CRITICAL CARE

Effect of chest compressions on the time taken to insert airway devices in a manikin

J. J. Gatward*, M. J. C. Thomas, J. P. Nolan† and T. M. Cook†

Department of Anaesthesia, Royal United Hospital, Combe Park, Bath BA1 3NG, UK
*Corresponding author. E-mail: jongatward@hotmail.com

Background. Resuscitation guidelines recommend that chest compressions should continue throughout attempts to place airway devices. Few data support the use of the tracheal tube over supraglottic airway devices (SADs) during cardiopulmonary arrest. This study was designed to evaluate the speed with which different airway devices could be placed with and without interrupting chest compressions.

Methods. Forty volunteer doctors regularly involved in cardiopulmonary resuscitation (CPR) were timed inserting four different airway devices [tracheal tube (TT), LMA Classic (cLMA), LMA ProSeal (PLMA), and igel] into a manikin, with and without stopping chest compressions.

Results. Chest compressions delayed the placement of the TT only (3.3 s, \( P < 0.0001 \)). Comparison of the speed of insertion of the different airway devices during CPR enabled ranking of the devices: igel (fastest), PLMA (second), and TT and cLMA (joint slowest). The igel was inserted approximately 50% faster than the other devices. Doctors who had previously inserted more than 50 tracheal tubes were significantly faster at intubating the trachea, but no faster at inserting SADs.

Conclusions. Our results show that continuing chest compressions has a minor effect on time for tracheal intubation and until clear human data are available the recommendation to intubate without interrupting CPR is therefore justified. The PLMA and igel (SADs with a gastric drain tube) were both faster to insert than the cLMA and offer additional benefits. They should be considered for use in CPR.

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The latest European Resuscitation Council (ERC) Guidelines emphasize minimizing interruptions to chest compressions, in order to maximize coronary and cerebral perfusion pressure. The guidelines stress that any placement of an advanced airway device should be achieved with the least possible interruption to chest compressions.

Previously, the perceived gold standard for airway management has been the tracheal tube; however, concern has been raised that the risks of failed intubation, misplaced tubes, and prolonged intubation times may outweigh the benefits. The ERC guidelines suggest that skilled operators should be able to intubate the trachea without stopping chest compressions, or with a brief pause on seeing the vocal cords to allow passage of the tube. No studies have been done to determine whether this strategy prolongs intubation time. Supraglottic airway devices (SADs) have been used successfully in resuscitation. The most commonly used device is the classic laryngeal mask airway (cLMA, Intavent Orthofix, Maidenhead, UK), which has been shown to provide adequate ventilation.

†Declaration of interest. The igels used in this study were donated free by the manufacturers (Intersurgical, Wokingham, UK). T.M.C. has received payment for lecturing from Intavent Orthofix and the LMA Company, both of which manufacture laryngeal mask airways. J.P.N. was co-author of the European Resuscitation Council Advanced Life Support Guidelines.
during cardiopulmonary resuscitation (CPR).\(^8\)\(^–\)\(^12\) Other SADs have been used but with few data to support them. The ProSeal\(^TM\) LMA (PLMA, Intavent Orthofix) is a variant of the LMA which has promise for resuscitation because of a better airway seal and the presence of a drain tube allowing functional separation of the respiratory and gastrointestinal tracts. The drain tube reduces gastric inflation and enables venting of gastric contents.\(^13\)\(^\) There are no data on whether chest compressions delay the insertion of these devices. More recently, there has been a suggestion that the igel\(^TM\) (Intersurgical, Wokingham, UK) may be a useful device in resuscitation.\(^14\) The igel is similar in functional design to the PLMA, incorporating a gastric drain tube. It has a gel-filled anatomically shaped mask and no cuff.

We have therefore investigated airway management using the tracheal tube, cLMA, PLMA, and igel, with and without interrupting chest compressions.

**Methods**

The study was given ethical approval by the Bath Research Ethics Committee. Doctors who may potentially be involved in airway management during CPR (anaesthetists, emergency physicians, and physicians) were invited to participate. Forty doctors agreed to participate, of which there were 29 anaesthetists, six emergency physicians, and five physicians. Each volunteer gave written consent before participating in the study.

