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**ORIGINAL RESEARCH**

# The Royal North Shore Hospital Emergency Department airway registry: Closing the audit loop

Toby FOGG,[1,2,3] Hatem ALKHOURI[4] and John VASSILIADIS[1,3,5]

[1]Emergency Department, Royal North Shore Hospital, Sydney, New South Wales, Australia, [2]CareFlight, Sydney, New South Wales, Australia, [3]Discipline of Emergency Medicine, Sydney University Medical School, Sydney, New South Wales, Australia, [4]Emergency Care Institute, Agency for Clinical Innovation, Sydney, New South Wales, Australia, and [5]Sydney Clinical Skills and Simulation Centre, Royal North Shore Hospital, Sydney, New South Wales, Australia

## Abstract

***Objective:*** We aim to investigate whether a bundle of changes made to the practice of endotracheal intubation in our ED was associated with an improvement in first pass success rate and a reduction in the incidence of complications.

***Methods:*** We used a prospective observational study.

***Results:*** The data on 360 patients who were intubated during an 18-month period following the introduction of these changes were compared with our previously published observational data. Success on first attempt at intubation improved 83.4% to 93.9% ($P < 0.0001$). The proportion of patients with one or more complication fell from 29.0% to 19.4% ($P < 0.042$). Oesophageal intubation fell from 4.0% to 0.3% ($P < 0.001$), and there was a non-significant reduction in the rate of desaturation, from 15.6% to 10.9% ($P < 0.07$).

***Conclusion:*** We have shown that, through the introduction of a bundle of changes that spans the domains of staff training, equipment and practice standardisation, we have made significant improvements in the safety of patients undergoing endotracheal intubation in our ED.

**Key words:** *airway management, complications, emergency medicine, intubation, quality improvement.*

## Introduction

Airway management is a fundamental aspect of many of the major resuscitations that take place in our EDs[1] and a skill that emergency physicians (EPs) should deliver in a safe and timely manner. A number of observational studies have been published describing how this practice is performed in EDs across the world either at a single[2–6] or multicentre[7–11] level. Following the publication of data on ED intubation from our institution,[12] it was decided to implement a bundle of changes to our practice in order to improve patient safety. These changes occurred across the broad domains of staff training, equipment and practice standardisation and are listed in Table 1. Similar audit cycles have been undertaken in adult[13] and paediatric[14] ICUs and a paediatric ED,[15] but to our knowledge, no such work has been described for a mixed ED.

We aim to investigate whether the changes made to the practice of endotracheal intubation in our ED were associated with an improvement in first pass success rate and a reduction in the incidence of complications.

### Key findings

- Significant improvements in RSI safety have been demonstrated.
- Changes introduced span the domains of staff training, equipment and practice standardisation.
- All EDs should consider auditing their practice in order to drive change.

## Methods

This prospective, observational study was carried out in the ED of the Royal North Shore Hospital, a major trauma centre in Sydney, Australia. The ED has an annual census of approximately 70 000 patients with a 20% paediatric attendance rate.

Permission for the study was granted by the Northern Sydney Local Health District Human Research Ethics Committee in June 2010.

Data on all attempts at intubation that occurred in the ED of the Royal North Shore Hospital over 18 months, between 1 October 2012 and 30 March 2014, were extracted from the Australia and New Zealand Emergency Department Airway Registry and was compared with data from the initial 18-month period, from 1 April 2010 to 30 September 2011.[12]

A 12-month interval between data sets was nominally chosen to allow as many staff as possible, many of whom rotate in and out of the ED during the course of their training, to become familiar with the new procedures. Furthermore, it was felt that by allowing a whole year between data sets, the second phase of the study would show the ongoing practice of individuals, rather than their transient adherence to a new

Correspondence: Dr Toby Fogg, Emergency Department, Royal North Shore Hospital, Reserve Road, St Leonards, NSW 2065, Australia. Email: tobyfogg@mac.com

Toby Fogg, BM, FACEM, FCEM, Staff Specialist; Hatem Alkhouri, BAppSci, MSc, PhD, Research Fellow; John Vassiliadis, MBBS, FACEM, Senior Staff Specialist.

