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CRITICAL CARE

Tracheal intubation in the critically ill: a multi-centre national study of practice and complications

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Editor's key points

- Complication rates associated with tracheal intubation in critically ill patients are relatively high.
- This paper presents data from the critical care units in Scotland.
- The complication rates as reported in this paper are lower than the previously reported figures.
- Importantly, the lower rate of complications could be because the doctors underwent a longer period of formal training in anaesthesia.

Background. Complications associated with tracheal intubation may occur in up to 40% of critically ill patients. Since practice in emergency airway management varies between intensive care units (ICUs) and countries, complication rates may also differ. We undertook a prospective, observational study of tracheal intubation performed by critical care doctors in Scotland to identify practice, complications, and training.

Methods. For 4 months, we collected data on any intubation performed by doctors working in critical care throughout Scotland except those in patients having elective surgery and those carried out before admission to hospital. We used a standardized data form to collect information on pre-induction physical state and organ support, the doctor carrying out the intubation, the techniques and drugs used, and complications noted.

Results. Data from 794 intubations were analysed. Seventy per cent occurred in ICU and 18% occurred in emergency departments. The first-time intubation success rate was 91%, no patient required more than three attempts at intubation, and one patient required surgical tracheostomy. Severe hypoxaemia (Sp_{O_2} <80%) occurred in 22%, severe hypotension (systolic arterial pressure <80 mm Hg) in 20%, and oesophageal intubation in 2%. Three-quarters of intubations were performed by doctors with more than 24 months formal anaesthetic training and all but one doctor with <6 months training had senior supervision.

Conclusions. Tracheal intubation by critical care doctors in Scotland has a higher first-time success rate than described in previous reports of critical care intubation, and technical complications are few. Doctors carrying out intubation had undergone longer formal training in anaesthesia than described previously, and junior trainees are routinely supervised. Despite these good results, further work is necessary to reduce physiological complications and patient morbidity.

Keywords: airway; audit; complications; intensive care; intubation, tracheal tube

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Tracheal intubation in critically ill patients can be difficult. Patients may be hypoxaemic, hypotensive, and cope poorly with induction and neuromuscular blocking drugs. Complications (which can be life-threatening) may occur in up to 40% of critically ill patients. Profound hypoxaemia may occur in around 25%,[1 2] severe hypotension in 10–25%,[1–3] and cardiac arrest in around 1.5%.[2–5] Mechanical complications such as oesophageal intubation and vomiting/aspiration occur more frequently than in patients undergoing anaesthesia for elective surgery.[1 2 6] The recently published fourth National Audit Project (NAP4) from the Royal College of Anaesthetists found that at least one in four major airway events occurred in the intensive care unit (ICU) or the emergency department (ED), often with particularly adverse outcomes.[7] Such complications do not depend only on patient factors; competence and expertise of the intubating doctor, choice and dose of induction and neuromuscular blocking drugs, and pre-induction management could be important. Technique and practice in emergency airway management varies between ICUs and in different countries, and as a result, complication rates may also differ. Competence and expertise in airway management[8] may vary among critical care doctors who may have little or no formal training in anaesthesia.[1 2] In contrast, ICUs in Scotland are currently staffed mostly by doctors from anaesthesia training programmes.[9] Therefore, we hypothesized that the rate of complications related to emergency airway management in the critically ill in Scotland might differ

from previously published international data.[1 2 4 5] We undertook a prospective, observational study of tracheal intubation performed by critical care doctors in Scotland to identify practice, complications and training, and to compare the results with previously described international patterns.

Methods

Ethical approval was granted by the East of Scotland Research Ethics Service; the need for patient consent was waived since the study simply documented existing clinical practice.

Patients and setting

Scotland has a population of around 5.2 million. There were 24 separate adult ICUs in Scotland in 2009 with a total of 145 funded level 3 (intensive care) beds into which around 10 000 patients are admitted each year. In 2009, 26.7% of patients died in hospital after ICU admission; the standardized mortality ratio for all ICUs was 0.84 (range 0.57–1.12).[9] All units in Scotland use the Wardwatcher® database[9] to record details, including patient information, admission diagnoses, severity of illness, organ support, and patient outcome. An annual national report is published which allows comparison of unit performance and provides overall characteristic data for patients admitted to critical care in Scotland. We invited all 24 units to participate in this national audit of tracheal intubation, identified a local co-ordinator in each unit, and designed a website containing supporting information, including definitions, to assist participants. We collected data between September 1 and December 31, 2009, on any tracheal intubation performed by a doctor working in critical care, regardless of where in the hospital, the intubation was performed. We excluded intubations performed in patients undergoing elective surgery and those done before hospital admission.