We investigated the time taken to ventilate the lungs of a manikin [adult Resusi Anne\(^TM\) with an Airway Trainer\(^TM\) head (Laerdal, Stavanger, Norway)] after insertion of the four different airway devices by each volunteer, both with and without chest compressions. This made a total of eight interventions per volunteer. The airway devices used were a standard size 8.0 mm internal diameter tracheal tube (Portex, UK), a size 4 LMA Classic\(^TM\), a size 3 LMA ProSeal\(^TM\), and a size 4 igel\(^TM\). The sizes chosen are consistent with data from previous efficacy studies on the same manikin.\(^15\)\(^–\)\(^17\) Each volunteer was asked for their previous experience with the four airway devices. They were then categorized as ‘experienced’, if they had performed more than 50 insertions,\(^18\) ‘moderately experienced’ (>10), ‘some experience’ (<10), or ‘novice’ (no experience). The manikin was placed on a standard hospital bed with a standard, foam-filled mattress, and the head in the ‘sniffing the morning air’ position on one hospital pillow. Volunteers were given time to practice intubating the trachea and inserting the SADs into the manikin. Those with no previous experience of a particular airway device were instructed and then encouraged to practice until they could place the device correctly. For placement of the TT, the volunteer was provided with a laryngoscope with a Macintosh size 3 blade and a 10 ml syringe to inflate the cuff. A gum elastic bougie was available for use if necessary. For cLMA insertion, volunteers used a standard digital insertion technique, whereas the PLMA was mounted on its introducer. A 50 ml syringe was provided to inflate the cuffs of these two devices. The igel was inserted according to the manufacturer’s instructions. The lubricated device is grasped by the integral bite block and its tip directed towards the hard palate. It is then inserted with a continuous but gentle push until resistance is felt.\(^19\) For the insertion of all the SADs, the volunteer was encouraged to open the mouth of the manikin by depressing the chin downwards. For each insertion, both the airway device and the manikin were well lubricated according to the manufacturer’s instructions. The order of the interventions was randomized for each volunteer by drawing tickets out of an opaque bag in order to minimize any learning effect across the study as a whole.

The volunteer stood at the head end of the manikin. The equipment necessary for each intervention was placed on the pillow next to the manikin’s head. Volunteers were instructed to place the airway device, inflate its cuff (where present) with the appropriate volume of air, connect a self-inflating bag, and attempt to ventilate the lungs of the manikin. There was no requirement to tie or tape the airway device in place; the device being stabilized by hand during the attachment of the self-inflating bag and subsequent ventilation. The volunteer was given a count of three, at which point they were allowed to pick up the airway equipment from the pillow and begin their attempt. The end-point of the attempt was taken as the point at which clear inflation of the lungs of the manikin was seen. Each attempt was timed using the same stopwatch. If clear ventilation was not visible, the volunteer was told that they were required to attempt to insert the device again, and the timing continued until successful ventilation was achieved.

For interventions during chest compressions, these were provided by an Advanced Life Support (ALS) Instructor starting before the attempt to manage the airway commenced. Chest compressions complied with ERC guidelines (at a frequency of 100 min\(^–\)\(^1\), compressing the chest by 4–5 cm).\(^20\) For the attempt at tracheal intubation, the volunteer was given the choice of allowing compressions to continue, or requesting that they be discontinued from visualization of the vocal cords to the passage of the tracheal tube. In this case, the number of seconds for which compressions were discontinued (the ‘hands-off’ time) was recorded using the secondary ‘lap function’ of the stopwatch.

We used the Shapiro–Wilks test and examination of frequency histograms to examine insertion time data for normality. Data for all devices were found not to be normally distributed and therefore non-parametric tests were applied. To examine differences between insertion times for a given device with and without CPR, we used the Wilcoxon signed rank test. To examine differences between insertion times for the four devices, we used Friedman’s ANOVA. Where \(P<0.05\), we then used post hoc Wilcoxon signed rank tests to determine individual device performances.