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**TABLE 1.** *Quality improvement changes made to the practice of RSI*

| | |
|---|---|
| Staff training and education | Intubation could only be performed by those with ≥3 months anaesthetics experience |
| | Weekly *in situ* simulation training, run by ED-Simulation Fellow |
| | Provision of part task training and cadaveric workshops |
| Equipment | Mandated use of a C-Mac video laryngoscope for all attempts† |
| Practice standardisation | Mandated the use of nasal prong apnoeic diffusion oxygenation |
| | Mandated use of a bougie or stylet for all intubation attempts |
| | Standardised pre-RSI checklist and difficult airway algorithm instituted |

†The C-Mac became available for use during the last 12 months of the pre-intervention phase. Its use was mandated during the second phase. RSI, rapid sequence induction.

set of guidelines, before they potentially reverted back to their original practice.

The sample size was based on inclusion of all patients requiring endotracheal intubation while they were in the ED. This included intubations performed without the use of drugs. The team leader or the intubator completed a data sheet (Appendix S1) as close to the time of intubation as possible. Any missing data were established through interview with the staff involved or from the medical record. The register of controlled drugs was regularly reviewed to ensure all episodes of rapid sequence induction (RSI) were recorded.

### *Definitions*

The definitions have been described previously.[12]

### *Data analysis*

Data collected using the registry forms were transcribed into a Microsoft Excel 2010 (Microsoft, Redmond, WA, USA) template. Descriptive statistics including median and inter-quartile range (IQR from the 25th to the 75th percentile), sample proportions and 95% confidence intervals were performed on all data using Graph-Pad Prism 5.03 (La Jolla, CA, USA). $X^2$ test or, as appropriate, exact tests were used to compare groups of categorical data. All tests were two-tailed. Statistically significant differences were considered at the $P < 0.05$ level and are presented where relevant.

## Results

During the pre-intervention period, 295 patients were intubated, while 360 were intubated during the post intervention period. The male to female ratio was 1.7 and 1.6:1, while the median age in each of the two groups was 52 (IQR 32–72) and 54 (IQR 33, 75) years: this includes 27 (9%) and 22 (6%) paediatric patients (age <17 years), respectively. The degree of derangement in patients' vital signs was similar between the two time periods (data not shown). Despite the increase of 22% in the number of intubations that occurred, there was no statistically significant change in the indications for intubations between the two phases. The main indications for intubations were overdose or ingestion in the medical group and head injury in the trauma group (Fig. 1).

### *Adherence with the changes*

The utilisation of the C-Mac video laryngoscope for the first attempt increased from 48.8% to 92.7%, $P < 0.001$. This was also accompanied with a 24.9% increase in the use of a bougie or a stylet, $P < 0.001$ (Table 2). The utilisation of the pre-intubation checklist and nasal prong apnoeic diffusion oxygenation was 92.7% and 88.4%, respectively, confirming that the majority of staff had incorporated these changes into their routine practice. Finally, the number of first attempts at intubations performed by novice physicians fell from 24 (8.1%) to three (0.01%), $P < 0.0001$ (Table 2).

### *Effects of the changes*

We observed a significant improvement of 10.5% in first pass success rate in the post-intervention phase from 83.4% to 93.9% ($P < 0.0001$) while success within one or two attempts improved from 96.3% to 99.2% (Table 3). The incidence of difficult laryngoscopy at the first attempt was significantly lower in the post-intervention (7.8%) compared with pre-intervention (17%) phase ($P < 0.001$).

The proportion of patients who had at least one complication fell from 29.0% to 19.4% ($P < 0.042$). Oesophageal intubation fell from 4.0% to 0.3%, $P < 0.001$, and there was a non-significant reduction in the rate of desaturation, from 15.6% to 10.9%, $P < 0.07$ (Table 4).

