CRITICAL CARE

Tracheal intubation in patients with cervical spine immobilization: a comparison of the Airwayscope®, LMA CTrach®, and the Macintosh laryngoscopes

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Background. The purpose of this study was to evaluate the effectiveness of the Pentax AWS®, and the LMA CTrach®, in comparison with the Macintosh laryngoscope, when performing tracheal intubation in patients with neck immobilization using manual in-line axial cervical spine stabilization.

Methods. Ninety patients undergoing anaesthesia who required tracheal intubation were randomly assigned to undergo intubation using a Macintosh (n=30), LMA CTrach® (n=30), or AWS® (n=30) laryngoscope. All patients were intubated by one of the three anaesthetists familiar with the use of each laryngoscope.

Results. The intubation difficulty scores were significantly higher with the Macintosh laryngoscope and were significantly lower with the AWS® compared with the LMA CTrach®. All 30 patients were successfully intubated with the Macintosh and the AWS® device, compared with 27 patients with the LMA CTrach®. The duration of both the first and the successful tracheal intubation attempts was significantly longer with the LMA CTrach® compared with the AWS® and Macintosh laryngoscopes. A greater number of optimization manoeuvres were required to facilitate tracheal intubation with the LMA CTrach® compared with the AWS® laryngoscope. The AWS® group had a significantly better Cormack and Lehane glottic view obtained at laryngoscopy compared with both other devices.

Conclusions. The AWS® laryngoscope has several advantages over the Macintosh laryngoscope, or LMA CTrach®, in patients undergoing cervical spine immobilization.

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Failure to adequately immobilize the neck during tracheal intubation in patients with cervical spine injuries can result in devastating neurologic outcomes.1 Anatomic studies that mimic complete C4–5 ligamentous injury demonstrate that manual in-line axial stabilization reduces segmental angular rotation and distraction.2 Consequently, in many institutions, where tracheal intubation is required in patients with potential cervical spine injuries, the rigid cervical collar is removed, and the cervical spine immobilized by means of manual in-line axial stabilization. However, a key concern is the fact that with cervical spine immobilization, it is more difficult to visualize the larynx using conventional laryngoscopy.3–5 Failure to successfully intubate the trachea and secure the airway remains a leading cause of morbidity and mortality, in the operating theatre,6–8 and in the emergency setting.9

Efforts to reduce the difficulty of tracheal intubation have prompted the development of a number of alternatives to Macintosh laryngoscope. The AWS® (Pentax Corporation, Tokyo, Japan)10–12 consists of a disposable...
transparent blade which fits over a 12 cm fibreoptic cable linked to a charge-coupled device camera, and a 2.4 in colour liquid crystal display screen (Fig. 1A). The LMA CTrach® (Intavent Orthofix Ltd, Maidenhead, UK) is a modified laryngeal mask airway, which incorporates an inbuilt integrated fibreoptic system and a detachable liquid crystal display colour viewer with a light source that facilitates visualization of glottis during intubation (Fig. 1B). Advantages over the Macintosh have been demonstrated for the LMA CTrach® in patients with normal airways and in morbidly obese patients. The efficacy of the LMA CTrach® has not been compared with the Macintosh in patients undergoing cervical spine immobilization. The Pentax AWS® has been demonstrated to perform better than the Macintosh in patients undergoing cervical spine immobilization. However, the relative efficacies of these devices in comparison with the Macintosh have not been compared in a single study.

The purpose of this clinical trial was to evaluate the relative efficacy of the LMA CTrach® and the AWS® laryngoscopes when used by experienced anaesthetists in patients undergoing neck immobilization by manual in-line axial stabilization, and to compare their performance with the Macintosh laryngoscope. We hypothesized that, in comparison with the Macintosh, these novel laryngoscopes would reduce intubation difficulty, as measured by the intubation difficulty scale (IDS) score. We further hypothesized that the AWS would reduce intubation difficulty compared with the LMA CTrach in this setting.