*P*-values derived from these tests were multiplied by six (the number of such tests applied) to correct for multiple comparisons before we considered significance. *P*-values, corrected where necessary, were considered significant when *P* < 0.05.

**Results**

The median times taken for 40 volunteers to insert the different airway devices with and without continuing chest compressions are shown in Table 1.

The effect of chest compressions on time to ventilation

Chest compressions were associated with a statistically significant delay in insertion time for the TT only. The median time difference was 3.3 s (CI 1.80–5.45, *P* = 0.0001). There were no significant differences found for the other three devices.

Effect of device on time to ventilation without chest compressions

The times to ventilation for each device were not uniform (Friedman’s ANOVA *P* < 0.05). Post hoc testing (Table 2) showed the igel was significantly quicker to insert than all other devices. Comparisons between each of the other devices showed no statistically significant difference. This allows ranking of the airway devices with the igel fastest, and all others equivalent. Median times to the nearest second were TT 16 s, cLMA 15 s, PLMA 14 s, and igel 7 s; giving a difference between the igel and all other devices of approximately 50%. There were four reinsertions (2 cLMA, 1 igel, 1 PLMA).

Effect of device on time to ventilation during continuous chest compressions

The times to ventilation for each device were not uniform (Friedman’s ANOVA *P* < 0.05). Post hoc testing (Table 3) showed that the igel was significantly faster to insert than all other devices. The PLMA was faster than the TT and cLMA, with no statistically significant difference between the TT and the cLMA. This allows ranking of the devices with the igel fastest, the PLMA next fastest, and the TT and cLMA slowest. Median times to the nearest second were TT 19 s, cLMA 15 s, PLMA 14 s, and igel 8 s. This gives a difference between the igel and all other devices of approximately 50%, and between the PLMA and the TT and cLMA of approximately 25%. The cLMA tended to rotate and displace laterally during chest compressions. This led to seven reinsertions in 40 placements, compared with one in 120 placements (a PLMA) for all other devices combined. Eighteen doctors chose to cease CPR for the passage of the tracheal tube: median ‘hands-off’ time was 4.5 s.

Table 1 Insertion times and median time differences (s) for airway devices with and without chest compressions (*n* = 40). Values for insertion times are presented as median [IQR (range)]. Significant differences are denoted in bold type

<table>
<thead>
<tr>
<th>Device comparison</th>
<th><em>P</em>-value</th>
<th>Corrected <em>P</em>-value</th>
<th>Difference between medians (s)</th>
<th>95% CI (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TT vs cLMA</td>
<td>0.0084</td>
<td>0.0504</td>
<td>2.75</td>
<td>0.90–4.40</td>
</tr>
<tr>
<td>TT vs iGEL</td>
<td>0.0001</td>
<td>0.0006</td>
<td>8.40</td>
<td>6.90–10.15</td>
</tr>
<tr>
<td>TT vs PLMA</td>
<td>0.0483</td>
<td>0.0006</td>
<td>1.70</td>
<td>0.00–3.50</td>
</tr>
<tr>
<td>cLMA vs iGEL</td>
<td>0.0001</td>
<td>0.0006</td>
<td>6.40</td>
<td>5.00–7.85</td>
</tr>
<tr>
<td>cLMA vs PLMA</td>
<td>0.334</td>
<td>2.004</td>
<td>-0.70</td>
<td>-2.25 to 0.90</td>
</tr>
<tr>
<td>iGEL vs PLMA</td>
<td>0.0001</td>
<td>0.0006</td>
<td>-6.70</td>
<td>-8.00 to -5.45</td>
</tr>
</tbody>
</table>

Table 2 Comparison of insertion times between devices without chest compressions. Significant differences are denoted in bold type