## Discussion

We believe this is the first paper to describe a full quality improvement audit cycle of the practice of endotracheal intubation in an Australasian ED. By adhering to the changes introduced, we have demonstrated that our success rate at first attempt of intubation increased significantly, and we were able to intubate more than 99% of our patients within one or two attempts. This success rate exceeds that shown by other observational studies of RSI performed in the ED[2–6,9–11] and is even comparable to those seen in the operating theatre.[16]

A suite of changes was required as the issues were multifactorial. As previously described, these changes ranged from implementing checklists and difficult airway algorithms, to team training in a simulation setting to cadaveric airway training.

These data illustrate that reviewing current practice and instituting change can make significant improvements in patient safety. A number of issues were

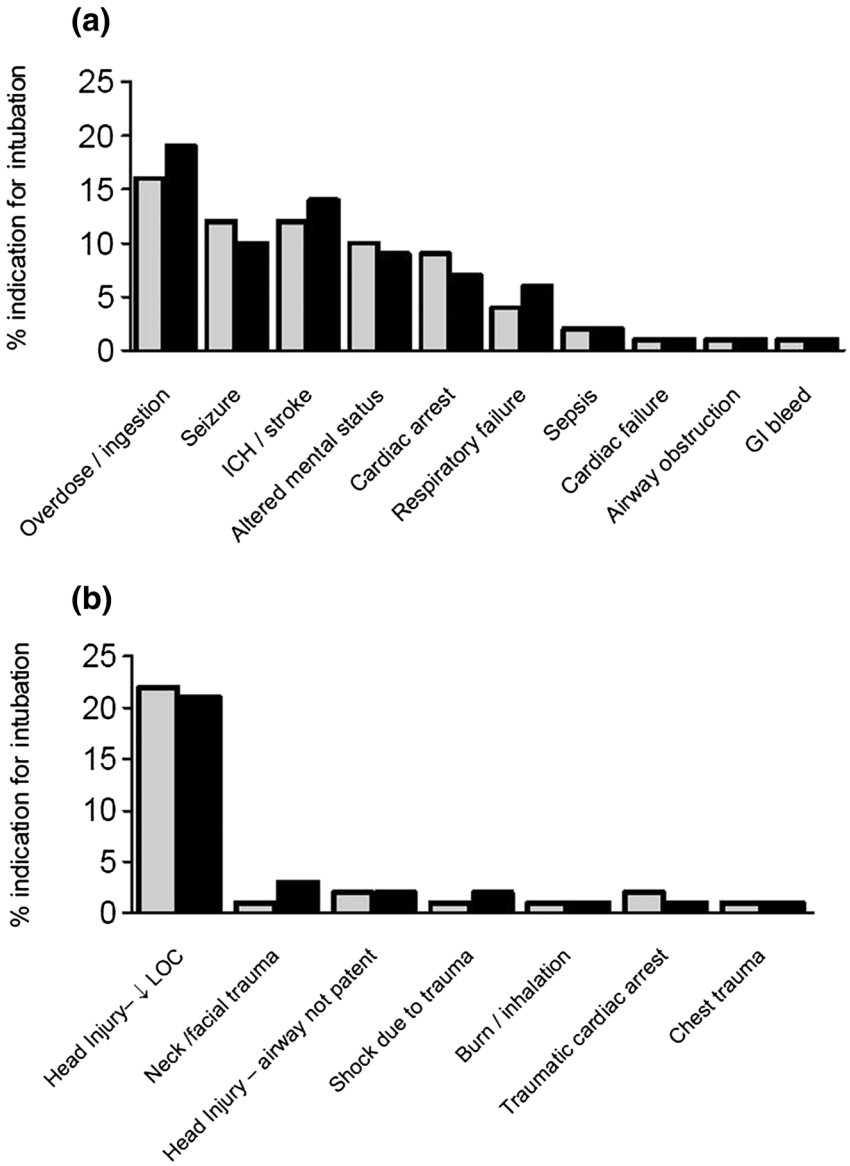


**Figure 1.** *Indications for intubation in the pre-□ and post-intervention ■phases for patients in the medical group (a) and trauma group (b). GI, gastrointestinal; ICH, intracranial hemorrhage; LOC, level of consciousness.*

identified in our previous study that impacted on first pass success rate and complication rates. The main ones being intubator skill level, training, equipment and team performance during a time critical and potentially challenging procedure on sick patients. The challenge was how to best address the previous issues in a timely and non-confrontational manner and at the same time improve patient care.