Methods

After obtaining approval by the Galway University Hospitals Research Ethics Committee (Galway, Ireland), and written informed patient consent, we studied 90 ASA I–III patients, aged 16 yr or older, undergoing general anaesthesia for surgery and requiring tracheal intubation. The study was done in a manner of a randomized, single blind, controlled clinical trial. Patients were excluded if risk factors for gastric aspiration, difficult intubation (Mallampatti class III or IV; thyromental distance <6 cm; and inter-incisor distance <3.5 cm), or both were present, or where there was a history of relevant drug allergy. All data were collected by an independent unblinded observer. The allocation sequence was generated by random number tables, and the allocation concealed in sealed envelopes, which were not opened until patient consent had been obtained. Patients were randomized to tracheal intubation with either the Macintosh (size 3 blade in females; size 4 in males), the CTrach®, or the AWS® laryngoscopes.

All patients received a standardized general anaesthetic. Standard monitoring included ECG, non-invasive arterial pressure, SpO₂, and measurement of end-tidal carbon dioxide and volatile anaesthetic levels. Bispectral Index (BIS®) (Aspect Medical Systems, Norwood, MA, USA) or Entropy® (GE Healthcare, Helsinki, Finland) monitoring was utilized in all patients. Before induction of anaesthesia, all patients were given fentanyl 1–1.5 μg kg⁻¹ i.v. Propofol 2–4 mg kg⁻¹ was titrated to induce anaesthesia in a dose sufficient to produce loss of verbal response. After induction of anaesthesia, all patients were manually ventilated with sevoflurane 2.0–2.5% in oxygen, and atracurium 0.5 mg kg⁻¹ was administered. Tracheal intubation was not performed until the BIS/Entropy score had decreased below 60, and additional boluses of propofol were administered to increase depth of anaesthesia if required. Three minutes after the administration of neuromuscular block, the pillow was removed and the neck immobilized using manual in-line axial stabilization applied by an experienced anaesthetist holding the sides of the neck and the mastoid processes, thus preventing flexion/extension or rotational movement of the head and neck.
Tracheal intubation was performed in each patient by one of the three anaesthetists (M.A.M., R.S., and S.C.) who were familiar with each of the devices. Each investigator had performed, with each device, at least 50 intubations in manikins and at least 20 intubations in the clinical setting. The tracheal tube was placed in the side channel of the Pentax AWS® laryngoscope in advance of the intubation attempt. The AWS® was inserted into the mouth in the midline and advanced slowly over the tongue along the palatal wall, until the epiglottis came into view. The blade was then advanced under the epiglottis, and the glottis was seen. The target symbol was aligned with the glottic opening, the tracheal tube was gently advanced through the glottis, then detached from the blade, and the AWS® blade was removed.

The CTrach® was inserted into the laryngopharynx, the cuff was inflated, and the position adjusted as necessary until effective ventilation was established. The viewer was then attached and the CTrach® adjusted to optimize the view of the glottis. Where the epiglottis was obstructing the view of the glottis, an up–down ‘Chandy’ manoeuvre was performed by withdrawing the LMA CTrach® 6 cm and reinserting it with cuff still inflated. These manoeuvres were repeated as required to correct epiglottic downfolding, and tracheal intubation was performed once the view of the glottis had been optimized. If a clear view of the glottis was not obtained, an attempt was still made to perform tracheal intubation using the best view obtainable.

The trachea was then intubated with a 7.5 mm tracheal tube in females, and an 8.0 mm tracheal tube in males, by one of the investigators. In patients intubated using the LMA CTrach®, the disposable, flexible, and reinforced LMA Fastrach® tracheal tube (Laryngeal Mask Company Ltd, San Diego, CA, USA) was used. A conventional polyvinylchloride tracheal tube was used in patients intubated with the AWS and Macintosh laryngoscopes. After successful tracheal intubation, in all patients, the lungs were mechanically ventilated for the duration of the procedure, and anaesthesia was maintained with sevoflurane (1.25–1.75%) in a mixture of nitrous oxide and oxygen in a 2:1 ratio. No other medications were administered, or procedures performed, during the 5 min data collection period after tracheal intubation. Subsequent management was left to the discretion of the anaesthetist providing care for the patient.

