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Malpositioning of supraglottic airway devices: preventive and corrective strategies

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Airway management is one of the cornerstones for modern anaesthesia and is vital for all patients undergoing general anaesthesia. Supraglottic airway devices (SADs) are increasingly used for managing airways. The World Health Organization estimates that worldwide, ~250 million patients undergo general anaesthesia for major surgery on an annual basis.[1] If we translate the figures of the 4th National Audit Project of the Royal College of Anaesthetists and Difficult Airway Society (NAP4) in the UK, where almost 60% of the patients receive SADs during anaesthesia, we can assume that annually, ~150 million such devices are used worldwide.[2 3]

Manufacturers continue to invest in research in designing these devices to prevent aspiration, resulting in first-generation (ventilation channel only) and second-generation (separation of ventilatory and gastric access channels) SADs, with several other modifications and characteristics designed to improve their functionality and safety.[4–6]

Anaesthetists consider the SAD to be a device that is easy to insert and that can be used for ever-increasing indications during various types of general surgery, obstetrics, and gynaecology. They also advocate its use in other areas, including the following: during cardiopulmonary resuscitation, in the department of emergency medicine, in the intensive care unit, in the prehospital setting, and as an important step in the difficult airway algorithm.[7–9]

Manufacturers hardly put efforts into verification of the correct placement or positioning of the device *in situ* after insertion. Contrary to the insertion of a tracheal tube, which is guided to the trachea under (in)direct vision of a (video)laryngoscope, the insertion of a SAD is virtually a 'blind' technique, whereby one relies on the practitioner's skills to insert the device correctly into the hypopharynx. Routine verifications include auscultation of the lungs and gastric area, capnogram, oxygen saturation, airway pressure, oropharyngeal leak pressure, and the gold standard to evaluate its position using a fibreoptic scope, which is typically inserted through the tube of the airway device. However, the use of a fibreoptic scope only helps in diagnosis of malpositioning but does not allow the ability to change an incorrectly positioned SAD.

Supraglottic airway devices are generally forgiving devices because even suboptimally positioned SADs still can provide adequate ventilation for the patients during short procedures. However, malpositioning of the device can result in severe leaks and

even obstruction of the airway, with potentially negative outcomes for the patient. Although the incidence of complications (e.g. airway trauma, obstruction, regurgitation, gastric distension with mechanical ventilation) is likely to be higher with an incorrectly placed SAD, clinical airway obstruction can result from other causes, such as laryngospasm and transient closure of the glottis.

Ideal position of a supraglottic airway device

Computed tomography scans (Fig. 1A) have revealed that the epiglottis is posteriorly deflected against the posterior pharyngeal wall in most (80%) patients.[10] Imaging studies have also shown that malpositioning of SADs occurs in 50–80% of patients.[11–13] Fibreoptic evaluation reveals that 50% of the time, the tip of the epiglottis may lie within the bowl of the device.[14 15]

Figure 1 shows several positions of SAD sitting in a manikin and in patients. Ideally, the correct size of the device should be inserted into the hypopharynx, with the distal tip of the SAD in the oesophagus, whereby the tip of the epiglottis is aligned with the proximal part of the (adequately inflated cuffed) mask (Fig. 1B and F). As such, the epiglottis rests on the outer side of the cuff, whereby the tube opening of the SAD opposes the entrance to the trachea.

If a cuffed SAD is used, it should be inflated with enough air to produce an adequate seal that allows both spontaneous and artificial ventilation, avoiding both hyperventilation (whereby the SAD risks being dislocated from its position) and hypoventilation (which increases the risks for aspiration; Table 1). Similar risks exist when an inappropriate size of the device is used. Non-cuffed SADs may also result in a leak attributable to lack of adequate alignment and seal between device and the epiglottis (Fig. 1G).

Consequences of malpositioned supraglottic airway device

Inappropriately sitting devices may result from use of an inappropriately small size, hypoinflation of the cuff, or too deep insertion of the device (Fig. 1C and H) or, conversely, a larger size device, hyperinflation of the cuff, or too superficial insertion of the device (Fig. 1D and I). The factors above can all result in misalignment of the opening of the tube of the SAD and the tracheal orifice, and subsequently, a leak or even malobstruction may ensue. Fairly often, the epiglottis is located in the bowl of the SAD (Fig. 1D). This does not necessarily cause airway obstruction (Fig. 1J). In the worst-case scenario, downfolding of the epiglottis (Fig. 1E) may result in a leak or obstruct adequate ventilation altogether, indicated by a very low oropharyngeal leak pressure and the absence of a normal capnogram trace, the presence of high airway pressure, and the inability to ventilate the patient. Anaesthetists will then try to readjust the device or take it out altogether and replace it with either another SAD or use a tracheal tube instead.