Procedure and data collection

The intubating doctor recorded all data on a specifically designed form immediately after tracheal intubation was performed. We documented details in three main sections: patient details, pre-induction physiology, and organ support; details of the intubation procedure; and immediate complications associated with tracheal intubation (Table 1).

Analysis

All data were entered into a Microsoft Access database and each entry was checked by a second person to ensure accuracy. We used Graphpad Prism version 5 (Graphpad Software Inc., San Diego, CA, USA) to perform basic descriptive statistical analyses, and the χ^2 test to compare incidence of complications and differences in outcome between the groups. We considered a P-value of <0.05 as significant.

Table 1 Data collected for each tracheal intubation

- Patient details, pre-induction physiology, and organ support
  - Age and gender of patient
  - Primary diagnosis
  - Oxygen saturation and systolic AP immediately before induction
  - Organ support being given before induction
  - Any airway assessment undertaken and anticipated difficulty of intubation
  - Outcome of patients admitted to an ICU
- Details of the intubation procedure
  - Time, location, indication for, and urgency of intubation
  - Reason for intubation—classed as
    - Patient newly admitted to ICU requiring mechanical ventilation
    - Patient deterioration
    - Problems with existing airway
    - Accidental extubation requiring re-intubation
    - Failed trial of extubation
    - Change of tracheal tube
    - Other
  - Urgency of intubation—classed as
    - Immediate
    - Urgent (within 30 min)
    - Semi-elective (>30 min)
    - Use of pre-oxygenation (3 min with a tight-fitting face-mask)
- Use of cricoid pressure
  - Use of induction drugs and neuromuscular blocking drugs (dose not recorded)
  - Laryngoscope used
  - Number of attempts at laryngoscopy
  - Best laryngoscopic view obtained (Cormack and Lehane classification)[36]
  - Use of capnography
  - Grade and speciality of the intubating doctor
  - Length of formal anaesthetic training undertaken by the intubating doctor
  - Degree of supervision for each attempt at intubation
- Immediate (i.e. within 30 min) complications related to tracheal intubation
  - Hypoxaemia—classed as
    - Sp_{O_2} <90%
    - Sp_{O_2} <80%
    - Sp_{O_2} <70%
  - Hypotension—classed as
    - Systolic AP <90 mm Hg
    - Systolic AP <80 mm Hg
    - Systolic AP <70 mm Hg
  - Cardiac arrest
  - Mechanical complications
    - Oesophageal intubation
    - Need for surgical airway
    - Vomiting or regurgitation of gastric contents

Results

Twenty-two of the 24 ICUs provided data. These 22 units account for 94% of patients admitted annually to ICUs and 91.5% of funded ICU (level 3) bed capacity in Scotland. During the study period, there were 3279 admissions to ICUs; of which, 2260 (69%) had tracheal intubation performed at some time during their hospital stay. We recorded

Table 2 Characteristics of patients with full outcome data (n=710). Data are shown as mean (SD), median (range), or number (%) as appropriate

Median age (yr)	54 (1–88)
Gender (male:female)	402:308
APACHE II score	18.6
APACHE II predicted mortality	34%
Mean length of critical care stay (days)	11 (13)
Critical care mortality (%)	186 (26%)
Mean length of hospital stay (days)	25 (26)
Hospital mortality (%)	237 (34%)
Diagnoses	
Respiratory infection	207 (29)
Other respiratory disorder	101 (14)
Sepsis/septic shock	62 (9)
Gastrointestinal disorder	87 (12)
Intracranial bleed/neurological disorder	62 (8)
Cardiovascular disorder	40 (6)
Drug overdose	32 (5)
Trauma	32 (5)
Seizures	25 (3)
Other	56 (8)

877 tracheal intubations performed by critical care doctors in the study period; in 83 instances, tracheal intubation was performed during cardiopulmonary resuscitation—we excluded these intubations for separate analysis (not reported here). Of the remaining 794 intubations, 56 did not have a unique Wardwatcher® identifier and a further 28 had incomplete outcome data recorded on Wardwatcher®. Thus, although data from all 794 intubations were available for the intubation procedure and complications, full patient characteristics and outcome data were available for 710 tracheal intubations (Table 2).