Our previous data showed that novice intubators had a particularly low first pass success rate (58.3%) so it was mandated that only doctors who had spent at least 3 months undertaking an anaesthetics placement would be allowed to attempt to intubate in the ED.[12] This decision was supported by other literature, with studies showing a clear relationship between experience and success and complication rates.[17–19] While relatively short, 3 months is the standard secondment to anaesthetics that ED trainees undertake at our institution, and it is accepted that such a period of time only acts as a foundation for ongoing training in ED-based airway management. We note that for the purposes of credentialing by the Australasian College for Emergency Medicine, anaesthetics is not a mandatory term as the requirement is 6 months of intensive care or anaesthetics.[20] We accept that 3 months of anaesthetics only acts as a foundation for ongoing training in ED-based airway management.

Since April 2013, a multidisciplinary *in situ* simulation scenario is held once a week in one of the resuscitation bays in the ED. The scenarios are designed to improve clinical knowledge as well as foster effective multidisciplinary teamwork and crisis resource management. Additional education has also taken place in lectures, the hospital's simulation centre and the cadaveric laboratory. In the cadaveric workshop, trainees and consultants practice airway management using various techniques that include standard laryngoscopy, video laryngoscopy, laryngeal mask airways and surgical airways.

An algorithm for airway management (Appendix S2) was developed by consensus among the EPs in our department, and while based on the Difficult Airway Society's guidelines,[21] it was tailored for use within our ED. Our objective was to try and standardise airway planning, thus enabling the resuscitation team to function more efficiently and more safely.[22] A pre-RSI checklist (Appendix S3) was also developed using Delphi methodology[23] among the EPs at our institution and then the ED Directors of NSW (unpublished study). The use of checklists in medicine has been shown to impart improved communication, reduced adverse events, better adherence to standard operating procedures and reduced morbidity and mortality.[24,25] Their use prior to an ED RSI was called for by the Fourth National Audit Project in the United Kingdom[26] and, in a recent simulation-based study, have been to reduce significant errors or omissions without delaying intubation.[27] Our checklist is used before the initiation of all RSIs, as a final check between the airway doctor and nurse that all the items on the list have already been planned for or performed, in a manner similar to that recently described for pre-hospital RSI.[28]

There is good evidence[4,29,30] that minimising attempts at intubation will

**TABLE 2.** *Compliance with interventions introduced; type of laryngoscope and adjuncts, pre-intubation checklist and apnoeic diffusion oxygenation*

| | Pre-intervention % (95% CI) | Post-intervention % (95% CI) |
|---|---|---|
| Laryngoscope (first attempt) | | |
| Macintosh | 50.8 (45.1–56.5) | 7.3 (4.6–10.0)* |
| C-Mac | 48.8 (43.1–54.5) | 92.7 (98.9–95.5)* |
| McCoy | 0.3 (0–0.9) | 0.0 (0–1) |
| Use of adjuncts (bougie or stylet) | | |
| On first attempt | 68.4 (63.0–73.8) | 93.3 (90.7–96.0)* |
| Neither used on first attempt | 31.6 (26.5–37.2) | 6.7 (4.3–9.9)* |
| Adjunct use on all attempts | 69.8 (64.8–74.4) | 88.3 (85.1–91.5)* |
| Use of pre-intubation checklist | 0.0 (0–1) | 92.7 † (88.9–96.5)* |
| Use of nasal prong apnoeic diffusion oxygenation | 0.0 (0–1) | 88.4 (84.7–92.1)* |
| Intubator experience on first attempt | | |
| Number of previous intubation < 10 | 8.1 (5.0–11.2) | 0.0 (0–0.1)* |

*$P < 0.0001$. †Data collection form was modified to capture this information. CI, confidence interval.