Malpositioning; preventive and corrective strategies

Different positions of SADs *in situ* pictures were captured with videolaryngoscopy (Fig. 1), and five common malpositions of

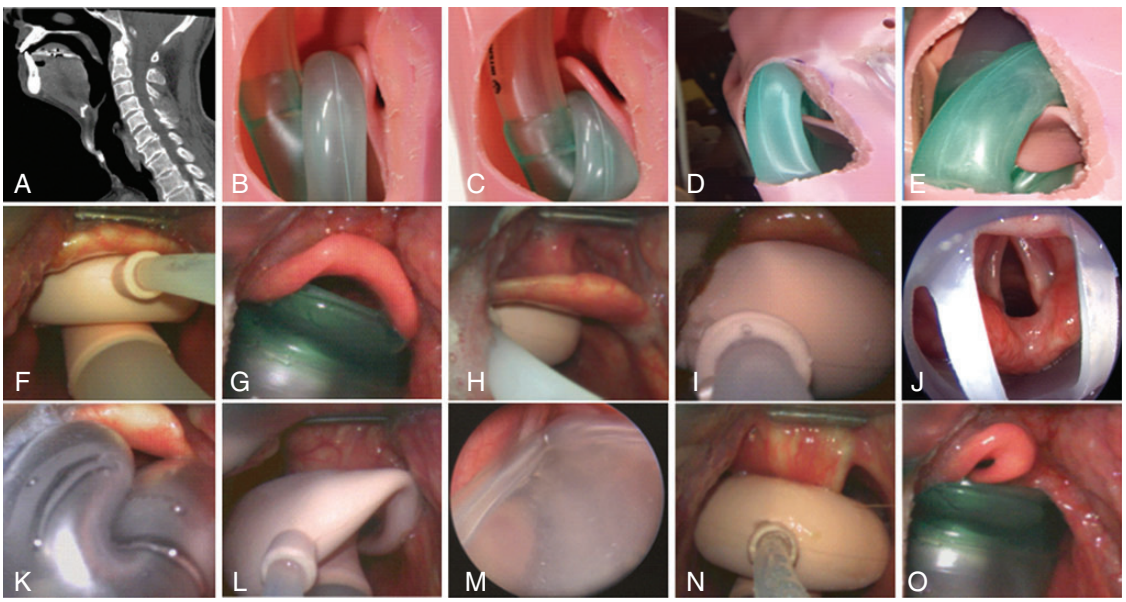

Fig 1 Malpositioning of supraglottic airway devices (SADs). (A) Computed tomography scan showing the epiglottis leaning backwards against the posterior wall of the oropharynx. (B) Ideal position of a SAD in a manikin (alignment of the tip of the epiglottis with the proximal cuff of the SAD, producing a good seal). (C) Supraglottic airway device inserted too deep, too small size of SAD, or hypoinflation of the cuff in a manikin. (D) Supraglottic airway device inserted too superficial, too large size of SAD, or hyperinflation of the cuff in a manikin. (E) Downfolding of the epiglottis in the bowl of the SAD in a manikin. (F) Ideal position of the SAD in a patient (adequate alignment of the tip of the epiglottis with the proximal cuff of the SAD and with the epiglottis resting on the outside of the device). (G) Lack of seal between a SAD (non-inflatable cuff) and the epiglottis in a patient. (H) Same as in (C) in a patient. (I) Same as in (D) in a patient. (J) Supraglottic airway device with the epiglottis in the bowl, showing posterior epiglottis (no obstruction). (K) Folding in the proximal polyvinyl chloride cuff causing a leak. (L) Tip of the distal cuff folding over. (M) Tip of the distal cuff sits between the vocal cords. (N) Downfolding of the epiglottis by the distal cuff of the SAD. (O) Folding double of the epiglottis in a patient. All SADs may cause identical problems irrespective of the manufacturer of the device.

Table 1 Flow chart that provides: steps to result in an adequately positioned SAD; trouble-shooting options [verify SAD position with (video) laryngoscope]; causes of a malpositioned SAD; and treatment options. SAD, supraglottic airway device

Adequately positioned SADs produce a good seal and no leak (ideal situation)	Malpositioned SADs produce a leak and airway obstruction (unwanted situation)
Five requirements of an ideally positioned SAD: (i) Tip of distal cuff in oesophagus (ii) Epiglottis resting on outside of SAD cuff (iii) Tip of epiglottis aligned with proximal cuff of SAD (iv) Cuff of SAD adequately inflated to produce seal (v) Avoidance of cuff folding (silicone is better than polyvinyl chloride)	Five causes of a malpositioned SAD: (i) Tip of distal cuff of SAD folding over/backward (ii) Tip of distal cuff of SAD between vocal cords (iii) Epiglottis in bowl of SAD without downfolding (iv) Epiglottis in bowl of SAD with downfolding (v) Epiglottis folding double
Trouble-shooting options:Intracuff pressure a maximum of 60 cm H_2O at induction and maintenance Avoid: • Cuff hyperinflation (dislocation of SAD) • Cuff hypoinflation (risk for aspiration) • Use of a too deep/too small SAD • Use of a too superficial/too large SAD	Treatment options: • Jaw thrust to open oropharyngeal space (increase distance between epiglottis and posterior wall of oropharynx) • Use of a railroading technique with the help of a bougie or orogastric tube • Magill forceps

the SAD were found, as follows: (i) the tip of the distal cuff folding over backwards (Fig. 1L); (ii) the tip of the distal cuff positioned between the vocal cords (Fig. 1M); (iii) positioning of the epiglottis in the SAD bowl without downfolding of the epiglottis (Fig. 1J); (iv) downfolding of the epiglottis in the bowl of the SAD (Fig. 1N); and (v) epiglottis folding double (Fig. 1O), creating an airway leak.