<table>
<thead>
<tr>
<th>Device comparison</th>
<th><em>P</em>-value</th>
<th>Corrected <em>P</em>-value</th>
<th>Difference between medians (s)</th>
<th>95% CI (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TT vs cLMA</td>
<td>0.1990</td>
<td>1.194</td>
<td>3.27</td>
<td>-7.00 to 6.00</td>
</tr>
<tr>
<td>TT vs iGEL</td>
<td>0.0001</td>
<td>0.0006</td>
<td>11.12</td>
<td>9.15–14.25</td>
</tr>
<tr>
<td>TT vs PLMA</td>
<td>0.0001</td>
<td>0.0006</td>
<td>6.00</td>
<td>4.20–8.95</td>
</tr>
<tr>
<td>cLMA vs iGEL</td>
<td>0.0001</td>
<td>0.0006</td>
<td>8.35</td>
<td>6.15–20.35</td>
</tr>
<tr>
<td>cLMA vs PLMA</td>
<td>0.0028</td>
<td>0.0168</td>
<td>2.77</td>
<td>0.95–12.60</td>
</tr>
<tr>
<td>iGEL vs PLMA</td>
<td>0.0001</td>
<td>0.0006</td>
<td>-5.62</td>
<td>-6.35 to -4.75</td>
</tr>
</tbody>
</table>
Time to ventilation for different doctors

There were 34 ‘experienced’ intubators and six who either had ‘moderate experience’, ‘some experience’, or were ‘novices’: we aggregated these six into a group. Comparing these two groups during chest compressions, experienced intubators performed intubation significantly faster than the other group (17.8 vs 23.2 s) (difference between medians 8.9 s, 95% CI 4–21 s, Mann–Whitney test P=0.006). There were no significant differences between these two groups for any other device. Comparing anaesthetists (n=29) with non-anaesthetists (n=11) during CPR showed no significant differences for any of the devices.

Discussion

In this study, chest compressions prolonged tracheal intubation by a median of 3.3 s. This is statistically significant, but is probably not clinically important. For all the SADs we studied, insertion times were not affected significantly by chest compressions. These data support the continuation of chest compressions throughout attempts to secure the airway. We also noted that doctors inexperienced with tracheal intubation took longer to perform tracheal intubation during chest compressions than experienced intubators, but that this effect was not seen for the SADs. These data support the use of SADs in resuscitation by those not already experienced in intubation.

Stopping chest compressions for the passage of the tracheal tube led to a median ‘hands-off time’ of 4.5 s. This is similar to the time taken to deliver two breaths, which takes place regularly during resuscitation. This delay is probably of limited clinical relevance, although ‘hands-off’ time of more than 10–20 s reduces the chance of successful defibrillation.21 22 Our data indicate that stopping CPR for the duration of the time taken to insert an airway device would usually interrupt chest compressions for longer than 10 s. They also indicate that time to ventilation is not prolonged importantly if tracheal intubation is performed during chest compressions. These findings support the advice in the current ERC guidelines: in experienced hands laryngoscopy should be performed while chest compressions are ongoing.1 Chest compressions should be discontinued only in order to pass the tube through the vocal cords and only if the intubator considers this necessary. Two of the three SADs we studied prolonged time to ventilation less than the TT and for all the SADs we studied, insertion times were not significantly affected by chest compressions. These data suggest that when a SAD is inserted, it should also be inserted without interruption to chest compressions.

The igel is approximately 50% faster to insert than the TT or the LMA, with or without interrupting chest compressions. The PLMA was about 25% faster to insert than the TT or cLMA during chest compressions. These data tentatively support the use of the igel and PLMA in preference to the cLMA during CPR.

The igel is a relatively new, CE marked device, which has some features that make it potentially very useful for CPR. The mask portion of the device is filled with an elastomer gel (styrene ethylene butadiene styrene). Unlike most other SADs, it does not require inflation with air and this undoubtedly contributed to the faster times to ventilation achieved in this study. Preliminary data suggest that the device is very easy to insert into patients and achieves an airway seal at least as good as the cLMA.13 Ongoing work has shown high insertion success rates both by experienced anaesthetists and by novices (unpublished data). The igel also incorporates a drain tube designed to separate the gastrointestinal and respiratory tracts, although the utility of this has yet to be demonstrated.