The primary endpoint was the IDS score. The IDS score, developed by Adnet and colleagues, is a quantitative scale incorporating multiple indices of intubation difficulty that more objectively quantifies the complexity of tracheal intubations (Appendix). The secondary endpoints were the rate of successful placement of the tracheal tube in the trachea and the duration of the tracheal intubation procedure. The duration of the intubation attempt was defined as the time taken from insertion of the blade or LMA CTrach® between the teeth until the tracheal tube was placed through the vocal cords, as evidenced by visual confirmation by the anaesthetist. However, in patients in whom the tracheal tube was not directly visualized passing through the vocal cords, the intubation attempt was not considered complete until the tracheal tube was connected to the anaesthetic circuit and evidence obtained of the presence of carbon dioxide in the exhaled breath. In patients intubated with the LMA CTrach®, the time taken to withdraw the LMA was not included in the duration of intubation attempts. A failed intubation attempt was defined as an attempt in which the trachea was not intubated, or which required >120 s to perform. In addition, the number of tracheal intubation attempts that required >60 s was also noted. A maximum of three intubation attempts were permitted. In the event that tracheal intubation was unsuccessful with the device tested, manual in-line axial stabilization was discontinued, and tracheal intubation was performed with the Macintosh laryngoscope. The duration of the first tracheal intubation attempt, and of the successful attempt in the case that the first attempt was not successful, was recorded. Additional endpoints included the number of intubation attempts and the number of optimization manoeuvres required (use of an airway intubating catheter, cricoid pressure, and second assistant) to aid tracheal intubation, and the Cormack and Lehane grade at laryngoscopy. The type of airway intubating catheter used was the Frova airway intubating catheter (William Cook Europe Ltd).

We based our sample size estimation on the IDS score. On the basis of our prior studies, we projected that the mean IDS score in patients undergoing tracheal intubation with the Macintosh in the setting of cervical spine immobilization would be 3.0. We considered that a clinically important reduction in mean IDS score would be a reduction of 2.0. Given an expected standard deviation of 2.25 from prior studies, and using an α=0.05 and β=0.2, for an experimental design incorporating three equal-sized groups, we estimated that 26 patients would be required per group. We therefore aimed to enrol 30 patients per group.

All analyses were performed on an intention-to-treat basis. Patient characteristic data and data for duration of intubation attempts and the instrument difficulty score were analysed using one-way analysis of variance (ANOVA), except for data for gender which were analysed using the χ² test. Data for the IDS score, the number of intubation attempts, and the numbers of optimization manoeuvres were analysed using ANOVA or Kruskal–Wallis ANOVA on ranks as appropriate. Success of tracheal intubation was analysed using the χ² test and Fisher’s exact test. The comparisons of haemodynamic data were analysed using two-way repeated-measures ANOVA, with group and time-point as the factors. In each case, post hoc between-group testing was performed using the Student–Newman–Keuls test. Continuous data are presented as mean (SD), ordinal data are presented as median (IQR), and categorical data are presented as number and...
Table 1 Patient characteristics. Data are reported as mean (range), mean (SD), median (IQR), or number

<table>
<thead>
<tr>
<th>Parameter assessed</th>
<th>Macintosh</th>
<th>AWS®</th>
<th>LMA CTrach®</th>
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<tbody>
<tr>
<td>Number per group</td>
<td>30</td>
<td>30</td>
<td>30</td>
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<tr>
<td>Male:female ratio</td>
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<td>13:17</td>
<td>14:16</td>
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<tr>
<td>Age (yr)</td>
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<td>47.7 (18–78)</td>
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<td>BMI (kg m⁻²)</td>
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<td>26.9 (4.1)</td>
<td>24.9 (3.0)</td>
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<td>II (I, II)</td>
<td>II (I, II)</td>
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<tr>
<td>Thyromental distance (cm)</td>
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<td>8.4 (0.9)</td>
<td>8.2 (1.1)</td>
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<tr>
<td>Inter-incisor distance (cm)</td>
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<td>4.3 (0.5)</td>
<td>4.3 (0.4)</td>
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<tr>
<td>Mallampati classification</td>
<td>II (I, II)</td>
<td>II (I, II)</td>
<td>II (I, II)</td>
</tr>
<tr>
<td>Bispectral index or Entropy score</td>
<td>29.0 (10.5)</td>
<td>32.1 (13.5)</td>
<td>32.4 (12.6)</td>
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</tbody>
</table>

The α-level for all analyses was set as $P<0.05$.

