Tracheal intubation without the use of neuromuscular blocking agents

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Before the early 20th century, intubation of the trachea had been described for conditions such as perioral tumours and laryngeal obstruction, and had been performed rather crudely, often using fingers as a makeshift laryngoscope and without any pharmacological agents.55–74 Insufflation of the trachea for the purpose of ether anaesthesia was introduced in 1909 in the USA, and in 1912 in the UK.20–46 Rowbotham refined the technique and described a series of cases in 1913.72–73 These early tracheal tubes were wide-bore catheters and were guided into the trachea using forceps. Neuromuscular blocking drugs to aid tracheal intubation were first introduced into clinical practice in 1942 in the USA,28 and within several years gained widespread acceptance in this country.92–7

Before this, tracheal intubation was usually performed under deep inhalational anaesthesia with ether. The continuing use of this technique to facilitate tracheal intubation with halothane and subsequently sevoflurane is still established, especially in paediatric practice. Since the advent of shorter-acting opioid drugs, intubating the trachea has been particularly successful when these drugs are used in combination with propofol. The technique has gained a small but popular niche in the armoury of the anaesthetist, when use of a neuromuscular blocking drug is undesirable. It may be used when there is a contraindication to a neuromuscular blocking drug, or in cases where tracheal intubation is necessary but prolonged muscle relaxation is not, such as in short ENT or gynaecological procedures. The technique may be the one of choice for the anaesthetist, using it as part of total intravenous anaesthesia without the use of a neuromuscular blocking drug. One avoids the potential serious and unwanted side-effects of succinylcholine, as well as the less common ones of non-depolarizing drugs, such as anaphylaxis. This review concentrates on the many studies that detail different techniques to intubate the trachea without muscle relaxation. Although no two studies are the same, and criteria for optimal intubating conditions vary, this review provides insight into how to approach this technique. The literature on this subject was retrieved using Medline (PubMed, Medline Plus). The following search terms were used alone and in combination: tracheal intubation, inhalational anaesthetics, lidocaine, fentanyl, alfentanil, remifentanil, haemodynamic response, pressor response, complications.

Inhalational agents

Halothane and enflurane

Although tracheal intubation under deep halothane anaesthesia was a well-established technique in paediatric patients, Yakaitis and colleagues were the first to evaluate the optimum end-tidal concentration for intubation.94 The concept of MAC\textsubscript{EI} (EI=endotracheal intubation) was described—the minimum alveolar concentration of halothane needed by 50% of the population to prevent all movement both during and immediately after tracheal intubation. They studied 37 children, aged 2–6 yr, and found the MAC\textsubscript{EI} value to be 1.4%, and found by extrapolation that the MAC\textsubscript{EI} value for 95% of this population was 1.9%. The study was performed at altitude, and after appropriate barometric calculations the MAC\textsubscript{EI} of halothane was recalculated as 1.3%.

The same group then applied these study techniques to enflurane in a similar age group of patients and found the MAC\textsubscript{EI} value to be 1.4%, and found by extrapolation that the MAC\textsubscript{EI} value for 95% of this population was 1.9%. The study was performed at altitude, and after appropriate barometric calculations the MAC\textsubscript{EI} of halothane was recalculated as 1.3%.
Sevoflurane

Children

Although halothane has been used for many years for smooth inhalational induction and good intubating conditions, it has been largely superseded by sevoflurane in the UK since the mid to late 1990s. The vast majority of publications in this subject have involved the inhalation of sevoflurane, using various approaches and combinations of other agents.

