Dimensional compatibility and limitations of tracheal intubation through supraglottic airway devices: a mannequin-based in vitro study

Moser, Berthold ; Kemper, Michael ; Kleine-Brueggeney, Maren ; Gasteiger, Lukas ; Weiss, Markus

Abstract: BACKGROUND Flexible bronchoscope-guided tracheal intubation through supraglottic airway devices (SGAs) is a well-established element of difficult intubation algorithms. Success can be limited by dimensional incompatibilities between tracheal tubes (TTs) and SGAs. METHODS In this in vitro study, we tested the feasibility of TT passage through SGAs, removal of SGAs over TTs, and the ability to guide the flexible bronchoscope with 13 TT brands (internal diameter, 6.5-8.0 mm) and ten different SGAs (4 and 5) in an intubation mannequin. RESULTS We tested 1,040 combinations of SGAs and TTs. Tracheal tube passage failed in 155 (30%) combinations of the five tested first-generation SGAs (117 [46%] with SGA 4, 38 [15%] with SGA 5) and in three (0.6%) combinations of the five tested second-generation SGAs (two [0.8%] with SGA 4 and one [0.4%] with SGA 5). The reason for failed passage of a TT through a first-generation SGA consistently was a too-narrow SGA connector. Removal of the SGA over the TT in the 882 remaining combinations was impossible for all sizes of reinforced TTs, except the Parker Reinforced TT, and was possible for all non-reinforced TTs. Only one combination with SGA 4 and 84 combinations with SGA 5 were not ideal to adequately guide the flexible bronchoscope. CONCLUSION Clinically relevant combinations of adult-size TTs and SGAs can be incompatible, rendering flexible bronchoscope-guided tracheal intubation through an SGA impossible. Additional limitations exist regarding removal of the SGA and maneuverability of the flexible bronchoscope.

DOI: https://doi.org/10.1007/s12630-021-01993-5

Posted at the Zurich Open Repository and Archive, University of Zurich
ZORA URL: https://doi.org/10.5167/uzh-206903
Journal Article
Published Version

The following work is licensed under a Creative Commons: Attribution 4.0 International (CC BY 4.0) License.

Originally published at:
Moser, Berthold; Kemper, Michael; Kleine-Brueggeney, Maren; Gasteiger, Lukas; Weiss, Markus (2021). Dimensional compatibility and limitations of tracheal intubation through supraglottic airway devices: a mannequin-based in vitro study. Canadian Journal of Anaesthesia = Journal Canadien d’Anesthésie, 68(9):1337-1348.
DOI: https://doi.org/10.1007/s12630-021-01993-5
Dimensional compatibility and limitations of tracheal intubation through supraglottic airway devices: a mannequin-based in vitro study

Compatibilité dimensionnelle et limitations de l’intubation trachéale avec des dispositifs supraglottiques : une étude in vitro sur mannequin

Berthold Moser, MD · Michael Kemper, MD · Maren Kleine-Brueggeney, MD, PhD · Lukas Gasteiger, MD · Markus Weiss, MD

Received: 2 January 2021 / Revised: 14 March 2021 / Accepted: 16 March 2021 / Published online: 20 May 2021 © The Author(s) 2021

Abstract

**Background** Flexible bronchoscope-guided tracheal intubation through supraglottic airway devices (SGAs) is a well-established element of difficult intubation algorithms. Success can be limited by dimensional incompatibilities between tracheal tubes (TTs) and SGAs.

**Methods** In this in vitro study, we tested the feasibility of TT passage through SGAs, removal of SGAs over TTs, and the ability to guide the flexible bronchoscope with 13 TT brands (internal diameter, 6.5–8.0 mm) and ten different SGAs (#4 and #5) in an intubation mannequin.

**Results** We tested 1,040 combinations of SGAs and TTs. Tracheal tube passage failed in 155 (30%) combinations of the five tested first-generation SGAs (117 [46%] with SGA #4, 38 [15%] with SGA #5) and in three (0.6%) combinations of the five tested second-generation SGAs (two [0.8%] with SGA #4 and one [0.4%] with SGA #5). The reason for failed passage of a TT through a first-generation SGA consistently was a too-narrow SGA connector. Removal of the SGA over the TT in the 882 remaining combinations was impossible for all sizes of reinforced TTs, except the Parker Reinforced TT, and was possible for all non-reinforced TTs. Only one combination with SGA #4 and 84 combinations with SGA #5 were not ideal to adequately guide the flexible bronchoscope.

**Conclusion** Clinically relevant combinations of adult-size TTs and SGAs can be incompatible, rendering flexible bronchoscope-guided tracheal intubation through an SGA impossible. Additional limitations exist regarding removal of the SGA and maneuverability of the flexible bronchoscope.

Electronic supplementary material The online version of this article (https://doi.org/10.1007/s12630-021-01993-5) contains supplementary material, which is available to authorized users.

B. Moser, MD · L. Gasteiger, MD Department of Anaesthesia and Intensive Care, Medical University of Innsbruck, Anichstraße 35, 6020 Innsbruck, Austria e-mail: lukas.gasteiger@tirol-kliniken.at

M. Kemper, MD Department of Anaesthesiology, University Children’s Hospital Zurich, Zürich, Switzerland

M. Kleine-Brueggeney, MD, PhD · M. Weiss, MD Department of Anaesthesiology, University Children’s Hospital Zurich, Zürich, Switzerland

Résumé

**Contexte** L’intubation endotrachéale guidée par bronchoscope flexible via un dispositif supraglottique (DSG) est un élément établi des algorithmes utilisés pour les intubations difficiles. La réussite de l’intubation peut être limitée par des incompatibilités dimensionnelles entre les tubes endotrachéaux (TET) et les DSG.

**Méthode** Dans cette étude in vitro, nous avons testé la faisabilité de faire passer un TET par un DSG, le retrait du DSG par-dessus le TET et la possibilité de guider un bronchoscope flexible avec 13 marques de TET (diamètre interne, 6,5-8,0 mm) et dix DSG différents (#4 et #5) sur un mannequin d’intubation.
Since then, several new disposable supraglottic airway devices (SGAs) have been introduced to the market. Newer comprehensive studies reporting dimensional limitations of SGAs as conduits for tracheal intubation exist only for children, and data for adults are missing.^{8,12}

The aim of this study was to investigate dimensional compatibilities and limitations of different brands and sizes of TTs used in adults for flexible bronchoscope-guided tracheal intubation through different brands and sizes of disposable SGAs.