**Results**

A total of 90 patients were entered into the study. Ninety-eight patients were consented to participate, but eight patients were not subsequently entered into the study due to delays in their surgical procedure taking place. Thirty patients were randomized to undergo tracheal intubation with each of the three devices. There were no significant differences in characteristics or baseline airway parameters between the groups (Table 1). There were no between-group differences with regard to anaesthetic management, including the doses of propofol and fentanyl administered, the number of additional propofol boluses required, or in end-tidal sevoflurane concentrations. There were no between-group differences in BIS® or Entropy® scores immediately before or after tracheal intubation in both groups.

The intubation difficulty scores were significantly higher with the Macintosh compared with both other devices, and also significantly higher with the LMA CTrach® compared with the AWS® laryngoscope (Fig. 2). Of interest, some of the highest IDS scores were seen with the LMA CTrach® (Fig. 2). The rate of successful tracheal intubation was significantly lower with the LMA CTrach® compared with both the Macintosh and AWS® laryngoscopes. All 30 patients were successfully intubated with the Macintosh and the AWS® device, compared with 27 patients with the LMA CTrach® (Table 2). If a lower maximum time of 60 s was permitted for successful intubation, the success rate for the LMA CTrach® decreased to 20, whereas there was no difference in the success rates for the Macintosh or AWS devices. The duration of both the first and the successful tracheal intubation attempts was significantly longer with the LMA CTrach® compared with the AWS® and Macintosh groups (Table 2).

There were no between-group differences in the number of attempts required with each device (Table 2). However, a greater number of optimization manoeuvres were required to facilitate tracheal intubation with the LMA CTrach® and the Macintosh compared with the AWS® laryngoscope (Table 2). The AWS® group had a significantly better Cormack and Lehane glottic view obtained at laryngoscopy compared with both other devices (Fig. 3). The distribution of Cormack and Lehane scores between the CTrach® and the Macintosh was significantly different, with more grade 3–4 views with the CTrach® and a predominance of grade 2 views with the Macintosh (Fig. 3).

There were no between-group differences in the incidence of complications, including the appearance of blood on the laryngoscope blade, or of minor lacerations to the airway (Table 2). There was no incidence of dental or more severe airway laceration with any laryngoscope. Arterial haemoglobin oxygen saturations were well maintained in all groups (Table 2).

The effects of laryngoscopy and tracheal intubation on the mean arterial blood pressure and heart rate were relatively modest. Heart rate increased significantly in the LMA CTrach® and Macintosh groups, but did not change in the AWS® group, after tracheal intubation (Fig. 4). Arterial pressure decreased significantly in each group after induction of anaesthesia. After tracheal intubation, mean arterial pressure increased back to baseline levels in all groups, and was not different between the laryngoscope groups (Fig. 5).

**Discussion**

The successful tracheal intubation of a patient with limited cervical spine movement or in whom movement of the cervical spine is not desirable presents a significant challenge even to the most experienced anaesthetist. Cervical spine immobilization reduces the quality of glottic exposure, by preventing the head extension and neck flexion necessary for optimal alignment of the three airway axes and exposure of the vocal cords using direct
laryngoscopic techniques. These manoeuvres may lead to failure to secure the airway, which may result in substantial morbidity and even mortality.

Efforts to reduce the difficulty of tracheal intubation in situations such as cervical immobilization have prompted the development of a number of alternatives to the Macintosh laryngoscope, including the AWS and LMA CTrach devices. Recent studies, by our group and others, have demonstrated that both the AWS and the Airtraq, a similar indirect laryngoscope device that also incorporates a side channel for the tracheal tube, possess considerable advantages over the Macintosh in the setting of cervical spine immobilization. In addition, the AWS laryngoscope also appears to cause less cervical spine movements during tracheal intubation when compared with the Macintosh or McCoy laryngoscopes. The efficacy of the LMA CTrach has not been determined in this setting. Of interest, the intubating LMA (iLMA) has demonstrated some promise in the setting of cervical spine immobilization. We wished to evaluate the relative efficacies of these novel devices when used by anaesthetists who were familiar with the use of these devices.