Seventy per cent of intubations occurred in ICUs with another 18% in EDs (Table 3). Around 40% took place at night and in three-quarters, the degree of urgency was considered immediate or urgent (Table 3). Most intubations were performed in patients newly admitted to intensive care requiring mechanical ventilation, and one-third of intubations were for problems with the existing airway, failed trial of extubation, or accidental extubation (Table 4). Many patients were very unwell before intubation; 23% were receiving non-invasive ventilation, 15% were receiving vasopressor by infusion, and 75% were breathing >60% oxygen. Furthermore, 39% had Sp_{O_2} <90%, 11% had Sp_{O_2} <80%, 20% had systolic arterial pressure (AP) <90 mm Hg, and 6% systolic AP <80 mm Hg. In 22 patients, tracheal intubation was known to have been difficult on a previous occasion. Two hundred and four predictors of difficult tracheal intubation were recorded in 197 patients; patient obesity (n=113), cervical spine immobilization after trauma (n=41), and abnormal airway anatomy (n=50) such as reduced mouth opening, reduced thyromental distance, or grade 3 or 4 Mallampati view. Seventeen of these 197

Table 3 Details of intubation procedure, including location, urgency, and timing. *Midazolam was given as co-induction in a further 72 intubations (the primary induction drug given in these intubations was: propofol 65, thiopental 5, and etomidate 2). C&L grade, Cormack and Lehane score

	Number	%
Location		
Intensive care unit	549	70
High-dependency unit	53	7
Hospital ward	24	3
Emergency department	140	18
Other	14	2
Not recorded	14	
Urgency		
Immediate	221	28
Urgent	411	53
Semi-elective	152	19
Not recorded	10	
Time of intubation		
08:00–19:59	481	61
20:00–07:59	309	39
Preparation		
Pre-oxygenation	666	84
Cricoid pressure	660	83
Induction drug		
Propofol	484	61
Thiopental	159	20
Etomidate	73	9
Ketamine	20	3
Midazolam*	30	4
None given	28	4
Neuromuscular blocker		
Succinylcholine	460	58
Rocuronium	195	25
Atracurium	72	9
None given	65	8
Opioid		
Alfentanil	254	32
Fentanyl	163	21
Remifentanil	9	1
Morphine	9	1
None given	361	45
Attempts at laryngoscopy		
1	719	91
2	70	9
3	5	1
Laryngoscopy view at first attempt (C&L grade)		
1	561	75
2	143	19
3	40	5
4	8	1
Not recorded	42	
Adjuncts used		
Bougie	140	18
Stylet	52	7
Capnography	426	54

Table 4 Reason for intubation (n=794; some records had more than one reason recorded)

Reason	Number	%
Patient newly admitted to ICU	432	54
Patient deterioration	82	10
Problems with existing airway	84	11
Change of tracheal tube	38	5
Failed trial of extubation	96	12
Accidental extubation	34	4
Other	38	5
Not recorded	28	

Table 5 Immediate complications of tracheal intubation (n=794)

	Number	%
Sp_{O_2}		
<90%	327	41
<80%	172	22
<70%	89	11
Systolic AP		
<90 mm Hg	260	33
<80 mm Hg	155	20
<70 mm Hg	79	10
Cardiac arrest	12	1.5
Oesophageal intubation	17	2
Failed intubation	2	0
Vomiting/regurgitation	17	2

patients (8.6%) had grade 3 or 4 laryngoscopic view compared with 31 of 555 patients (5.6%) with no predictors of difficulty.

The drugs used and the main details of the intubation procedure are shown in Table 3. Induction drugs were given in 96% of intubations and neuromuscular blocking drugs were given in 92%. Tracheal intubation at the first attempt was obtained in 91%, five patients (1%) had three attempts at intubation, and no patient underwent more than three attempts at intubation. Two failed primary intubations required insertion of a Proseal laryngeal mask, one of which required progression to surgical tracheostomy to secure the airway. Videolaryngoscopy and fibreoptic laryngoscopy were each used in six intubations. We did not find any statistically significant difference in first-time success rate or the number of intubation attempts, when we compared those patients who were given a neuromuscular blocking drug and those who were not (one attempt 90% *vs* 95%; two attempts 9% *vs* 3.5%; three attempts 1% *vs* 1.5%, respectively).