**Methods**

This was a laboratory-based *in vitro* study dedicated to the testing of various TT-SGA combinations for intubation in a bench-based approach, and the testing of various TT-SGA combinations for intubation in a mannequin, namely the Laerdal Airway Management Trainer (Laerdal Medical, AS, Stavanger, Norway).

Thirteen brands of TTs with IDs of 6.5–8.0 mm (four different sizes) as well as five first-generation and five second-generation disposable SGAs #4 and #5 were ordered in 2019 and used for this study (Table 1). Selection was based on commonly used and locally available types of SGA and TT. The maximal ID of the TTs that fit through a specific SGA, as indicated by the manufacturer (product brochures, internet information), are summarized in Table 2. For the SGA air-Q® Blocker (Cookgas®, Saint Louis, MO, USA), sizes #3.5 and #4.5 were used as they best correspond to sizes #4 and #5 of other SGA models. For the SGA iLTS-D® (VBM Medizintechnik GmbH, Sulz a. N., Germany), size #4.5 was used, corresponding to size #4 and size #5 of other SGA models. Outer diameters of 13 brands and four TT sizes as provided by the manufacturer are summarized in the Appendix. The lengths of all included brands and the sizes of TTs were measured without connector.

For *in vitro* dimensional feasibility testing of tracheal intubation through SGAs, a single-use flexible bronchoscope (aScope® 4 Broncho Regular endoscope; OD, 5.0/5.4 mm; length, 600 mm; working channel width, 2.2 mm; Ambu A/S, Ballerup, Denmark) and an intubation mannequin (Laerdal Airway Management Trainer, Adult; Laerdal Medical, AS, Stavanger, Norway) were used.

Tracheal tubes and SGAs were assessed in the following *in vitro* experimental setups:

---

**Keywords** supraglottic airway device · tracheal tube · flexible bronchoscope · intubation · tracheal

Tracheal intubation through supraglottic airway devices (SGA) is a well-established element of algorithms for the management of the unanticipated difficult airway.¹⁻⁴ Algorithms emphasize the importance of flexible bronchoscope guidance, since blind intubation through SGAs is associated with low success rates.⁵ Flexible bronchoscope-guided intubation through an SGA is a procedure that is easy to learn and perform with high success rates and is therefore the recommended technique.⁵⁻⁷

Tracheal intubation through an SGA may be hampered by dimensional incompatibilities, such as a mismatch of the internal diameter (ID) of the SGA in relation to the outer diameter (OD) of the tracheal tube (TT) or its cuff balloon, or limited freedom to manually maneuver the flexible bronchoscope with the TT mounted above the SGA.⁸⁻¹² A structured overview of dimensional compatibilities is essential for the success and safety of flexible bronchoscope-guided intubation through SGAs and impacts the selection of equipment, which is particularly important in emergency situations. Several studies have investigated the feasibility of the technique and differences between different SGAs as conduits for flexible bronchoscope-guided intubation with regard to success and intubation times.⁷,¹³⁻¹⁶

---

[^1]: Laerdal Medical, AS, Stavanger, Norway
[^2]: Cookgas®, Saint Louis, MO, USA
[^3]: iLTS-D® (VBM Medizintechnik GmbH, Sulz a. N., Germany)
[^4]: VBM Airway Management Trainer (VBM Medical, Sulz a. N., Germany)
[^5]: Laerdal Medical Airway Management Trainer (Laerdal Medical, AS, Stavanger, Norway)
[^6]: Laerdal Medical Airway Management Trainer (Laerdal Medical, AS, Stavanger, Norway)
[^7]: Laerdal Medical Airway Management Trainer (Laerdal Medical, AS, Stavanger, Norway)
[^8]: Laerdal Medical Airway Management Trainer (Laerdal Medical, AS, Stavanger, Norway)
[^9]: Laerdal Medical Airway Management Trainer (Laerdal Medical, AS, Stavanger, Norway)
[^10]: Laerdal Medical Airway Management Trainer (Laerdal Medical, AS, Stavanger, Norway)
[^11]: Laerdal Medical Airway Management Trainer (Laerdal Medical, AS, Stavanger, Norway)
[^12]: Laerdal Medical Airway Management Trainer (Laerdal Medical, AS, Stavanger, Norway)
[^13]: Laerdal Medical Airway Management Trainer (Laerdal Medical, AS, Stavanger, Norway)
[^14]: Laerdal Medical Airway Management Trainer (Laerdal Medical, AS, Stavanger, Norway)
[^15]: Laerdal Medical Airway Management Trainer (Laerdal Medical, AS, Stavanger, Norway)
[^16]: Laerdal Medical Airway Management Trainer (Laerdal Medical, AS, Stavanger, Norway)
Intubation through supraglottic airway devices

Experimental setup 1: TT passage through the SGA

Feasibility and ease of full insertion of the TT through the SGA with a 15-mm connector were assessed. The only SGA whose connector could easily be removed for flexible bronchoscope-guided intubation, as indicated by the manufacturer, was the air-Q. In the air-Q, the SGA connector is designed to be removed for tracheal intubation through the SGA, while in the other SGAs, the connector is firmly inserted and can only be removed with difficulty, if at all.

Outcome parameters were as follows: easy passage, passage with resistance but possible, or passage not possible. In the case of resistance or failure to advance the TT, the maximal position of the TT tip in the lumen of the SGA was noted as follows: proximal SGA inlet, in the SGA lumen, or distal SGA outlet.

Experimental setup 2: SGA removal over the TT

We evaluated the feasibility of SGA removal over the TT by pushing the TT through the SGA with a stabilizing rod (air-Q® “removal stylet” size 1 for adults; Cookgas®, Saint Louis, MO, USA). Outcome parameters were successful or unsuccessful SGA removal over the IT.