A group of Japanese workers produced a series of studies, mostly in children, designed similar to those of Yakaitis, before sevoflurane became available in the UK. In the first of these, 36 children aged 1–9 yr were studied. If the patient coughed or made purposeful movement, they were given a bolus of thiopental or succinylcholine and excluded from the study, leaving 22 suitable patients. Each concentration at which laryngoscopy and tracheal intubation were attempted was predetermined with an up-and-down method, using 0.5% as a step size and a single measurement was obtained per patient. Laryngoscopy and intubation were attempted only after the ratio of alveolar to predetermined inspiratory concentration had been maintained at greater than 0.95 for 15 min. The calculated MAC_EI for sevoflurane was 2.7%, 30% above the MAC_50 level of 2% for this age group, agreeing with the results from the halothane and enflurane studies by Yakaitis. The same group of investigators then compared the MAC_EI with the MAC to prevent movement in 50% of patients undergoing laryngeal mask insertion. Forty-two children aged 1–9 yr were studied, and the MAC_EI was similar to before, at 2.8%. Using this information, a study was designed to see how quickly, and at what optimal end-tidal concentration, the trachea could be intubated. Twenty-nine children were studied, aged 2–8 yr. The breathing circuit was saturated with sevoflurane 5% and the children were allocated to seven predetermined end-tidal concentrations before induction, ranging from 1.5 to 4.5%, in 0.5% increments. The results showed that 80 and 100% of patients underwent smooth tracheal intubation at end-tidal concentrations of 4 and 4.5% respectively, and that the effective dose for 50% of the population (ED50, equivalent to the MAC_EI) was 3.1%. This is 0.3–0.4% higher than previously reported in a similar group of patients, presumably because of the difference in brain concentrations as a result of a shorter intubation time. The time taken to reach an end-tidal concentration of 4.5% and intubate averaged 210 s. However, numbers were small, ranging between two and eight patients in each group. The addition of nitrous oxide 33 and 66% has been shown to decrease the MAC_EI value in children aged 1–7 yr by 18 and 40%, from 2.7% with sevoflurane alone, to 2.2% and 1.6% respectively. This is entirely predictable, considering the additive effect on MAC of nitrous oxide.

Different inhalational agents have also been compared. In one study, O’Brien and colleagues studied 40 fit, healthy children, aged 3–10 yr in a double-blind randomized controlled trial. Patients were induced with either halothane and nitrous oxide 60%, or sevoflurane and nitrous oxide 60%. The concentrations of each potent inhalational agent were increased gradually to 5 and 8% respectively and the trachea was intubated when the pupils were small and central. The mean time to reach the clinical end-point for intubation was 200 s for the halothane group and 243 s for the sevoflurane group (P=0.015). Satisfactory intubating conditions, based on the Helbo-Hansen scoring system, were achieved in 19/20 patients in each group. In the sevoflurane group, however, only seven out of 20 patients had an ideal score, compared with 12 out of 20 patients in the halothane group. The time to tracheal intubation (Time_EI) using equipotent concentrations of sevoflurane (5%) and halothane (2.5%) has also been compared in 40 children aged 1–7 yr. Using the up and down method starting at 240 s, the Time_EI 50 and Time_EI 95 for the sevoflurane/halothane groups were 147 s/214 s and 194 s/255 s respectively, consistent with their relevant blood gas solubility.

The success of these previous studies led researchers to determine if sevoflurane alone could achieve as rapid and effective intubating conditions as thiopental and succinylcholine. This would make it a potentially attractive technique to intubate the trachea for short procedures. Thwaites and colleagues studied 64 healthy children aged 3–10 yr undergoing tonsillectomy, receiving either sevoflurane 8% and nitrous oxide 66% in oxygen, or propofol 3–4 mg kg⁻¹ and succinylcholine 2 mg kg⁻¹. Both groups were intubated at 150 s by a blinded investigator. Although intubation was successful in all cases, excellent conditions were scored in only 55% of cases in the sevoflurane group, compared with 82% cases in the propofol/succinylcholine group.

Using a technique from a previous study, sevoflurane 8% in nitrous oxide 60% was compared with propofol/succinylcholine (3 mg kg⁻¹ and 1 mg kg⁻¹) and propofol alfentanil (3 mg kg⁻¹ and 10 µg kg⁻¹) in 120 children aged 3–12 yr. Patients in the sevoflurane group were intubated after 3 min, whilst the other groups were intubated after 60 s. Acceptable conditions were found in 97.5, 87.5 and 52.5% respectively, prompting the authors to state that the sevoflurane technique is a satisfactory alternative to the gold standard of succinylcholine and propofol when intubating children in a non-urgent situation. The mean end-tidal concentration just before intubation was 4.2%. This agrees with the previously quoted studies that an end-tidal concentration of 2×MAC is required for successful intubation in almost all children. This would take approximately 3 min under normal circumstances when breathing these high concentrations of sevoflurane.
**Adults**