Immediate complications associated with tracheal intubation are shown in Table 5. Twenty-two per cent of patients had severe hypoxaemia (Sp_{O_2} <80%) and 20% had severe hypotension (systolic AP <80 mm Hg) (Fig. 1). Neither the severity of hypoxaemia nor hypotension after intubation was related to outcome (Sp_{O_2} ≥90%, ICU mortality 23.5%; 80–89%, 31.4%; 70–79%, 31.2%, <70%, 25.6%; P=0.208: systolic AP ≥90 mm Hg, ICU mortality 24.6%; 80–89 mm Hg, 32.2%; 70–79 mm Hg, 25.7%, <70 mm Hg, 31.4%, P=0.356). However, choice of induction drug appeared to be related to the development of hypotension. Ninety-four per cent of patients had systolic AP ≥80 mm Hg before induction of anaesthesia. Sixty of these patients had systolic AP <70 mm Hg after induction; the drugs used were propofol in 38 patients, etomidate in two, thiopental in eight, ketamine in one, and midazolam in 11. The relative risk (95% confidence intervals) for developing systolic AP <70 mm Hg after each induction drug was: etomidate 0.37 (0.09–1.46); thiopental 0.69 (0.33–1.42); ketamine 0.74 (0.11–5.02); propofol 0.99 (0.60–1.64); and midazolam 4.49 (2.56–7.88). Mechanical complications were infrequent with oesophageal intubation being recorded in only 2% of cases, and vomiting or regurgitation of gastric contents also occurring in 2%.

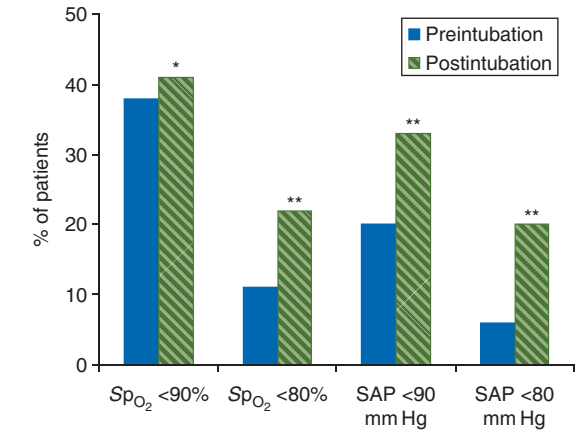

Fig 1 Percentage of patients with hypoxaemia or hypotension before and after tracheal intubation. *P=NS, **P<0.001 compared with preintubation.

Three-quarters of intubations were performed by doctors with >24 months of formal anaesthetic training, and all but one doctor with <6 months training had senior supervision (Table 6). As the number of attempts at intubation increased so did the proportion of intubating doctors with >12 months anaesthetic training (attempt 1, 82%; attempt 2, 93%, attempt 3, 100%). Intubation in patients with predictors of difficulty was more likely to be performed by a senior doctor. The success rate of tracheal intubation was related to the duration of formal anaesthetic training undertaken by the intubator (P<0.001, Table 6). One hundred and thirty-five intubations were done by trainees with <12 months of formal anaesthetic training; 44 of these occurred overnight and only five were not supervised by a more experienced doctor.

Discussion

In this survey, we found a very high rate of successful tracheal intubation in critically ill patients and rates of

Table 6 Anaesthetic experience of intubator and rate of successful intubation for the first attempt at tracheal intubation

Months spent in formal anaesthetic training	Number (%)	Number supervised by senior intubator (%)	Success rate (%)
<6	74 (10)	73 (99)	69
6–12	61 (8)	52 (85)	77
12–24	61 (8)	43 (70)	90
>24	565 (74)	155 (27)	95

physiological complications comparable with those reported previously. The study has the particular advantage of involving a national perspective with 92% of ICUs in Scotland contributing and includes more than 800 intubations with a well-characterized data set. It thus provides a comprehensive snapshot of current practice in Scottish critical care, and focuses clearly on ICUs and EDs, locations identified as having avoidable deaths due to airway complications.[7 10] Our findings confirm very high success rates for tracheal intubation in often challenging circumstances, but also highlight areas where improvements could be made to reduce complications.