Experimental setup 3: free distance to manually operate the flexible bronchoscope between the TT tip mounted on the flexible bronchoscope and the SGA connector

We assessed the free distance for manual operation of the Ambu aScope with the TT mounted on it (Electronic Supplementary Material [ESM], eFig. 1). The flexible bronchoscope loaded with the TT was inserted through the SGA until the tip of the flexible bronchoscope was level with the vocal cords. Thereafter, the distance between the

### TABLE 1 Supraglottic airway devices and tracheal tubes used in this study

| SGA brand name          | Study name | Generation | Reference number | Manufacturer, location, country |
|-------------------------|------------|------------|------------------|---------------------------------|
| air-Q® Blocker          | air-Q      | 1<sup>st</sup> | 3045             | Cookgas®, Saint Louis, MO, USA   |
| Ambu® Aura-i<sup>TM</sup> | Aura-i     | 1<sup>st</sup> | 329500000        | Ambu A/S, Ballerup, Denmark     |
| Ambu® Aura Once<sup>TM</sup> | AuraOnce   | 1<sup>st</sup> | 321500000        | Ambu A/S, Ballerup, Denmark     |
| LMA® Unique<sup>TM</sup> | Unique     | 1<sup>st</sup> | 125050           | Teleflex Medical, Athlone, Ireland |
| Portex® Soft Seal       | Portex     | 1<sup>st</sup> | 100/220/500      | Smith Medical, Kent, United Kingdom |
| Ambu® AuraGain<sup>TM</sup> | AuraGain   | 2<sup>nd</sup> | 408500000        | Ambu A/S, Ballerup, Denmark     |
| i-gel®                  | i-gel      | 2<sup>nd</sup> | 82050000         | Intersurgical GmbH, Sankt Augustin, Germany |
| iLTS-D®                 | iLTS       | 2<sup>nd</sup> | 32-08-045-1      | VBM Medizintechnik GmbH, Sulz a. N., Germany |
| LarySeal™ Pro           | LarySeal   | 2<sup>nd</sup> | 038-94-850       | Flexicare Irvine, CA, USA       |
| LMA® Protector<sup>TM</sup> | Protector  | 2<sup>nd</sup> | 192050           | Teleflex Medical, Athlone, Ireland |

| TT brand name           | Study name | Reference number | Manufacturer, location, country |
|-------------------------|------------|------------------|---------------------------------|
| Covidien Mallinckrodt<sup>TM</sup> Hi-Contour | Mallinckrodt | 107-80           | Covidien, Athlone, Ireland      |
| Covidien Mallinckrodt<sup>TM</sup> Safetyflex<sup>TM</sup> | Mallinckrodt Reinforced | 118-80 M        | Covidien, Athlone, Ireland      |
| Intersurgical InTube™   | Intersurgical | 8040080         | Intersurgical Ltd, Wokingham, Berkshire, UK |
| Intersurgical InTube™ reinforced | Intersurgical reinforced | 8060080       | Intersurgical Ltd, Wokingham, Berkshire, UK |
| Parker Flex-Tip® tracheal tube | Parker         | 1-PFHV-80       | Parker Medical, Highlands Ranch, CO, USA |
| Parker Flex-Tip® Reinforced Tracheal Tube | Parker Reinforced | 1-PFRC-80    | Parker Medical, Highlands Ranch, CO, USA |
| Rueschelit® SuperSafe Clear | Ruesch         | 112482-80       | Teleflex Medical, Athlone, Ireland |
| Rueschflex              | Ruesch replaced | 104202-80      | Teleflex Medical, Athlone, Ireland |
| Portex® tracheal tube   | Portex       | 100/150/080     | Smith Medical, Kent, UK         |
| Portex® tracheal tube reinforced | Portex replaced | 100/110/080   | Smith Medical, Kent, UK         |
| Unomedical HiLo         | Unomedical   | UM61110080     | ConvaTec, Deeside, Flintshire, UK |
| Unomedical UnoFlex™     | Unomedical   | UM61214080     | ConvaTec, Deeside, Flintshire, UK |
| Microcuff®              | Microcuff    | 35216           | Halyard, Zaventem, Belgium      |

Disposable first- and second-generation SGAs size #4 and #5 as well as TTs with a sized internal diameter of 6.5–8.0 mm included in the study. SGA reference number is given for #5 and TT reference number is given for size ID 8.0 mm.

SGA = supraglottic airway device; TT = tracheal tube
TT tip and the upper border of the SGA connector was measured using an electronic sliding caliper (Sliding Calliper, Serie 500 – ABSOLUTE AOS Digimatic; Brütsch/Rüegger Werkzeuge AG, Urdorf, Switzerland). We considered a free distance of at least 20 mm desirable for good clinical performance. Accordingly, TT-SGA combinations being less than 20 mm or those showing negative values were assessed. Negative distances mean that the tip of the TT mounted on the flexible bronchoscope reached the SGA connector before the tip of the flexible bronchoscope entered the vocal cords.

For all experimental setups, the external surface of the TTs, the flexible bronchoscope, as well as the internal surface of the SGAs were lubricated with medical silicone spray prior to testing (Ruesch Silikonspray; Willy Ruesch GmbH, Kernen-Rommelhausen, Germany). This was consistent with daily practice of using extensive lubrication to reduce surface frictions between the different pieces of equipment to a minimum. In our setting, lubrication was essential for differentiation of resistances and obstructions caused by dimensional incompatibility of the airway devices from those resistances caused by surface frictions between different synthetic materials. In experimental setup 1, 13 brands and four different sizes of TT were investigated in SGAs of ten different brands and two sizes (Table 1). Two TTs and SGAs (A/B) were tested for each brand and size (total, 104 TTs and 40 SGAs; 1,040 combinations). A TT with an ID of 8.0 mm was first passed through each SGA #5. The same experiment was repeated while downsizing TTs by half a number until reaching size ID 6.5 mm. Thereafter, the experiments were repeated in SGAs #4 in the same way. Experimental setups 2 and 3 included all combinations of SGAs and TTs with possible passage of the TT through the SGA as tested in Experimental setup 1.

