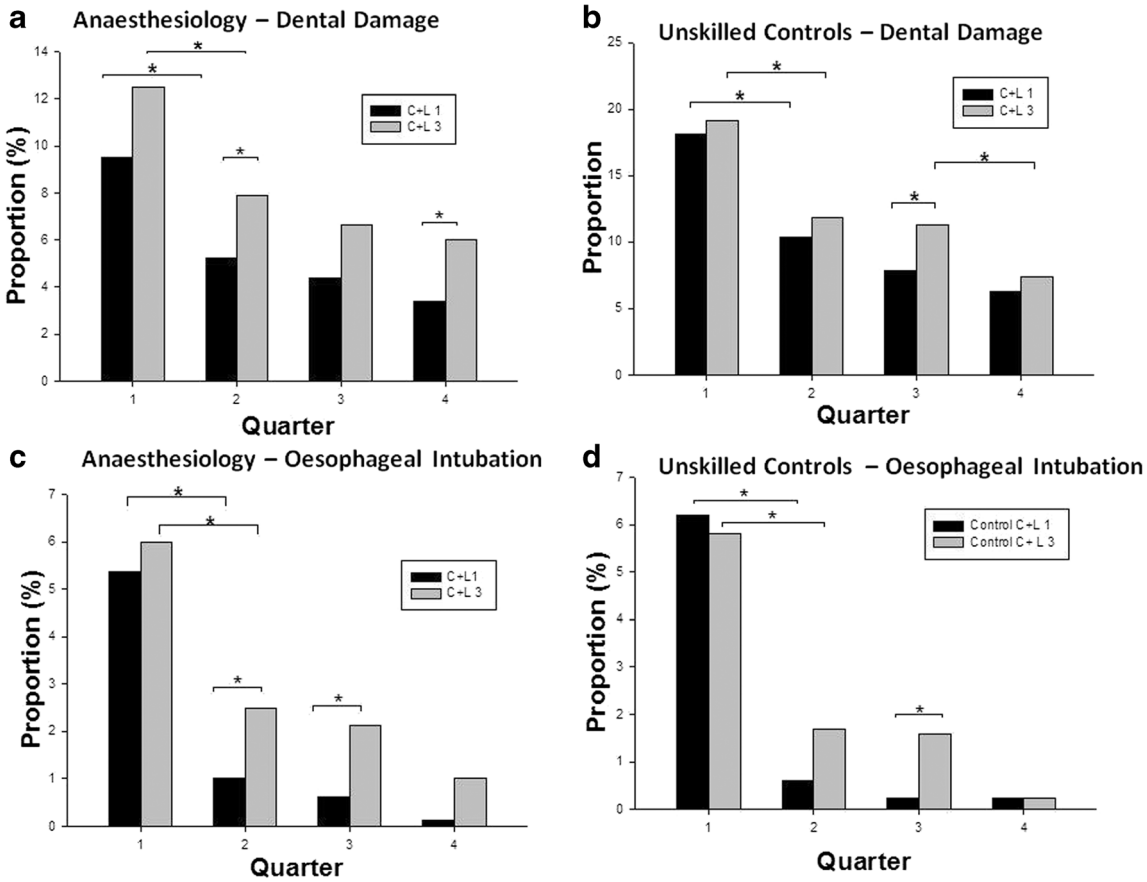

Fig. 4 Dental damage and oesophageal intubation. **a** Anaesthesiology–dental damage. **b** Controls–dental damage. **c** Anaesthesiology–oesophageal intubation. **d** Controls–oesophageal intubation. *$P < 0.05$ easy vs. difficult configuration. C&L: Cormack and Lehane Grade

achievement of procedural competency using the CUSUM analysis (Fig. 5, Table 2).

Discussion

This study was conducted to explore the acquisition of procedural skill in rigid bronchoscopy in anaesthesiologists assessed by both time required and complications. The data from this study show that acquisition of this skill can be achieved by anaesthesiologists within ten repetitions in a difficult airway manikin model and eight in an easy model. The relatively minor differences in measured outcomes between anaesthesiologists and unskilled controls, i.e. time to successful device placement, dental injury and accidental oesophageal intubation, indicate that prior experience with conventional laryngoscopy does not confer any advantage in terms of learning the technique of rigid bronchoscopy. The increased procedural times and complications in the difficult airway model suggest that training should be performed in both the easy and difficult models. The data also indicate that variation in learning curves between individuals exists. The purpose of unskilled controls was to demonstrate if there was a difference between subjects with and without prior airway skills. The data on unskilled controls could be applied to novices in anaesthesia where more focus needs to be applied to dental damage.