Similar methods were used to determine the MAC\textsubscript{EI} in adults, who seem to require much higher concentrations of volatile agent than children for the same effect.\textsuperscript{47} In 86 ASA I or II adult patients, the MAC\textsubscript{EI} sevoflurane for 50% of the population was 4.5%. The authors account for this difference by the irritation and subsequent coughing caused by the cuff of adult tracheal tubes, and the fact that children have a relatively greater brain perfusion and quicker uptake. In another study, 20 healthy adult volunteers were anaesthetized on three separate occasions, using three different techniques;\textsuperscript{56} technique 1 was tracheal intubation after induction with sevoflurane 6–7% and nitrous oxide 66%; technique 2 was tracheal intubation after induction with sevoflurane 6–7% and oxygen 100%; and technique 3 was laryngeal mask insertion after induction with sevoflurane 6–7% and nitrous oxide 66%. The time to successful intubation was used as the end-point. The mean time in the sevoflurane/oxygen 100% group was 6.4 min, longer than that of the sevoflurane/nitrous oxide 66% group at 4.7 min. It can therefore be seen that even when breathing sevoflurane 8%, a significantly longer period of inhalation is required for adults.

Sevoflurane 8% can be as satisfactory as neuromuscular blocking drugs for producing the necessary conditions for intubating the trachea, but cannot achieve the speed of onset of effect for rapid sequence intubation. Iamaroon studied 120 adult patients,\textsuperscript{38} randomized into receiving thiopental 5 mg kg\textsuperscript{-1} and succinylcholine 1 mg kg\textsuperscript{-1}, or sevoflurane 8% in nitrous oxide 66%. The succinylcholine group were intubated by a blinded investigator at 1 min and achieved almost 100% success rate with good or excellent conditions, whereas the sevoflurane group breathed 3 vital capacity breaths in a primed circuit followed by 4 min normal breathing to achieve almost the same results.

To achieve a similar time profile to children, adults need to be premedicated. In one study, 24 healthy adult volunteers were anaesthetized on three separate occasions,\textsuperscript{65} and premedicated with fentanyl (2.4 μg kg\textsuperscript{-1}), midazolam (36 μg kg\textsuperscript{-1}) or both drugs (B) using a quarter of the doses because of a previously described synergistic effect.\textsuperscript{4} Patients breathed sevoflurane 8% and nitrous oxide 66% in oxygen at time intervals varying between 2.5 and 6.5 min. Logistic regression analyses showed that good-quality intubating conditions could be achieved after 3.1 min and 2.5 min in the midazolam and combined groups respectively, several minutes shorter than in the fentanyl group. This is surprising, as it has been reported previously that midazolam and fentanyl have similar MAC sparing properties, but it may be that the synergistic effect mentioned previously was not evident here.\textsuperscript{4} The authors speculate that this inconsistency arises from the increased chest wall rigidity seen in the patients receiving fentanyl, leading to a reduced minute volume, and hence less delivery of anaesthetic to the alveoli. Katoh and colleagues\textsuperscript{44} pretreated a group of 80 ASA I–II adults with fentanyl 1, 2 and 4 μg kg\textsuperscript{-1}, given 4 min before intubation. This resulted in a markedly decreased MAC\textsubscript{EI} of sevoflurane of 2.07, 1.45 and 1.37% respectively, compared with 3.55% without fentanyl. Similarly, the addition of remifentanil 1 μg kg\textsuperscript{-1} followed by an infusion of 0.25 μg kg\textsuperscript{-1} min\textsuperscript{-1} reduced the MAC\textsubscript{EI} to 2%, the MAC\textsubscript{EI} of 95% of the population being 3.2%.\textsuperscript{15}

**Difficult airway**

Sevoflurane has a lower blood gas solubility and is less likely to cause cardiac depression or arrhythmias than halothane. This has made it an attractive alternative for use in the difficult airway. Several reports now exist of its successful use in predicted difficult intubations, including acute epiglottitis.\textsuperscript{30, 33, 56, 78} These patients have been managed in one of two ways: either by increasing the inspired concentration of sevoflurane in a stepwise way, or a high-concentration induction. There is disagreement among authors as to which technique actually produces the least amount of clinically significant side-effects, such as excitation, laryngospasm and coughing.\textsuperscript{89} Consensus appears to favour a stepwise approach either by increasing inspired concentrations by 1–2% quickly or by preoxygenation and starting at sevoflurane 8%, without priming the circuit first. Because of the relatively fast onset of sevoflurane, some authors advise caution with its use in difficult airways, noting that speed of induction may not be desirable in some circumstances because of increased risk of respiratory depression.\textsuperscript{8} 18, 32, 42