The material used in the production of the SAD cuff is important, because polyvinyl chloride-based cuffs tend to create foldings in the proximal part of the SAD (Fig. 1K), with a potential leak as a result, even if the cuff is adequately inflated (maximal intracuff pressure of 60 cm H_2O). Medical-grade silicone-based cuffs seem not to have this disadvantage when adequately inflated (Fig. 1F and I).

Strategies to readjust any malpositioning of the SAD can be obtained if one uses a (video)laryngoscope, which allows visual confirmation of an adequately positioned epiglottis and airway device. Dr Archie Brain, in his very first publication on the LMA-Classic in the *BJA*, advised that any malfunctioning airway should be checked with a laryngoscope.[16] The use of jaw thrust during insertion of the SAD may help in creating more room in the oropharynx, thereby increasing the distance between the epiglottis and the posterior wall of the oropharynx.[13] Other techniques include a railroading technique with the help of a bougie, orogastric tube ,or Magill forceps.

The proposed flow chart (Table 1) may help anaesthetists in checking the position of the epiglottis and the SAD *in situ* and allows manoeuvres to be made to adjust any malpositioning.

Selection of the correct SAD, the right size, and all efforts to prevent aspiration are all secondary to the correct positioning of the device *in situ*. The epiglottis clearly plays an important role in the correct positioning of any SAD. As downfolding of the epiglottis can occur with any of existing SADs, less than optimal positioning may cause problems in creating a patent airway. Our primary role is to create a safe and effective patent airway. Only by seeing what we do and confirming an adequate position of the device *in situ* can we be satisfied and go on to the next step of anaesthesia. Manufacturers are advised to concentrate on providing optimal viewing tools to help us in this effort.

Authors' contributions

All authors approved the final manuscript and attest to the integrity of the original data and the analysis reported in this manuscript.

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Tracheal tube insertion is an essential part of modern paediatric anaesthesia and critical care: let us get it right

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> 'A clever person solves a problem. A wise person avoids it.'
> Albert Einstein

This quote clearly defines the basis of correct airway management in paediatric anaesthesia and intensive care by modern experienced clinicians. However, nowhere in medicine is an error rate of 20–50% viewed as acceptable and yet insertion of a tracheal tube of the correct size and correct depth has been associated with large error rates, especially in children <1 yr of age. Many formulae exist to attempt to determine the correct depth of insertion of a tracheal tube (whether by oral or nasal route). The original formula [(age/4)+4] for selection of the size of tracheal tube (internal diameter in millimetres) seemed easy enough, if you accepted that ~30% of tracheal tubes would be exchanged. With the widespread introduction of cuffed tubes, a much lower rate is now expected.[1] Viewing and inserting the tracheal tube into the trachea rather than the oesophagus is facilitated by training and experience, with end-tidal capnography providing the gold standard of confirmation, providing the patient has cardiac output and pulmonary blood flow.[2 3]

The correct distance for tracheal tube insertion has proved problematic. With the exception of premature gestation-based recommendations,[4] current age-based formulae have long been recognized as inadequate. Newer weight,[5] length,[6] and anthropomorphic alternatives, such us foot length,[7] middle finger length,[8] and tragus to nares length,[9] have all been studied and found to be better alternatives for infants. Many of these studies were retrospective, and almost all excluded any significant anomalies and pathology. Relative to the age-based predictions, they all demonstrate superior performance, but there remains a 10–20% incidence of tracheal tubes that require adjustment.

Neunhoffer and colleagues,[10] in the March issue of the journal, offer body surface area as an alternative sizing coefficient. Infants (<1 yr of age) were designated as having a correctly placed tracheal tube if the tip was >0.5 cm above the carina (children, >1 yr of age, >1.0 cm) and not <0.5 cm not below the level of the larynx (children not <1.0 cm) on a supine chest X-ray with the jaw in the neutral position. One hundred and thirty-five infants and 102 children were evaluated retrospectively according to two standard formulae.[5] Correction was necessary in 51% of tracheal tubes inserted orotracheally in infants, 44% nasotracheally in infants, 27% orotracheally in children, and 22% nasotracheally in children. These patients were used to create new surface-based formulae and prospectively tested in a small pilot study of 123 patients, 85 infants, and 38 children. The incorrect placement in infants decreased from 46 to 25% in infants and from 26 to 10% in children. This paper confirms what is well known about intubating the small child; that with age and growth, tracheal length increases.[11] The expected depth increases with age, height, and body surface area (which is mathematically coupled to height), and the tracheal tube depth in infants is more difficult to predict than in older children.