Salud et al. assessed camera-guided rigid bronchoscopy in thoracic surgeons in a pressure sensing bronchoscopy task trainer and found no difference in performance times between novices and experts. [15] However, less pressure was exerted in contact areas by the expert group in that study. This extrapolates to our study in which a greater frequency of dental injury was observed in those without prior laryngoscopy skills. In Salud's study, completion of rigid bronchoscopy which included carinal inspection and bronchoscope withdrawal required 45.3 and 45.9 s experts and novices, respectively. [15] These times were notably slower than those observed in our study, but importantly, the theoretical context in Salud's study was diagnostic examination with as opposed to emergency airway management. There are a number of related studies in which investigators have examined acquisition of procedural competence in emergency airway management in laboratory settings. In a manikin study, Wong et al. observed procedural time and success rate using a 40-s threshold in anaesthesiologists performing percutaneous dilation cricothyroidotomy and found that procedural time plateaued by the fourth attempt and success rate at the fifth attempt. [12]

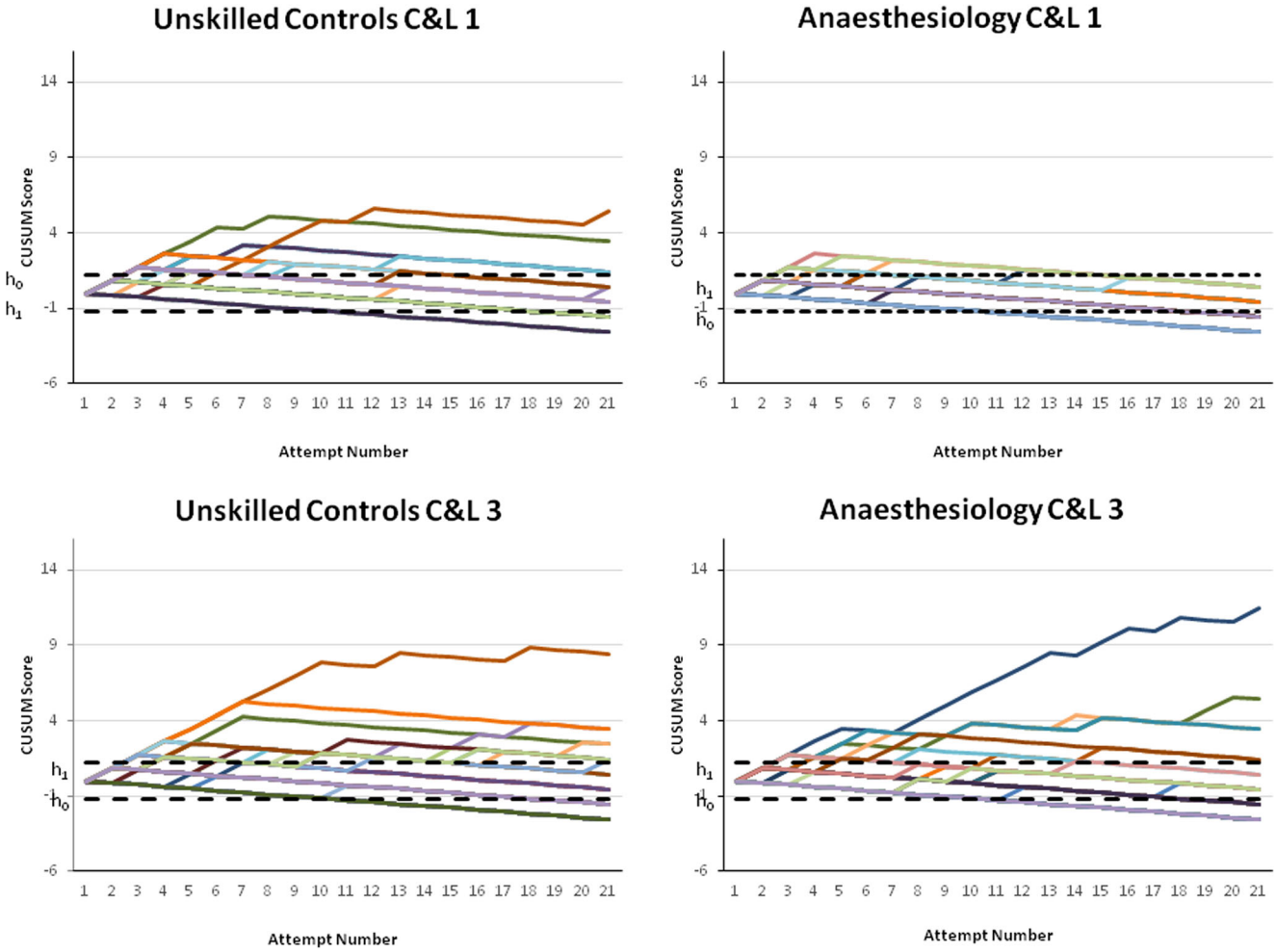

Fig. 5 CUSUM analysis of procedural success. h_0: lower decision limit. h_1: upper decision limit C&L: Cormack and Lehane Grade

At the fifth attempt, 96% of participants performed cricothyroidotomy within the 40-s limit. Progressive improvement in procedural times for multiple cricothyroid access techniques over four consecutive attempts has also been been documented in manikin models. [16] Similar to other studies on skill acquisition in anaesthesiology personnel, the number of repetitions required to achieve procedural competency varies widely between techniques. [17] There is consequently considerable debate regarding the volume of procedures required for either competence or expertise. [9] In a recent survey of UK trainees, participants, who were themselves anaesthesiologists, felt that 10 fibre-optic intubations were required for competence. [9] Konrad who observed trainees over a 1-year period estimated that anaesthesiology residents required 57 intubations, 71 spinal and 90 epidurals for competency where competency was defined as adequate technical performance rather than an arbitrary time limit. [18] The number of repetitions advocated by Konrad is clearly much greater than the 9 and 10 repetitions that our study indicated. Konrad also observed marked improvement with 20 repetitions with slower skill acquisition with more complex techniques.