**Lidocaine**

Lidocaine has been reported to be a useful intravenous and topical adjunct to facilitate tracheal intubation, both on its own and with different short-acting opioids, in doses of 1–2 mg kg\textsuperscript{-1}.\textsuperscript{10, 17, 25, 37, 64, 92} Mulholland and colleagues\textsuperscript{64} found no statistically significant difference in intubating conditions when they compared two groups receiving propofol 2.5 mg kg\textsuperscript{-1} and either saline or lidocaine 1.5 mg kg\textsuperscript{-1}, administered 1 min before attempted intubation. Thirty-three per cent of patients in the lidocaine group were deemed to have unsatisfactory or impossible intubation conditions when they compared two groups receiving propofol 2.5 mg kg\textsuperscript{-1} and either saline or lidocaine 1.5 mg kg\textsuperscript{-1}, administered 1 min before attempted intubation. This agrees with Grange,\textsuperscript{25} who also found pretreatment with lidocaine no better than saline. However, in doses of 1 mg kg\textsuperscript{-1}, intravenous lidocaine has been shown to halve the dose of alfentanil or remifentanil needed to produce comparable intubating conditions.\textsuperscript{17, 92}

Several papers have also examined the effectiveness of intravenous lidocaine to suppress the cough reflex.\textsuperscript{69, 79} Yukioka and colleagues\textsuperscript{96} showed that the optimum dose to suppress the cough reflex completely was 2 mg kg\textsuperscript{-1} administered intravenously at 1 min before intubation. However, even though the authors did not report any patient with significant side-effects, they conclude that this dose may be
associated with systemic toxicity, some patients having blood concentrations as high as 8 μg kg⁻¹, as measured by gas chromatography from regular arterial sampling.

Tracheal intubation causes a marked pressor response, raising the mean arterial pressure and mean heart rate significantly. This may be potentially harmful in patients with cardiac disease or raised intracranial pressure, and may be exaggerated in both treated and untreated hypertensive patients. Lidocaine does not appear to alter this response. Miller and colleagues found no protective effect when 1.5 mg kg⁻¹ was administered 3 min before laryngoscopy. Similar findings were seen in a study by Braemmer-Jorgensen, using the same dose given 2 min before laryngoscopy. The addition of laryngotracheal lidocaine seems to be more successful in facilitating tracheal intubation. Bulow and colleagues used propofol 2.5 mg kg⁻¹ and alfentanil 30 μg kg⁻¹, and then sprayed the vocal cords with lidocaine 160 mg 90 s before intubation. Satisfactory conditions were obtained in all 27 patients in this group compared with 73% in the saline group. But laryngotracheal administration of lidocaine does not alter this pressor response to laryngoscopy and tracheal intubation.

Induction agents

**Thiopental** has been used as the sole agent to facilitate tracheal intubation. In 1948, Lewis described a series of 200 patients who received either a blind nasal, or direct oral intubation after thiopental 500–750 mg. There were two failures in the blind nasal group and six in the direct laryngoscopy group. Lewis encountered severe problems with coughing, although the quality of overall intubating conditions was not specified as no scoring systems were used. This study merely highlights that any hypnotic, if given in significant doses, will provide enough obtundation to facilitate tracheal intubation.

**Propofol** provides better jaw relaxation and attenuation of laryngeal reflexes than thiopental. When used alone for tracheal intubation, propofol 2.5 mg kg⁻¹ provided satisfactory conditions in 19/20 (96%) patients and ideal intubating conditions in 14/20 (60%) patients. These patients were premedicated with diazepam 10 mg and droperidol 5 mg, and therefore the results may be better than expected. This contrasts with Mulholland and Carlisle, who found that 56% of patients had unsatisfactory conditions with the same dose of propofol. However, the method and standard endpoints for quality of tracheal intubation vary in these two studies.

Opioids

Three opioid drugs have been studied in detail for their use in tracheal intubation: fentanyl and, in particular, alfentanil and remifentanil.