### Table 2

<table>
<thead>
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<th>Parameter assessed</th>
<th>Macintosh</th>
<th>AWS</th>
<th>LMA CTrach</th>
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<tr>
<td></td>
<td>Overall success rate (%)</td>
<td>Max time permitted 120 s (%)</td>
<td>Max time permitted 60 s (%)</td>
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<td></td>
<td>30 (100%</td>
<td>30 (100%</td>
<td>30 (100%</td>
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<td>29 (96.7)</td>
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<td></td>
<td>16 (52.8)</td>
<td>24 (80)</td>
<td>14 (46.2)</td>
</tr>
</tbody>
</table>

### Figures

**Fig 3** Cormack and Lehane laryngoscopy grade view during the first tracheal intubation attempt with each laryngoscope. The number of patients is shown above each bar. The distribution of Cormack and Lehane grades in each group is significantly different (P<0.001, Kruskal–Wallis ANOVA on ranks).

**Fig 4** Graph representing the changes in heart rate after tracheal intubation with each device. The data are given as mean (sd). *Significant change in heart rate over time within each group. 30 s Pre-Ind, 30 s before induction of anaesthesia; −30, 30 s before tracheal intubation; +60, 60 s post-tracheal intubation; +120, 120 s post-tracheal intubation; +180, 180 s post-tracheal intubation; +300, 300 s post-tracheal intubation.

**Fig 5** Graph representing the changes in mean arterial pressure after tracheal intubation with each device. The data are given as mean (sd). *Significant change in heart rate over time within each group. 30 s Pre-Ind, 30 s before induction of anaesthesia; −30, 30 s before tracheal intubation; +60, 60 s post-tracheal intubation; +120, 120 s post-tracheal intubation; +180, 180 s post-tracheal intubation; +300, 300 s post-tracheal intubation.
indirect laryngoscopes in patients undergoing cervical spine immobilization, and to compare these devices with the gold standard Macintosh laryngoscope.

Our findings demonstrate that the LMA CTrach did not offer an advantage over the Macintosh laryngoscope in patients undergoing cervical spine immobilization. In fact, fewer patients were successfully intubated with the CTrach. This is likely to have been due to the fact that more patients undergoing intubation with the CTrach had a Cormack and Lehane glottic grade 3 or 4. We experienced considerable difficulties in obtaining an optimal view of the glottis with the CTrach, a problem which has been previously reported. Furthermore, even in patients where a good view of the glottis was obtained, the quality of exposure was occasionally reduced due to fogging of the lens, the presence of secretions, and due to damage to the fiberoptics caused by repeated sterilization of the CTrach. Our overall success rate of 90% in patients undergoing cervical immobilization with the LMA CTrach, where tracheal intubation attempts of up to 120 s were permitted, does compare well with previous reports of a 93% success rate with this device in normal patients. However, if we limited the intubation time to 60 s, the success of tracheal intubation decreased to 67%.

The duration of tracheal intubation attempts was significantly longer with the LMA CTrach, a finding consistent with previous studies. However, the clinical importance of the longer duration of tracheal intubation attempts with the CTrach is questionable. The technique required for tracheal intubation with the CTrach is not directly comparable with that for the other devices tested, as it is a two-step procedure, requiring placement of the LMA and confirmation of effective ventilation before passage of the tracheal tube. It must be emphasized that the LMA CTrach was sited correctly at the first attempt and provided effective ventilation in all patients, including those in whom tracheal intubation was not successfully accomplished, as seen in previous studies. In fact, the biggest contribution to prolonged tracheal intubation times was not the positioning of the LMA CTrach, but was due to the time required to optimize the view of the glottis to enable passage of the tracheal tube. Failure to obtain a good view of the glottis was the reason for each failed tracheal intubation attempt with the LMA CTrach.