All measurements of SGA and TT lengths and the assessments in experimental setups 1–3 were repeated twice by two different anesthesiologists and in randomized order for TT brands and SGA brands and for each run (**www.random.org**). Data were recorded in Microsoft Excel (Microsoft Office Professional Plus 2013, Redmond, WA, USA). Measured and calculated distances are presented as mean (standard deviation [SD]) for tables and as mean for graphical presentation.

**Results**

Experimental setup 1 (n = 1,040 TT-SGA combinations)

We made a total of 4,160 attempts to advance a specific TT through an SGA (13 TT brands x 4 IDs = 52 tubes x 10 SAD brands x 2 sizes = 20 = 1,040 combinations, two

| SGA brand | SGA #4 (3.5 for air-Q) | SGA #5 (4.5 for air-Q) |
|-----------|------------------------|------------------------|
|           | ID of SGA (mm) | Max. ID of TT | Recommended for BW or BL | Length of SGA (mm) | ID of SGA (mm) | Max. ID of TT | Recommended for BW or BL | Length of SGA (mm) |
| air-Q     | 14         | 7.5       | 50–70 kg | 172.8 (0.6) | 15 | 8.5       | 70–100 kg | 186.8 (1.3) |
| Aura-i    | 12.4      | 7.5       | 50–70 kg | 173.4 (1.1) | 12.7 | 8       | 70–100 kg | 187.4 (2.2) |
| Aura      | 9.6           | n.a.     | 50–70 kg | 182.4 (1.4) | 10.6 | n.a.     | 70–100 kg | 206.5 (1.5) |
| Unique    | n.a.       | n.a.     | 50–70 kg | 201.1 (0.5) | n.a. | n.a.     | 70–100 kg | 221.7 (0.8) |
| Portex    | 11         | 50–70 kg | 214.3 (2.1) | 12 | n.a. | 70–100 kg | 228.9 (1.6) |
| AuraGain  | 12.7      | 7.5       | 50–70 kg | 170.2 (2.9) | 12.9 | 8       | 70–100 kg | 182.7 (1.8) |
| i-gel     | 12.3      | 7         | 50–90 kg | 175.1 (1.3) | 13.2 | 8       | > 90 kg | 184.8 (2.9) |
| iLTS      | n.a.       | 8        | > 155cm | 191.2 (0.9) | n.a. | 8       | > 155 cm | 191.2 (3.2) |
| LarySeal  | n.a.       | 8        | 50–70 kg | 156.8 (1.1) | n.a. | 8       | 70–100 kg | 164.2 (1.4) |
| Protector | 13         | 7.5       | 50–70 kg | 180.0 (3.1) | 13 | 7.5       | 70–100 kg | 194.7 (2.4) |

*air-Q #3.5 corresponds to SGA #4 and air-Q #4.5 corresponds to SGA #5*
### TABLE 3 Possible combinations for intubation of TTs through SGAs

| Size (ID) | Name | AirQ | AirLife | Unique | Portex | Ademanes | Lpl | ILBaud | LapSteel | Proctor |
|-----------|------|------|---------|--------|--------|----------|-----|---------|----------|---------|
| 6.5       | 8.8  | A    | A       | A      | A      | X        | X   | X/B     | X/B      | X/B     |
| 7.0       | 9.6  | A    | A       | A      | A      | A        | X   | X/B     | X/B      | X/B     |
| 7.5       | 10.2 | A    | A       | A      | A      | A        | X   | X/B     | X/B      | X/B     |
| 8.0       | 10.9 | A    | A       | A      | A      | A        | X   | X/B     | X/B      | X/B     |
| 6.5       | 8.8  | A    | A       | A      | A      | A        | X   | X/B     | X/B      | X/B     |
| 7.0       | 9.6  | A    | A       | A      | A      | A        | X   | X/B     | X/B      | X/B     |
| 7.5       | 10.2 | A    | A       | A      | A      | A        | X   | X/B     | X/B      | X/B     |
| 8.0       | 10.9 | A    | A       | A      | A      | A        | X   | X/B     | X/B      | X/B     |
| 6.5       | 8.8  | A    | A       | A      | A      | A        | X   | X/B     | X/B      | X/B     |
| 7.0       | 9.6  | A    | A       | A      | A      | A        | X   | X/B     | X/B      | X/B     |
| 7.5       | 10.0 | A    | A       | A      | A      | A        | X   | X/B     | X/B      | X/B     |
| 8.0       | 10.7 | A    | A       | A      | A      | A        | X   | X/B     | X/B      | X/B     |
| 6.5       | 8.8  | A    | A       | A      | A      | A        | X   | X/B     | X/B      | X/B     |
| 7.0       | 9.6  | A    | A       | A      | A      | A        | X   | X/B     | X/B      | X/B     |
| 7.5       | 10.2 | A    | A       | A      | A      | A        | X   | X/B     | X/B      | X/B     |
| 8.0       | 10.9 | A    | A       | A      | A      | A        | X   | X/B     | X/B      | X/B     |
| 6.5       | 8.8  | A    | A       | A      | A      | A        | X   | X/B     | X/B      | X/B     |
| 7.0       | 9.6  | A    | A       | A      | A      | A        | X   | X/B     | X/B      | X/B     |
| 7.5       | 10.0 | A    | A       | A      | A      | A        | X   | X/B     | X/B      | X/B     |
| 8.0       | 10.7 | A    | A       | A      | A      | A        | X   | X/B     | X/B      | X/B     |
| 6.5       | 8.8  | A    | A       | A      | A      | A        | X   | X/B     | X/B      | X/B     |
| 7.0       | 9.6  | A    | A       | A      | A      | A        | X   | X/B     | X/B      | X/B     |
| 7.5       | 10.2 | A    | A       | A      | A      | A        | X   | X/B     | X/B      | X/B     |
| 8.0       | 10.8 | A    | A       | A      | A      | A        | X   | X/B     | X/B      | X/B     |
| 6.5       | 8.8  | A    | A       | A      | A      | A        | X   | X/B     | X/B      | X/B     |
| 7.0       | 9.6  | A    | A       | A      | A      | A        | X   | X/B     | X/B      | X/B     |
| 7.5       | 10.2 | A    | A       | A      | A      | A        | X   | X/B     | X/B      | X/B     |
| 8.0       | 10.8 | A    | A       | A      | A      | A        | X   | X/B     | X/B      | X/B     |
| 6.5       | 8.8  | A    | A       | A      | A      | A        | X   | X/B     | X/B      | X/B     |
| 7.0       | 9.6  | A    | A       | A      | A      | A        | X   | X/B     | X/B      | X/B     |
| 7.5       | 10.2 | A    | A       | A      | A      | A        | X   | X/B     | X/B      | X/B     |
| 8.0       | 10.8 | A    | A       | A      | A      | A        | X   | X/B     | X/B      | X/B     |