**Fentanyl** has been shown to blunt the pressor response to laryngoscopy and intubation optimally 5 min after administration, which is longer than after alfentanil or remifentanil. Streibel and colleagues designed a double-blind, randomized controlled trial to compare the intubating conditions between thiopental (mean 5.5 mg kg⁻¹)/fentanyl 100 μg/succinylcholine 1 mg kg⁻¹ and propofol (mean 2.4 mg kg⁻¹)/fentanyl 100 μg. No significant differences were found in overall intubating conditions between the two groups of 25 gynaecological patients.

In a study of 60 ASA I or II children, De Fatima and colleagues found that fentanyl 3 μg kg⁻¹ given 5 min before propofol 3 mg kg⁻¹ was the optimal dose regime, and resulted in satisfactory intubating conditions in 75% of patients. This is compared with 20% (P<0.05) and 80% (n.s.) of patients given propofol 2.5 mg kg⁻¹ and 3.5 mg kg⁻¹ respectively.

**Alfentanil**

Alfentanil has been used successfully as an adjunct to blunt the pressor response and to allow faster tracheal intubation when combined with non-depolarizing neuromuscular blocking drugs. Table 1 summarizes the many studies using alfentanil as an alternative to neuromuscular blocking drugs for intubation of the trachea. Most studies vary in design, type of premedication, dose of alfentanil and clinical end-point, making it difficult to decide on the best drug regimen. Doses given vary between alfentanil 10 and 50 μg kg⁻¹. With doses as low as 10 μg kg⁻¹, Alcock and colleagues found that good or excellent conditions were found in 43/50 (86%) of patients, five out of the 50 patients requiring succinylcholine to facilitate intubation. This is in contrast to Davidson and Gillespie, who found that, with the same dose, intubating conditions were ideal in only 20% patients, increasing to 73% when the dose was doubled to 20 μg kg⁻¹, after induction with propofol 2.5 mg kg⁻¹. The main difference with this study was using a time, predetermined from a pilot study, after injecting propofol 2.5 mg kg⁻¹ to intubating of 45 s. The previous two studies used loss of eyelash reflex as an end-point, and had no reference to the timing of intubation, perhaps resulting in less optimal plasma concentrations of alfentanil.

Type of premedicant has an effect on success of intubation with lower doses of alfentanil. In a study by Harsten and Gillberg, 33/37 (89%) patients had good or ideal
intubating scores using only alfentanil 10 μg kg\(^{-1}\) with propofol 2.5 mg kg\(^{-1}\). In this instance, triazolam 0.25 mg was given 30–45 min before induction. Coghlan and colleagues found that intubation was possible in 83% of patients using this dose, though the authors did specify that 47% of patients moved and 63% coughed during intubation.\(^{12}\) Other studies have been less encouraging at these smaller doses. A dose of alfentanil 40 μg kg\(^{-1}\) was needed by patients in a study by Scheller and colleagues to provide satisfactory intubating conditions in most patients. When 30 μg kg\(^{-1}\) was used, 5/15 patients required succinylcholine to facilitate intubation. However, in this study intubation was attempted approximately 3 min after the start of an 80 s infusion of alfentanil. In addition, only propofol 2 mg kg\(^{-1}\) was administered, compared with the slightly higher doses used in most other studies. In children, a higher incidence of acceptable intubating conditions was generally found for the equivalent dose of alfentanil, although this was given with higher induction doses of propofol, usually between 3 and 4 mg kg\(^{-1}\).\(^{36,38,82}\) These studies highlight the crucial effect propofol has when using this technique.

Alfentanil has been used successfully in a case of a difficult airway after both fibre-optic intubation and deep inhalational anaesthesia with halothane had failed.\(^{59}\) The authors used alfentanil 25 μg kg\(^{-1}\) followed by propofol 1 mg kg\(^{-1}\) to visualize the glottis, and stated that the effects of alfentanil could have been readily antagonized by naloxone if necessary. Others have reservations about the use of alfentanil in a potentially difficult airway, and are guarded about the ease of reversibility with naloxone and the relatively high failure rate of intubation with this dose.\(^{24,53}\) These authors advise caution and state that the technique of choice in such situations is always awake fibre-optic intubation.