Currently, the American Board of Thoracic Surgery mandates a minimum of 40 bronchoscopy procedures for professional certification of their trainees. The procedural threshold training requirements for rigid bronchoscopy is 20 for the American College of Chest Physicians, The American

Table 2 Procedural competence using CUSUM analysis

	C&L 1	C&L 3	*P* value
Anaesthesiologists (*N*, %)	35/40 (87.5)	32/40 (80.0)	NS
Controls (*N*, %)	30/40 (75.0)	25 /40 (62.5)	NS

Data are number, percentage. C&L: Cormack and Lehane Grade

CUSUM cumulative sum method

Thoracic Society and the European Respiratory Society with a further 15 per year for maintenance of competency. [8] For practicing or trainee anaesthesiologists, in the absence of access to regular thoracic surgery cases in which rigid bronchoscopy is routinely performed, the only realistic method of skill acquisition and maintenance of rigid bronchoscopy skills is in simulation settings, which provide opportunity for structured assessment of individual skills and competency. [19]

Limitations of the current study: Our study examined only one aspect of rigid bronchoscopy, i.e. the correct placement of the rigid bronchoscope in the trachea. It did not examine the ability to provide emergency oxygenation or lung ventilation nor did it evaluate other important competencies in relation to the technique. [8, 20] A further limitation of the manikin model is that it does not replicate the type of anatomy or pathology in which emergency rigid bronchoscopy may have a valid clinical role, e.g. extra or intraluminal tracheal obstruction. [21, 22] We did not assess skill retention and cannot comment on the interval at which retraining should occur. A matching non-airway trained group of physicians and surgeons at a similar stage of training may have been a better unskilled control group. This cohort would have a similar set of medical skills and provide better matching with anaesthesiology trainees.

In conclusion, this study shows that the technical skill of rigid bronchoscopy can be acquired within 10 repetitions in a manikin model. We recommend that both easy and difficult airway models are used during training as both procedural competence and complication frequency vary with the laryngoscopic grade of the model. Anatomically relevant models and simulation-based training may add additional educational benefit. Advanced laryngoscopic skills are not required prior to training in this technique.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent Informed consent was obtained from all individual participants included in the study.

Abbreviations C&L, Cormack and Lehane; CUSUM, Cumulative sum method; SD, Standard deviation; SEM, Standard error of mean

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