*Intubation through supraglottic airway devices*
attempts per anesthesiologist, two anesthesiologists). Results for the four attempts performed were consistent among the two investigators for all combinations tested. Failure to pass a TT through the five first-generation SGAs tested occurred in 155 (30%) of 520 combinations. These included 117 (46%) combinations with SGA #4 and 38 (15%) combinations with SGA #5. Failure to pass a TT through the five second-generation SGAs occurred in another three (0.6%) of 500 combinations: two (0.8%) combinations with SGA #4 and one (0.4%) combination with SGA #5 (Table 2). The reason for failed TT passage through a first-generation SGA was consistently a too-narrow SGA connector (Table 3). The Portex SGA #4 connector, for example, has a cone-shaped form with a measured minimal ID of 8.20 mm, making passage of all TTs included in this study impossible (ESM, eFig. 2).

Experimental setup 2 (n = 882 TT-SGA combinations [1,040 combinations-158 failed combinations])

Removal of the SGA over the TT was assessed in the remaining 882 combinations. Results for all four attempts performed were consistent among the two assessors for all combinations tested. Because the adapter was fixed to some TTs, its removal was not possible in all sizes of reinforced TTs except in one brand, the Parker Reinforced TT (Parker Medical, Highlands Ranch, CO, USA). For all other TTs, the SGA could be removed over the TT using the stabilizing rod (Table 4).

Experimental setup 3 (n = 882 TT-SGA combinations)

Measured lengths of SGAs and TTs are summarized in Table 2 and Table 5, respectively. The free distance for manual guidance of the flexible bronchoscope between TT tip and SGA connector ranged from 18.5 to 102.0 mm in SGAs #4 (n = 401), with just one TT-SGA combination showing a free distance of less than 20 mm. The free distance in SGAs #5 ranged from – 30.5 to 84.0 mm (n = 481), with 84 (18%) TT-SGA combinations being less than 20 mm and 23 (5%) showing negative values (Fig. 1). The latter were particularly observed in three of five brands of reinforced TTs, namely the Mallinckrodt Reinforced TT (Covidien, Athlone, Ireland), the Parker Reinforced TT (Parker Medical, Highlands Ranch, CO, USA), and the Ruesch Reinforced TT (Teleflex Medical, Athlone, Ireland). These reinforced TTs are about 20 mm longer than other similarly sized TTs tested (Table 5).

Discussion

This in vitro study investigated dimensional compatibilities and limitations of several currently available brands of TT and SGA for tracheal intubation by any technique (blind, flexible bronchoscope-guided, light-guided, use of the airway exchanger catheter) using an intubation mannequin. The main findings were that failure to pass the TT through the SGA occurred mainly with first-generation SGAs, where the TT tip became wedged mainly in the SGA connector (Table 3). The Portex SGA #4 connector, for example, has a cone-shaped form with a measured minimal ID of 8.20 mm, making passage of all TTs included in this study impossible (ESM, eFig. 2).

Tracheal tube passage through the SGA

Our findings concerning TT sizes for possible passage through the SGA were not in full agreement with recommendations given by the manufacturers, as seen in Table 3, shown by the white squares with an X. We found that some combinations were possible with easy passage of a TT with a larger ID (8.0 mm and 7.5 mm) than recommended by the manufacturer, in two first-generation SGAs #4 and another two second-generation SGAs. The first-generation SGAs Portex (Smith Medical, Kent, UK), Aura Once (Ambu A/S, Ballerup, Denmark), and Unique (Teleflex Medical, Athlone, Ireland) are associated with a high rate of failed TT passage through the SGA, except for some in combination with a TT size ID 6.5. This is in accordance with previous clinical reports using these first-generation devices with either TTs size ID 6.0 or an
TABLE 4 Feasibility of removal of different TTs through different SGAs