### Remifentanil

Remifentanil has a similar clinical onset time to alfentanil and has also been found to blunt the pressor response to tracheal intubation.\(^{31,68,87}\) Studied in comparable doses, the degree of attenuation is similar.\(^{60}\) Table 2 summarizes the studies involving remifentanil to facilitate tracheal intubation. Again, most studies vary in the timing of drug administration, study design and doses, varying between remifentanil 0.5 and 5 μg kg\(^{-1}\). In the first of these studies, Stevens and Wheatley\(^{70}\) found that remifentanil 3 μg kg\(^{-1}\), given with propofol 2 mg kg\(^{-1}\), was the minimum dose necessary to produce acceptable intubating conditions in nearly all patients. A dose of 2 μg kg\(^{-1}\) was associated with an incidence of 75% in good or ideal conditions, whereas clinically acceptable intubating conditions

<table>
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<th>Study (year)</th>
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<tr>
<td>Hovorka (1991)(^{37})</td>
<td>100 adult females, 2 groups of 50. Single-blind randomized trial. G1 L 1.5/AL30/Th5, G2 L 1.5/AL 30/P 2.5. Easy intubation 48% G1, 22% G2 (P&lt;0.05).</td>
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<td>Saarivaara (1991)(^{35})</td>
<td>59 adults, 4 groups. G1 Sal/P 2.5, G2 AL 20/P 2.5, G3 AL 30/P 2.5, G4 AL 30/P 2. Good to moderate conditions in 79% patients G3, compared with 38% G1.</td>
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<td>Scheller (1992)(^{26})</td>
<td>75 adults, 5 groups. G1 Sc 1/Th 4, G2–5 AL 30–60/P 2. G1 had significantly increased HR and BP after intubation. AL 40/P 2 allowed acceptable intubating conditions in most patients.</td>
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<tr>
<td>Davidson (1993)(^{17})</td>
<td>60 adult females, 4 groups. G1 AL 10/P 2.5, G2 L 1/AL 10/P 2.5, G3 AL 20/P 2.5, G4 L 1/AL 20/P 2.5. Acceptable intubating conditions in 20, 73, 73 and 93% respectively.</td>
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<td>Hiller (1993)(^{36})</td>
<td>45 children, 3 groups. G1 L 1/AL 20/P 3–3.5, G2 AL 20/P 3–3.5, G3 AL 40/P 3–3.5. Good to moderate intubating conditions in 87–100% patients in all groups.</td>
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<tr>
<td>Grange (1993)(^{25})</td>
<td>45 adults, 3 groups. G1 P 2.5/Sal, G2 P 2.5/AL 20, G3 P 2.5/L 1.5. Good or excellent conditions in 20, 93 and 33% of patients respectively.</td>
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<td>Coghlan (1993)(^{12})</td>
<td>60 adults, 2 groups. G1 P2, G2 P/2/AL 20. Intubation successful in 73 and 83% respectively, but coughing in 97% G1 and 63% in G2. Movement occurred in 93% G1 and 47% in G2.</td>
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<tr>
<td>Alcock (1993)(^{1})</td>
<td>100 adults, 2 groups. G1 Sc 1/P 2.5, G2 AL 10/P 2.5. Good or excellent conditions in 100% G1, 86% G2.</td>
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<td>McConaghy (1994)(^{38})</td>
<td>60 children, 3 groups. G1 AL 5, G2 AL 10, G3 AL 15. All groups received induction dose of propofol until loss of verbal contact. Conditions excellent in 20, 70 and 80% respectively. Propofol dose required significantly less with increasing alfentanil dose.</td>
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<tr>
<td>Steyn (1994)(^{82})</td>
<td>80 children, 2 groups. G1 Sc 1.5, G2 AL 15. Both groups received P3–4. Acceptable intubating conditions in 87 and 80% respectively (n.s.).</td>
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<tr>
<td>Wong (1996)(^{91})</td>
<td>119 adults, 4 groups. G1 AL 15, G2 AL 30, G3 Propofol only, G4 Sc 1. Propofol titrated until loss of verbal command. Good or moderate conditions in all patients in groups 2 and 4. Conditions not significantly different in groups 1 and 3 (28/30 and 22/30 good or moderate).</td>
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<tr>
<td>Stevens (1998)(^{81})</td>
<td>140 adults, 7 groups. G1–6 AL 40 and either Et 0.3, P2 or Th 4. In each group half the patients received lidocaine 1. G7 Th 4/Te 4/Sc 3/Sc 3, P and Et groups better conditions to Th group. All groups results enhanced by L. No difference between Et, P and Th/Te/Sc groups apart from BP maintained in Et group.</td>
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<tr>
<td>Harsten (97)(^{33})</td>
<td>80 adults, 2 groups. G1 AL 10/Th 5/Sc 1, G2 AL 10/P 2.5. 100% good/ideal conditions G1, 89% G2 (P&lt;0.05). Triazolam used as premedication.</td>
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<td>Collins (2000)(^{13})</td>
<td>144 adults, 3 groups. G1 Sal/P 2.5/AL 20, G2 Tc 3/P 2.5/AL 20, Sc 1 G3 Sal/P 2.5/AL 20/Sc 1.5. Patients preoxygenated with either saline or tubocurarine. All patients intubated, vocal cords closed in 6% G1, incidence of movement significantly higher in G1 (37%). Incidence of myalgia significantly higher in G3 than G1 or G2 for first 48 h.</td>
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G=the relevant group; L=lidocaine; AL=alfentanil; P=propofol; Sal=saline; Sc=succinylcholine; Th=thiopental; Et=etomidate; Tc=tubocurarine; n.s.=not statistically significant.
were recorded in only 35% of patients given 1 μg kg⁻¹. The results of this study are similar to studies conducted by Grant and Woods,26.92.93 which show that remifentanil 2 μg kg⁻¹ consistently provides good or ideal intubating conditions in 80–90% of patients. This contrasts with the work of others,3.48.62 who have found that doses as high as 4 μg kg⁻¹ are necessary to obtain excellent conditions in most patients (Table 2). In most of these studies, at doses of remifentanil 2 μg kg⁻¹ and above, blood pressure and heart rate are significantly reduced compared with baseline levels, leaving most authors to conclude that the technique is not to be recommended in elderly or compromised patients.