We found that >90% of patients had tracheal intubation achieved successfully at the first attempt, only 1% of patients underwent three attempts, and only one patient required surgical tracheostomy. Other studies have found a first-time success rate between 63% and 75%[1 2 4 11] with around 12% of patients requiring three or more attempts.[1 2 4] We found a low rate of mechanical complications; for example, the rate of oesophageal intubation in our study was 2% compared with rates between 1.3% and 9.7% in other studies.[1–4 6 12 13] There is a clear link between the number of attempts at intubation and development of complications in the critically ill; the frequency of severe hypoxaemia increased 14-fold in patients who required more than two attempts at tracheal intubation, while the frequency of regurgitation and cardiac arrest both increased seven-fold.[4] The Difficult Airway Society recommends that no more than three attempts should be made at intubation.[14] Although this recommendation may be true for patients undergoing anaesthesia, it is less applicable to critically ill patients where the option of wakening the patient may not be realistic. It is therefore very encouraging that no patient in our study required more than three attempts at intubation and that a surgical airway was required in only one. We cannot use the data from our study to provide guidance for what to do if intubation is unsuccessful in the critically ill; however, this has been discussed in detail elsewhere.[15 16] The rates of physiological complications such as hypoxaemia or hypotension are similar to previous studies[1–4] but are higher than those found in a French study when a protocol for tracheal intubation (which included pre-oxygenation with positive pressure ventilation, the use of etomidate or ketamine as the induction drug, and early use of vasopressor therapy) was introduced.[12] It is difficult to compare our results directly with those from other studies. Those from North America[1 4 6] reflect different populations and practices to those from Europe,[2 11 12] and some studies have examined intubations only in critical care while others have studied intubations in other hospital locations; choice of induction drug and the use of neuromuscular blocking drugs varied, and the seniority and experience of staff performing intubation was different.

The patients in our study were seriously ill before intubation—nearly 40% had Sp_{O_2} <90%, three-quarters were receiving >60% oxygen, and one-fifth had systolic AP <90 mm Hg. It is therefore not surprising that physiological complications after intubation, such as hypoxaemia and hypotension, were common. However, the number of patients with Sp_{O_2} <80% doubled after intubation, and the number with systolic AP <80 mm Hg increased three-fold, suggesting that induction of anaesthesia and tracheal intubation may have contributed directly to patient morbidity. Although the vast majority of patients received pre-oxygenation for 3 min via a tight-fitting face-mask before intubation was attempted, this may not prevent desaturation in critically ill patients[17] and extending the period of pre-oxygenation to 8 min is of limited additional benefit.[18] Since the incidence of hypoxaemia is dramatically reduced when pre-oxygenation is used in conjunction with positive-pressure ventilation,[12] this combination should be used where appropriate before tracheal intubation in the critically ill.

Hypotension is a common feature in anaesthesia-related deaths.[19] Critically ill patients with hypotension are at greater risk[2 6 20] and are more likely to die,[6] although severity of hypotension did not correlate with outcome in these data. Choice of induction drug may be important in minimizing the occurrence of hypotension in the critically ill. Etomidate and ketamine affect AP less than thiopental or propofol, and propofol has the greatest potential for cardiovascular instability and hypotension. In our study, propofol was used in more than 60% of patients given an induction drug, while etomidate or ketamine was used in only 12%. Hypotension before induction did not appear to influence the choice of induction drug: in more than 50% of patients with systolic AP <80 mm Hg, propofol was chosen for use. This finding supports similar findings in two previous studies where propofol was used in 49% and 80% of rapid sequence inductions of anaesthesia performed outside the operating theatre.[3 11] Propofol is the most commonly used induction drug in the UK and the high rate of propofol use may reflect the background training in anaesthesia and experience of the intubators in critical care in Scotland. Hypotension is related to the dose of induction drug given,[21] and although we did not record the doses of induction drugs in our study, the risk of developing hypotension was greater after midazolam or propofol than after etomidate, ketamine, or thiopental. Anaesthesia-related hypotension is more frequent when propofol is used, particularly in patients aged >50 yr and those in ASA class III or IV.[22 23] In a recent French study, when the use of etomidate or ketamine for induction in ICU increased