The PLMA, which has been widely used in anaesthetic practice, is mentioned in the ERC guidelines with the caveat that it has never been studied for use in this setting. There is evidence that it creates a much better airway seal (median leak pressure 30–32 cm H₂O) than the cLMA.18 Along with the oesophageal drainage tube, this helps to functionally separate the respiratory tract from the gastrointestinal tract.23 It has also been shown to ventilate the lungs of a manikin as effectively as a TT and better than the cLMA or LMA-Unique (Intavent Orthofix) during simulated CPR.24 The device therefore has several potential benefits in resuscitation. A systematic review of its use found lower first-attempt insertion success than the cLMA which is likely to prolong insertion times.23 In this study, we found the PLMA somewhat faster to insert than the cLMA, but only during chest compressions. This may be because of the use of the introducer tool. However, it is also possible that the results in a manikin will not be replicated in vivo.

The only SADs currently recommended by the ERC for use in CPR (and tested in this setting) are the cLMA, the Combitube™ (Kendall-Sheridan, Argyll, NY, USA), and the Laryngeal Tube (LT, VBM GmbBh Sulz, Germany). Of the three, the cLMA is used most commonly and neither the Combitube nor the LT is used regularly in the UK. The recommendation for the use of the cLMA is based on several studies showing its efficacy during CPR. It is easier to insert than a TT25–27 and achieves better ventilation than bag-mask ventilation.28 It is also likely that it is popular because of familiarity from anaesthetic practice.

However, there are some well-recognized problems with the cLMA in emergencies. The cLMA forms a relatively low pressure seal with the pharynx (median 16–22 cm H₂O)23 and this can impede or prevent effective ventilation, particularly if airway resistance is high or pulmonary compliance low, as is often the case in patients during CPR. In this study, we noted the lack of stability of the cLMA, with rotation and dislodgement during chest compressions requiring frequent replacement. This undoubtedly contributed to the significantly longer times to ventilation seen with the cLMA. We did not require volunteers to tie or tape the airway device in situ at any stage. We felt that this was justified as it is common practice to
establish satisfactory ventilation of the lungs before securing an airway device.

If an SAD is to be used during CPR, it is logical to use the one that is easily and rapidly inserted, that enables ventilation and offers optimal patient (airway) protection. Our data suggest that there may be limitations to the cLMA. The times to ventilation for both the PLMA and the igel were significantly faster than the cLMA, although the difference is probably only clinically useful for the igel. When combined with their improved airway seal and design features that make protection of the airway more likely, it is clear that these devices should be further considered for a role in CPR. Further investigation is required, particularly of the igel on which there are few data, into the use of these devices during CPR in patients.

The principal limitation of this study is that it was performed on a manikin instead of patients. The manikin used was chosen as it allows simulated chest compressions and airway management. Extensive evaluation of manikins designed for cLMA and SAD insertion and advanced airway management found the Laerdal Resusci Anne™ with Airway Trainer™ head to be the best manikin overall for performance of the tasks included in this study. As such, we believe that we have studied these airway interventions, during CPR, in the best available simulator. Despite this, a recognized problem with manikin studies is that times to perform airway interventions are generally quicker than in real patients. It is likely that this effect will be greater for tracheal intubation than for the placement of SADs. This implies that the differences we have found in this study will be larger and of greater clinical relevance in humans. Although we believe this is plausible, it is unproven but might usefully be studied. As with all manikin studies, it is difficult to predict how our findings would translate into clinical practice in real patients. For example, it is unclear whether the lateral displacement of the cLMA noted during CPR occurs in patients. Another limitation of the study was that we made no measure of the efficacy of ventilation in the manikin, requiring only that the chest rose visibly. We also made no measure of the extent of gastric inflation caused by each device.

In conclusion, this manikin study supports the ERC guideline that practitioners with advanced airway skills attempting to place a tracheal tube should do so without interrupting chest compressions, or with only a brief pause to enable passage of the tube. Our data also show that SADs may be inserted during chest compression without delaying ventilation significantly. The PLMA and igel may be inserted more rapidly than the cLMA. Further investigation is required into the use of the PLMA and igel during CPR in patients.

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