The successful intubating conditions coupled with a potential short apnoea time of remifentanil draw comparisons with administration of succinylcholine in a rapid sequence induction technique. Stevens and Wheatly30 found the mean duration of apnoea was 204–244 s, with doses varying between 1–4 μg kg⁻¹. This contrasts with work by Woods and colleagues,93 who showed that the median duration of apnoea with remifentanil 1 μg kg⁻¹ combined with lidocaine 1 mg kg⁻¹ was 270 s, that of remifentanil 2 μg kg⁻¹ being 487 s. The optimal target level of remifentanil for intubation has also been studied, using a target controlled infusion of both propofol (Graseby 3500 pump) and remifentanil (Alaris IVAC pump using pharmacokinetic data for remifentanil).90 Anaesthesia was induced in 60 ASA I–II patients with a propofol target of 6.5 μg ml⁻¹, reducing to 3 μg ml⁻¹ after 1 min. Three target levels of remifentanil were chosen: 19, 15 and 11 ng ml⁻¹, reducing to 10, 8 and 6 ng ml⁻¹ after 1 min. Intubation was attempted at 4 min, and was satisfactory in 75, 75 and 35% in the three groups respectively.

A rapid sequence induction using remifentanil has been described in a 12-year-old child with a potentially difficult airway, after a gunshot wound. The patient had a family history of malignant hyperpyrexia, and a propofol–remifentanil induction was deemed the technique of choice in this unusual situation, in which neither an awake fibre-optic intubation nor tracheostomy would have been appropriate. The patient received propofol 3 mg kg⁻¹ and remifentanil 4 μg kg⁻¹ and underwent uneventful laryngoscopy and subsequent anaesthesia.34

In most of the studies assessing intubating conditions with the short-acting opioid drugs, induction with propofol has been carried out. Neither thiopental nor etomidate can provide similar conditions for this situation.21