| Size (ID) | 3.5 | 4.5 | 5.5 | 4 | 5 | 4 | 5 | 4 | 5 | 4 | 5 | 4.5 | 4 | 5 | 4 | 5 |
|-----------|-----|-----|-----|---|---|---|---|---|---|---|---|-----|---|---|---|---|
| Mallinckrodt | 6.5 | 7.0 | 7.5 | 8.0 | 6.5 | 7.0 | 7.5 | 8.0 | 6.5 | 7.0 | 7.5 | 8.0 | 6.5 | 7.0 | 7.5 | 8.0 |
| Mallinckrodt Reinforced | 6.5 | 7.0 | 7.5 | 8.0 | 6.5 | 7.0 | 7.5 | 8.0 | 6.5 | 7.0 | 7.5 | 8.0 | 6.5 | 7.0 | 7.5 | 8.0 |
| In-Tube | 6.5 | 7.0 | 7.5 | 8.0 | 6.5 | 7.0 | 7.5 | 8.0 | 6.5 | 7.0 | 7.5 | 8.0 | 6.5 | 7.0 | 7.5 | 8.0 |
| In-Tube Reinforced | 6.5 | 7.0 | 7.5 | 8.0 | 6.5 | 7.0 | 7.5 | 8.0 | 6.5 | 7.0 | 7.5 | 8.0 | 6.5 | 7.0 | 7.5 | 8.0 |
| Parker Flex | 6.5 | 7.0 | 7.5 | 8.0 | 6.5 | 7.0 | 7.5 | 8.0 | 6.5 | 7.0 | 7.5 | 8.0 | 6.5 | 7.0 | 7.5 | 8.0 |
| Parker Flex Reinforced | 6.5 | 7.0 | 7.5 | 8.0 | 6.5 | 7.0 | 7.5 | 8.0 | 6.5 | 7.0 | 7.5 | 8.0 | 6.5 | 7.0 | 7.5 | 8.0 |
| Ranch | 6.5 | 7.0 | 7.5 | 8.0 | 6.5 | 7.0 | 7.5 | 8.0 | 6.5 | 7.0 | 7.5 | 8.0 | 6.5 | 7.0 | 7.5 | 8.0 |
| Ranch Reinforced | 6.5 | 7.0 | 7.5 | 8.0 | 6.5 | 7.0 | 7.5 | 8.0 | 6.5 | 7.0 | 7.5 | 8.0 | 6.5 | 7.0 | 7.5 | 8.0 |
| Portex | 6.5 | 7.0 | 7.5 | 8.0 | 6.5 | 7.0 | 7.5 | 8.0 | 6.5 | 7.0 | 7.5 | 8.0 | 6.5 | 7.0 | 7.5 | 8.0 |
| Portex Reinforced | 6.5 | 7.0 | 7.5 | 8.0 | 6.5 | 7.0 | 7.5 | 8.0 | 6.5 | 7.0 | 7.5 | 8.0 | 6.5 | 7.0 | 7.5 | 8.0 |
| Unomedical | 6.5 | 7.0 | 7.5 | 8.0 | 6.5 | 7.0 | 7.5 | 8.0 | 6.5 | 7.0 | 7.5 | 8.0 | 6.5 | 7.0 | 7.5 | 8.0 |
| Unomedical Reinforced | 6.5 | 7.0 | 7.5 | 8.0 | 6.5 | 7.0 | 7.5 | 8.0 | 6.5 | 7.0 | 7.5 | 8.0 | 6.5 | 7.0 | 7.5 | 8.0 |
| Masiscoft | 6.5 | 7.0 | 7.5 | 8.0 | 6.5 | 7.0 | 7.5 | 8.0 | 6.5 | 7.0 | 7.5 | 8.0 | 6.5 | 7.0 | 7.5 | 8.0 |
Aintree exchange catheter for intubation (COOK MEDICAL LLC, Bloomington, IN, USA).

Others have also pointed out that limitations exist for these SGAs regarding TT ID and TT length. Apart from the ID and the length of the airway tube of these SGAs, the angulation and the bars at the SGA opening were also reported to hinder intubation. As the design of most of the older first-generation SGAs is similar to the one of the LMA Classic™ Airway (LMA; Teleflex Medical, Athlone, Ireland) that was designed for ventilation and not for intubation, this finding was not surprising. Accordingly, no information is available from the manufacturer with regard to TT size able to fit through the SGA. The higher failure rate for reinforced TTs can likely be explained by their larger OD in some brands and sizes (Appendix). In contrast, the two first-generation SGAs, air-Q and Aura-i (Ambu A/S, Ballerup, Denmark), especially designed for flexible bronchoscope tracheal intubation through the SGA, feature an increased ID of the SGA lumen and shortened length of the SGA tube, resulting in improved compatibilities.

**TABLE 5** Lengths of TTs studied

|                      | Length of TT ID 6.5 mm | Length of TT ID 7.0 mm | Length of TT ID 7.5 mm | Length of TT ID 8.0 mm |
|----------------------|------------------------|------------------------|------------------------|------------------------|
| Mallinekrodt         | 295.5 (0.5)            | 306.8 (0.2)            | 316.5 (0.1)            | 331.4 (0.2)            |
| Mallinekrodt         | 321.3 (0.3)            | 328.1 (0.5)            | 347.7 (0.3)            | 346.2 (0.3)            |
| Intersurgical        | 312.9 (0.3)            | 326.1 (0.2)            | 336.0 (0.3)            | 336.0 (0.2)            |
| Intersurgical        | 330.1 (0.2)            | 331.8 (0.2)            | 332.3 (0.2)            | 338.4 (0.1)            |
| Parker               | 295.3 (0.1)            | 313.4 (0.4)            | 315.3 (0.1)            | 330.5 (0.2)            |
| Parker Reinforced    | 314.7 (0.1)            | 325.0 (0.3)            | 341.8 (0.1)            | 350.0 (0.1)            |
| Ruesch               | 301.7 (0.3)            | 317.9 (0.2)            | 333.2 (0.2)            | 343.3 (0.1)            |
| Ruesch Reinforced    | 335.7 (0.2)            | 347.3 (0.2)            | 353.5 (0.2)            | 357.8 (0.1)            |
| Portex               | 302.7 (0.1)            | 306.4 (0.3)            | 311.9 (0.2)            | 328.2 (0.1)            |
| Portex Reinforced    | 301.8 (0.4)            | 313.4 (0.3)            | 324.2 (0.4)            | 333.5 (0.3)            |
| Unomedical           | 299.3 (0.4)            | 311.7 (0.2)            | 318.0 (0.3)            | 331.1 (0.2)            |
| Unomedical Reinforced| 300.2 (0.2)            | 307.6 (0.3)            | 315.2 (0.2)            | 336.9 (0.1)            |
| MicrOCuff            | 292.4 (0.2)            | 303.9 (0.2)            | 313.9 (0.4)            | 324.3 (0.1)            |

Measured lengths without connector of the 13 brands and four sizes of TT. Lengths are mean (standard deviation) and given in mm. ID = internal diameter; TT = tracheal tube.
Of note, almost all combinations with second-generation devices permitted passage of the TT through the SGA, although they include an additional gastric channel. Our findings show that they have in general an increased ID of the SGA lumen and are generally shorter than first-generation devices (Table 2). Following the recommendations of current difficult airway guidelines that recommend using second-generation instead of first-generation SGAs (DAS, ASA), the risk posed by incompatible combinations of SGA and TT would significantly reduce.\textsuperscript{1,2} Nevertheless, despite the guidelines, first-generation SGAs are still widely used. This stands in contrast to children, where dimensional incompatibilities persist even with second-generation SGAs.\textsuperscript{9} The small IDs of pediatric SGAs mean that many combinations of SGA and TT were incompatible, particularly in the small SGA sizes combined with cuffed TTs.\textsuperscript{8}