In contrast, our study demonstrates that the Pentax AWS laryngoscope performed better than the LMA CTrach and the Macintosh laryngoscopes in these patients. These findings confirm and extend our previous findings regarding the utility of this device in patients undergoing cervical spine immobilization. The AWS reduced the intubation difficulty score, enhanced the Cormack and Lehane glottic view, and reduced the number of optimization manoeuvres required compared with the LMA CTrach and the Macintosh laryngoscopes. Five patients intubated with the AWS did require the use of an airway intubating catheter to facilitate tracheal intubation because of an inability to position the view of vocal cords in the target symbol on the monitor display, a manoeuvre which has been previously described. Of importance, the AWS caused less haemodynamic stimulation than the other laryngoscopes. Heart rate was not altered significantly with this device during intubation attempts, in contrast to the other devices. A blunted heart rate response to intubation has also been previously described with the AWS and also with the Airtraq, a similar device to the AWS. These findings may reflect the fact that these devices provide a view of the glottis without need to align the oral, pharyngeal, and tracheal axes, reducing cervical movement, thereby reducing the potential for haemodynamic stimulation.

An important potential advantage of the AWS device is that it has single-use disposable blades. This removes concerns regarding the potential for multi-use intubation devices to facilitate transmission of prions, which are thought to be responsible for causing variant Creutzfeldt–Jakob disease. These concerns arise from the difficulties in ensuring that all proteinaceous material has been removed from reusable laryngoscope blades during cleaning and sterilization. In recognition of these concerns, the guidelines of the Association of Anaesthetists of Great Britain and Ireland state that ‘single use intubation aids’ should be used where possible.

Three important limitations exist regarding this study. First, we acknowledge that the potential for bias exists, as it is impossible to blind the anaesthetist to the device being used. Furthermore, certain measurements used in this study, such as laryngoscopic grading, are by their nature subjective. In fact, the appropriateness of using the Cormack and Lehane classification with indirect laryngoscopes, which may reduce the difficulty of obtaining a good glottic view, but not reduce the difficulty of tracheal intubation, is open to question. The advantage of using the Cormack and Lehane classification is that it is well understood by clinicians, and widely used in clinical practice. Reassuringly, there was a good agreement between subjective indices of difficulty of intubation and more objective measures, such as the intubation difficulty score. Secondly, this study was carried out by experienced users of each device. The results seen may differ in the hands of less experienced users. Finally, the relative efficacies of these devices in comparison with other promising devices such as the Airtraq, McGrath, Bonfils, iLMA, or Bullard laryngoscopes have not been determined. Further comparative studies are needed to determine the relative efficacies of these devices.

In conclusion, the AWS laryngoscope appears to possess more advantages over the Macintosh laryngoscope than the LMA CTrach when used by experienced anaesthetists in patients undergoing cervical immobilization.
Funding
Pentax Ltd provided the AWS® device and disposable blades, and Intavent Orthofix Ltd provided the LMA CTrach® free of charge for use in the study. All other support came from institutional, departmental, or both sources.

Appendix: IDS score

The IDS score is the sum of the following seven variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
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<tr>
<td>N1</td>
<td>Number of intubation attempts &gt; 1</td>
</tr>
<tr>
<td>N2</td>
<td>The number of operators &gt; 1</td>
</tr>
<tr>
<td>N3</td>
<td>The number of alternative intubation techniques used</td>
</tr>
<tr>
<td>N4</td>
<td>Glottic exposure (Cormack and Lehane grade minus 1)</td>
</tr>
<tr>
<td>N5</td>
<td>Lifting force required during laryngoscopy (0, normal; 1, increased)</td>
</tr>
<tr>
<td>N6</td>
<td>Necessity for external laryngeal pressure (0, not applied; 1, applied)</td>
</tr>
<tr>
<td>N7</td>
<td>Position of the vocal cords at intubation (0, abduction/ not visualized; 1, adduction)</td>
</tr>
</tbody>
</table>

Note: IDS score reproduced from Adnet and colleagues.16

References
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