Table 2 Summary of the studies with remifentanil

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<tr>
<td>Stevens (1998)30</td>
<td>80 adults, 4 groups. G1 P 2/R 1, G2 P 2/R 2, G3 P 2/R 3, G4 P 2/R 4. Acceptable intubating conditions in 35, 75, and 100% respectively. Duration of apnoea &lt;5 min after tracheal intubation in all groups. Infusion of remifentanil over 90 s, before induction agent given.</td>
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<td>Grant (1998)26</td>
<td>60 adults, 3 groups. G1 P 2/R 0.5, G2 P 2/R 1, G3 P 2/R 2. Acceptable intubating conditions in 20, 50 and 80% respectively. Bolus of remifentanil given before induction agent; intubation 90 s later.</td>
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<tr>
<td>Alexander (1999)2</td>
<td>60 adults, 3 groups. G1 P 2/R 2, G2 P 2/AL 50, G3 P 2/S 1C. Excellent intubating conditions in 35, 85 and 100% respectively. Bolus of remifentanil given after induction agent; intubation 60–120 s later.</td>
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<tr>
<td>Alexander (1999)3</td>
<td>60 adults, 3 groups. G1 P 2/R 3, G2 P 2/R 4, G3 P 2/R 5. Poor intubating conditions in 40, 5 and 5% respectively. MAP&lt;45 mm Hg, requiring ephedrine in 10, 25 and 30% of patients. Technique as above.</td>
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<tr>
<td>Woods (1999)93</td>
<td>40 adults, 2 groups previously shown to be successful for intubation. G1 P 2/R 2, G2 P 2/R 2/L1. Aim of study to show apnoea time before intubation, to mimic situation when unable to intubate. Median time of apnoea G1 487 s, G2 270 s (P&lt;0.05).</td>
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<tr>
<td>McNeil (2000)62</td>
<td>60 adults, 3 groups. G1 P 2/R 2, G2 P 2/R 4, G3 P 2/S 1C. Similar intubating conditions G2 and G3. 20% patients G1 had purposeful movement or persistent coughing. Remifentanil groups showed dose dependent on cardiovascular depression.</td>
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<tr>
<td>Klemola (2000)49</td>
<td>Mean duration of apnoea 9.3, 12.8 and 6.0 min (P&lt;0.001).</td>
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<td>Klemola (2000)49</td>
<td>80 children 3–9 yr, 4 groups. G1 P 3.5/R 2, G2 P 3.5/R 4, G3 P 3.5/R 2/Roc 0.2, G4 P 3.5/Roc 0.4. Excellent conditions in 55, 90 and 65% respectively. Atracurine given preinduction and remifentanil groups showed only slight changes in cardiovascular variables compared with preinduction values.</td>
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</table>

G=the relevant group; L=lidocaine; R=remifentanil; P=propofol; Sal=saline; Sc=succinylcholine; Th=thiopental; Roc=rocuronium. All numbers are the appropriate doses for that drug.

Conclusions

The literature describes successful techniques to intubate the trachea without the use of neuromuscular blocking agents under general anaesthesia. The technique offers a useful alternative when these drugs are either contraindicated or undesirable. Many clinicians routinely practise without neuromuscular blocking drugs unless clinically indicated. It is difficult to make any particular recommendations because clinical opinion is often based on personal experience, and dose regimes may vary between clinicians. It is the authors’ experience that sevoflurane is best inhaled in a stepwise way, until the end-tidal concentration is at least 2×MAC. The use of alfentanil and remifentanil to
facilitate intubation of the trachea is particularly helpful in paediatric ENT procedures. Doses of alfentanil 20 μg kg
−1 should ensure successful, trouble-free intubation in most cases, small boluses of propofol being given if intubating conditions at the time are not ideal. Most authors agree that remifentanil 2 μg kg
−1 followed by propofol 2 mg kg
−1 provides a balance between acceptable intubating conditions and a short apnoea period for children undergoing short procedures. In adults, remifentanil 2 μg kg
−1, given approximately 90 s before intubation, is the authors’ starting dose to facilitate tracheal intubation. If intubating conditions are deemed less than ideal, an additional bolus of remifentanil 1 μg kg
−1 should ensure good intubating conditions in most ASA I or II patients. The addition of lidocaine achieves better intubating conditions mainly because of suppression of the cough reflex, and adds little to ease of laryngoscopy or passage of a tracheal tube through the vocal cords. Because of the diversity in study methods and interpretation of the quality of tracheal intubation, each technique and subsequent results must be interpreted within the clinical situation described.

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