from 35% to 76%, the incidence of severe hypotension was reduced by half.[12] Etomidate has caused controversy recently in association with biochemical evidence of adrenal suppression[24 25] which some observers believe has adverse consequences in the critically ill.[26–28] However, etomidate does not affect outcome in patients with a range of critical illnesses,[29–31] and outcomes after its use in critically ill patients are not different from those after ketamine.[32] The choice of induction drug in critical illness remains controversial, but it may be important to use a drug which is less likely to be associated with significant hypotension.

The anaesthetic experience of the intubators and the level of supervision of junior medical staff in our study were very good. More than 80% of doctors undertaking the first attempt at intubation had >12 months of formal anaesthetic training, and nearly three-quarters had >24 months. Such experience undoubtedly contributed to the very high first-time success rates for tracheal intubation and very low incidence of mechanical complications. We cannot directly compare levels of training with those described in previous studies as most were from countries where training programmes are not directly comparable with the UK. Schwartz and colleagues[6] noted that 31% of intubations were performed by anaesthesia residents and 30% by critical care fellows; they defined a person as being 'skilled in airway management' if they had completed more than 6 months of anaesthesia residency or if they were a critical care attending physician. A more recent study of 3423 emergency tracheal intubations performed by anaesthesia residents with at least 24 months of training in anaesthesia found a very low rate of mechanical complications, although 3% of patients required three or more attempts at intubation.[13] Another North American study found that tracheal intubation performed by an 'expert' operator was more likely to be successful, take fewer attempts and be associated with fewer complications and lower mortality than intubations performed by 'non-experts';[1] however, only 56% of their 'expert' intubators had any anaesthetic training. In France, Jaber and colleagues[2] described having two operators as a protective factor in reducing complications related to tracheal intubation but only 68% of intubators had undergone training in anaesthesia. The recent NAP4 study found that education and training were causal or contributory factors in 58% of ICU cases reported.[7] A recent UK study done after the publication of the NAP4 report found that 83% of out-of-theatre intubations were performed by an intubator with >6 months of anaesthesia experience.[3] Our findings suggest that the present situation in Scottish critical care is very robust, with a high proportion of intubators with >24 months of formal anaesthesia training and excellent levels of supervision of junior staff. However, medical staffing in UK critical care is changing rapidly with many more doctors in critical care having little or no formal anaesthetic training. There is an increasing onus on consultants covering critical care areas to be immediately available or to perform airway management personally. It may be interesting to repeat this study in 5 yr to assess any impact of such changes in critical care staffing.

Capnography was used in 54% of intubations in our study. Capnography is recommended to confirm tracheal tube position in all intubations including those which are performed outside the operating theatre,[33] and others have highlighted the need for capnography in these locations.[34 35] The recent NAP4 study highlighted a number of cases where morbidity and mortality in intensive care and EDs were associated with a lack of capnography. Almost 90% of intubations in our study were performed in the ICU or the ED where capnography should be used routinely. This area of practice must be improved.

Our study has some limitations. Two ICUs did not contribute to data collection. It is unlikely that data from these two units would alter the main findings substantially, although we cannot be certain about this. The study was observational—some intubations may have been missed, some data will have been lost or incorrectly collected, and some outcome data are missing. However, it is the largest prospective study of tracheal intubation performed by critical care doctors in the UK, reflects practice throughout Scotland capturing more than 90% of critical care workload, and the results have important implications for ICUs throughout the UK.

In conclusion, we found that critical care doctors in Scotland achieved tracheal intubation at the first attempt in more than 90% of patients, no patient had more than three attempts at intubation, and the rate of mechanical complications was around 2%; intubators are generally experienced in the procedure and have undergone a longer period of formal anaesthesia training than is described in previous studies; and junior trainees are routinely supervised. However, severe hypoxaemia and hypotension occurred in around 20% of patients, similar to previous studies. Improved strategies such as more effective pre-oxygenation, changing the induction drug used, and better use of capnography are needed to reduce physiological complications and possible patient morbidity.

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Declaration of interest

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