Supraglottic airway device removal over the TT

In general, it has been shown that SGAs do not need to be removed for shorter operations when a TT is placed over an SGA, which does not increase throat soreness or hoarseness.\textsuperscript{13–15} In children, there even exists a clear recommendation to leave the SGA in place when challenged with a difficult airway.\textsuperscript{21} Another option is to insert a tube exchanger into the trachea over the SGA and then remove the SGA over the inserted tube exchanger and subsequently advance the TT over the airway exchanger.\textsuperscript{22,23}

Removal of the SGA may, however, become necessary in the case of oro-maxillary interventions as well as when transferring the patient to the intensive care unit for postoperative ventilation. To remove the SGA over the TT, the TT connector needs to be removed, which is not always possible with reinforced TTs often used for flexible bronchoscope-guided intubation because of their easy passage and the possibility to follow the curves of the bronchoscope. In contrast to cuffed pediatric TTs, in which the cuff pilot balloon was shown to be bigger than the ID of pediatric SGAs (particularly sizes 1 and 1.5), thus making it impossible to remove the SGA over the TT,\textsuperscript{7} the pilot balloon was not a reason for failed passage in the tested adult sizes. The major factor inhibiting removal of the TTs in the present study was the TT connector that is firmly attached to most reinforced TTs.

Free distance for manual guidance of the flexible bronchoscope between TT tip and SGA connector

In our clinical judgement, a minimal distance of 20 mm between the TT tip and the connector of the SGA seems to be required for manual handling/guidance of the flexible bronchoscope, at least to or through the level of the vocal cords (ESM, eFig. 1). In 85 combinations of TT and SGA, there was no free space, and in many more combinations less than 20 mm were available. This was mainly related to longer tubes (in particular reinforced TTs) and to SGAs #5. Reduced free space for manipulation of the flexible bronchoscope above the SGA connector hampers rotation and forward-backward guidance of the flexible bronchoscope. Since flexible bronchoscopes are rarely longer than 600 mm, the TT may be inserted into the SGA without protruding from the distal SGA lumen tube and the flexible bronchoscope can then be manipulated from above the TT connector.\textsuperscript{24} The difficulty caused by not having enough space in which to guide the flexible bronchoscope will be increased with greater SGA length, mostly from first-generation SGAs, as seen in Table 2. Finally, a “perfect” SGA-TT combination for flexible bronchoscope intubation is a balance of optimal TT length and SGA length, since, on the one hand, longer TTs include the risk of reduced maneuverability of the flexible bronchoscope above the SGA connector, and, on the other hand, shorter TTs entail the risk of the cuff being placed in the subglottic region or even between the vocal cords.\textsuperscript{24} It is important to remember that the original technique described by the manufacturer for flexible bronchoscope-guided intubation through the LMA\textsuperscript{®} Fastrach\textsuperscript{TM} (Teleflex Medical, Athlone, Ireland) was by placing the TT through the tube of the SGA until the tip of the TT was near the exiting aperture of the SGD.\textsuperscript{25} The TT subsequently was inserted into the trachea under flexible bronchoscopic control. If the minimal distance between the TT tip and the connector of the SGA is less than 20 mm, this could be a possible solution.

The implications of our findings are that specific lists or tables for the selection of dimensionally compatible equipment for possible flexible bronchoscope-guided or “blind” intubation through SGAs or even sets with compatible equipment should be available wherever patients are anesthetized. This is of particular importance in emergency situations, where time for adequate planning and for choosing compatible equipment is limited. Special caution must be given to wire-enforced TTs, which may fail to pass through the SGA, may fail SGA removal and may fail to allow a free distance for manipulation of the flexible bronchoscope above the SGA connector, particularly in SGA #5. Wire-enforced tubes are therefore not the first choice of TT for intubation through SGAs. Alternatively, a special set could be prepared institutionally or developed in collaboration with the manufacturer, as was previously the case with the intubating laryngeal mask airway including a special TT with long cuff inflation line, stabilizing rod, and an SGA with sufficient ID.\textsuperscript{26,27} Currently, this is only
provided in the newly marketed air-Q SGA with a considerably shortened SGA tube, removable SGA adapter, and different sizes of pushing rods.

For the current study, the following limitations are to be considered. The data are from an in vitro assessment. This might not fully reflect the situation in human patients in vivo. It does, however, provide similar and therefore comparable conditions for all TT and SGA combinations tested. While assessment of passage and removal is not affected by the in vitro design of this study, the position of the SGA within the mannequin may differ from that in individual patients. Nevertheless, in contrast to human studies with anatomical differences between patients, it can be assumed that the position of the SGA in a mannequin is largely the same. Therefore, assessment of the free distance for manipulating the flexible bronchoscope allows combinations to be identified that are critical to the free distance available for manipulating the flexible bronchoscope. Finally, while this study included a comprehensive selection of commonly used SGAs and TTs, we acknowledge there might be other combinations with good compatibility or dimensional limitations that we have not investigated.

In conclusion, the current comprehensive update on in vitro dimensional compatibilities between a selection of SGAs and TTs shows that for adult sizes too, there exist many incompatible combinations, rendering tracheal intubation through these SGAs impossible. This was particularly the case with several first-generation SGAs and with wire-reinforced TTs.

Fig. 1 Free distances above the SGA connector for manual guidance of the Ambu aScope flexible bronchoscope (length, 600 mm) with the TT mounted and the tip of the flexible bronchoscope placed level with the vocal cords using 13 TT brands, ID sizes 6.5 (●), 7.0 (■), 7.5 (▲) and 8.0 mm (▲) through SGAs of ten different brands, size #4 and #5. Negative values indicate a TT tip placed within the SGA connector or even deeper in the SGA lumen. Missing values indicate combinations with no possible TT passage through a specific SGA. Values are means. ID = internal diameter; SGA = supraglottic airway device; TT = tracheal tube
Author contributions Berthold Moser contributed to the conception and design of study, development of methodology, data measurement and collection, analysis and interpretation of data, drafting of article, and final approval of manuscript. Michael Kemper contributed to the design of the study, development of methodology, collection of data, analysis and interpretation of data, and final approval. Maren Kleine-Brueggeney contributed to the development of methodology, drafting and critical revision, and final approval. Lukas Gasteiger contributed to the design of the study, statistics, analysis, critical revision, and final approval. Markus Weiss contributed to the design of the study, development of methodology, analysis and interpretation of data, revision of article, and final approval.