**TABLE 3.** *Grade of laryngoscopy and success at intubation*

| | Pre-intervention % (95% CI) | Post-intervention % (95% CI) |
|---|---|---|
| Laryngoscopy | | |
| Difficult laryngoscopy on first attempt† | 17.0 (13.0–21.7) | 7.8 (5.0–11.0)* |
| Success at intubation | | |
| Success at first attempt | 83.4 (78.7–87.2) | 93.9 (90.9–96.1)* |
| Success at second attempt | 12.9 (9.5–17.2) | 5.3 (3.2–8.1) |
| Success at third attempt | 2.0 (0.9–4.4) | 0.6 (0.1–2) |
| Success at fourth attempt | 1.0 (0.4–3.0) | 0.3 (0–1.5) |
| Success at fifth attempt | 0.3 (0.1–1.9) | 0.0 (0–1) |

*$P < 0.001$. †If a C-Mac video laryngoscope was used, this is taken to be the best of either the direct view or the video screen. CI, confidence interval.

minimise complications as well as facilitating any rescue intubations in the face of previous failed attempts using alternate techniques.[31] In our attempts to maximise first pass success, we mandated the use of techniques and adjuncts traditionally used for rescue attempts or the predicted difficult airway. This was based on the assumption that ED airways are hard to assess and difficult to be predicted prior, so it is safer to have the mindset that the airway will be difficult from the beginning and prepare accordingly.

Our previous data[12] suggested that a higher first pass success rate occurred when a bougie or stylet was utilised to aid insertion of the endotracheal tube (ETT), and this is in keeping with previous work.[21,32–34] As a consequence of such high bougie use, we changed to using Parker Flex tip ETTs (Parker Medical, Englewood, CO, USA). These have a soft bevelled tip that reduces the space between the bougie and the ETT, minimising the chance of impingement, commonly known as arytenoid hang-up, as the ETT is advanced over the bougie.[35]

The use of a C-Mac video laryngoscope (Karl Storz GmbH & Co. KG, Tuttlingen, Germany) as the default device for every intubation has been encouraged as there is good evidence that it not only improves

**TABLE 4.** *Incidence of complications occurring after all intubations performed during pre-intervention and post-intervention phases*

| | Pre-intervention % (95% CI) | Post-intervention % (95% CI) |
|---|---|---|
| None occurred | 71.0 (65.4–76.0) | 80.6 (76.1–84.4)* |
| Desaturation – $SpO_2 < 93\%$ | 15.6 (11.8–20.3) | 10.9 (7.9–14.7) |
| Mainstem bronchial intubation | 4.0 (2.2–7.0) | 2.6 (1.4–4.8) |
| Oesophageal intubation | 4.0 (2.2–7.0) | 0.3 (0.0–1.6)** |
| Hypotension | 4.0 (2.2–7.0) | 2.0 (1.0–4.1) |
| Cardiac arrest | 2.2 (1.0–4.7) | 0.6 (0.2–2.1) |
| Equipment failure | 2.2 (1.0–4.7) | 2.3 (1.2–4.5) |
| Bradycardia < 60/min | 0.7 (0.2–2.6) | 0.3 (0.1–1.6) |
| Laryngospasm | 0.7 (0.1–2.6) | 0.0 (0.0–1.1) |
| Other | 0.7 (0.1–2.6) | 0.6 (0.2–2.1) |
| Vomit – no aspiration | 0.7 (0.1–2.6) | 0.3 (0.1–1.6) |
| Dental trauma | 0.4 (0.0–2.0) | 0.0 (0.0–1.1) |
| Medication error | 0.4 (0.0–2.0) | 0.0 (0.0–1.1) |
| Airway trauma | 0.0 (0.0–1.4) | 0.6 (0.2–2.1) |
| Vomit with aspiration | 0.0 (0.0–1.4) | 0.6 (0.2–2.1) |

*$P = 0.0415$. **$P = 0.0008$. CI, confidence interval; $SpO_2$, peripheral oxygen saturation.

glottic view but also improves first pass success rates.[36–40] It should be noted that the C-Mac became available for use 6 months into the first phase of data collection.

We encouraged the use of the advanced concepts of pre-oxygenation and peri-intubation oxygenation as described by Weingart and Levitan.[41,42] In particular, the use of nasal prong apnoeic diffusion oxygenation has been strongly emphasised, and evidence is building that this technique is effective at reducing desaturation associated with intubation.[43]

The changes were made by engaging in a collaborative fashion our medical and nursing staff. A suite of changes was required as the issues were multifactorial, but the combination of the C-Mac with a bougie or stylet for most episodes of intubation may well have made the largest difference in intubation success. However, the study was not designed to accurately identify which change was the most beneficial, or for that matter least. It is impossible to state whether these changes would have the same effect if implemented in another department. All we can say is that by undertaking an audit into our intubation practice, we identified areas that we could improve in.

Each ED will have its own unique challenges to overcome and address. We would encourage each department to be open to the idea to review how 'you do business' and not be afraid to tackle the issues in an open and collegiate manner. Almost all of the changes made are within the scope of most EDs.

The reader may rightly question the relatively high rate of desaturation that this study has demonstrated. However, we would like to point out that, unlike other observational studies that used 90% as the cut-off for desaturation,[4,44,45] we chose to use 93% as our lower limit for safe oxygen saturation in order to provide a margin of safety before critical desaturation occurs.[46] In other words, we feel that if, during an RSI, an unwell patient desaturates to 91%, this should be deemed a noteworthy near miss for a more critical desaturation, and the practitioner should reflect on this and try and improve future practice. Furthermore, of the 38 (10.9%) patients who had a hypoxic complication, 20 (5.7%) were hypoxic prior to the RSI. This emphasises that careful attention to an oxygenation strategy prior to and during an RSI is vitally important, particularly in those patients with respiratory compromise.

### *Limitations*

This study was carried out at a single institution and so the results cannot be felt to be representative of all EDs in Australasia. Furthermore, the study was observational in nature and required that the intubator complete the form. Reporter bias would tend to improve glottic visualisation and under-report complications, as demonstrated by Kerrey *et al.*[5] in a study involving video review of all cases of RSI in a paediatric ED. Data entry was not always contemporaneous, but in all cases, attempts at improving accuracy were made by interviewing the intubator and reviewing the medical records. Despite these efforts, it was still not possible to completely capture all the data for every intubation. However, it is unlikely that any episode of RSI was not recorded, because of regular review of the controlled drugs register.

As there were a number of strategies employed to address the deficiencies that were identified by the first study, we cannot identify which change was the most significant.

The Hawthorne effect,[47] specifically a change in a person's behaviour attributable to their awareness of being studied, may also have played a role, especially because a checklist needed to be followed prior to intubation.

## Conclusion

We have shown that, through a suite of interventions, we have been able to improve the safety of ED endotracheal intubation, and we would encourage others not only to review their current practice but to review how they too can care better for the sickest patients in their care.

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## *Author contributions*

TF devised and developed the project, developed the data collection form, was involved in data collection, instituted the practice improvement changes and wrote the first draft of the manuscript.

HA was involved in data management and analysis and edited the manuscript.

JV developed the project, developed the data collection form, was involved in data collection, instituted the practice improvement changes and edited the manuscript.

## *Competing interests*

None declared.

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## Supporting information

Additional supporting information may be found in the online version of this article at the publisher's web site:

**Appendix S1.** Australia and New Zealand Emergency Department Airway Registry data sheet.
**Appendix S2.** Royal North Shore Hospital Emergency Department airway algorithm.
**Appendix S3.** Out of theatre pre-intubation checklist.