Funding Open access funding provided by University of Innsbruck and Medical University of Innsbruck.

Disclosures None.

Funding statement This project was supported only by departmental resources.

Editorial responsibility This submission was handled by Dr. Stephan K.W. Schwarz, Editor-in-Chief, Canadian Journal of Anesthesia/ Journal canadien d’anesthésie.

Open Access This article is licensed under a Creative Commons Attribution-NonCommercial 4.0 International License, which permits any non-commercial use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if changes were made. The images or other third party material in this article are included in the article’s Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article’s Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit http://creativecommons.org/licenses/by-nc/4.0/.

Appendix: Outer diameter of TT as indicated by the manufacturer (mm) for TT ID

| Manufacturer          | OD of TT ID 6.5 mm | OD of TT ID 7.0 mm | OD of TT ID 7.5 mm | OD of TT ID 8.0 mm |
|-----------------------|--------------------|--------------------|--------------------|--------------------|
| Mallinckrodt          | 8.8                | 9.6                | 10.2               | 10.9               |
| Mallinckrodt Reinforced| 8.8                | 9.6                | 10.2               | 11.0               |
| Intersurgical         | 8.7                | 9.3                | 10.0               | 10.7               |
| Intersurgical reinforced | 8.8               | 9.5                | 10.0               | 10.7               |
| Parker                | 8.8                | 9.6                | 10.2               | 10.9               |
| Parker Reinforced     | 9.0                | 9.6                | 10.2               | 10.8               |
| Ruesch                | 8.7                | 9.3                | 10.0               | 10.7               |
| Ruesch reinforced     | 9.0                | 9.6                | 10.2               | 10.8               |
| Portex                | 8.5                | 9.2                | 10.2               | 10.7               |
| Portex reinforced     | 9.8                | 10.4               | 11.1               | 11.9               |
| Unomedical            | 8.7                | 9.3                | 10.0               | 10.7               |
| Unomedical reinforced | 8.9                | 9.7                | 10.3               | 10.8               |
| Microcuff             | 8.7                | 9.3                | 10.2               | 10.8               |

ID = internal diameter; OD = outer diameter; TT = tracheal tubes
References

1. Apfelbaum JL, Hagberg CA, Caplan RA, et al. Practice guidelines for management of the difficult airway: an updated report by the American Society of Anesthesiologists Task Force on Management of the Difficult Airway. Anesthesiology 2013; 118: 251-70.

2. Frerk C, Mitchell VS, McNarry AF, et al. Difficult Airway Society 2015 guidelines for management of unanticipated difficult intubation in adults. Br J Anaesth 2015; 115: 827-48.

3. Pennant JH, White PF. The laryngeal mask airway. Its uses in anaesthesiology. Anaesthesiology 1993; 79: 144-63.

4. Duckett J, Fell P, Han K, Kimber C, Taylor C. Introduction of the I-gel supraglottic airway device for prehospital airway management in a UK ambulance service. Emerg Med J 2014; 31: 505-7.

5. Theiler L, Kleine-Brueggeney M, Urwyler N, Vogt A, Greif R. Randomized clinical trial of the i-gel® and Magill tracheal tube or single-use ILMA® and ILMA™ tracheal tube for blind intubation in anaesthetized patients with a predicted difficult airway. Br J Anaesth 2011; 107: 243-50.

6. Timmermann A. Supraglottic airways in difficult airway management: successes, failures, use and misuse. Anaesthesia 2011; 66(Suppl 2): 45-56.

7. Kleine-Brueggeney M, Theiler L, Urwyler N, Vogt A, Greif R. Randomized trial comparing the i-gel® and Magill tracheal tube with the single-use ILMA® and ILMA® tracheal tube for fibreoptic-guided intubation in anaesthetized patients with a predicted difficult airway. Br J Anaesth 2011; 107: 257-1.

8. Kleine-Brueggeney M, Kotarlic M, Theiler L, Greif R. Limitations of pediatric supraglottic airway devices as conduits for intubation - an in vitro study. Can J Anaesth 2018; 65: 14-22.

9. Mauch J, Haas T, Weiss M. Distance from the laryngeal mask grip to endotracheal tube tip. A crucial point during fiberoptic intubation in children (German). Anaesthesist 2012; 61: 123-8.

10. Weiss M, Gerber AC, Schmitz A. Continuous ventilation technique for laryngeal mask airway (LMA) removal after fiberoptic intubation in children. Paediatr Anaesth 2004; 14: 936-40.

11. Weiss M, Goldmann K. Caution when using cuffed tracheal tubes for fibreoptic intubation through paediatric-sized laryngeal mask airways. Acta Anaesthesiol Scand 2004. DOI: https://doi.org/10.1111/j.1399-6576.2004.0038d.x.

12. Weiss M, Mauch J, Becke K, Schmidt J, John M. Fibre optic-assisted endotracheal intubation through the laryngeal mask in children (German). Anaesth Intensivmed Notfallmed Schmerzther 2009; 58: 716-21.

13. Moser B, Audige L, Keller C, Bramacome J, Gasteiger L, Bruppacher HR. A prospective, randomized trial of the Ambu AuraGain™ laryngeal mask versus the LMA protector airway in paralysed, anaesthetized adult men. Minerva Anestesiol 2018; 84: 684-92.

14. Moser B, Audige L, Keller C, Bramacome J, Gasteiger L, Bruppacher HR. Flexible bronchoscopic intubation through the AuraGain™ laryngeal mask versus a slit Guedel tube: a non-inferiority randomized-controlled trial. Can J Anaesth 2017; 64: 1119-28.

15. Moser B, Keller C, Audige L, Dave MH, Bruppacher HR. Fiberoptic intubation of severely obese patients through supraglottic airway: a prospective, randomized trial of the Ambu® AuraGain™ laryngeal mask vs the i-gel®® airway. Acta Anaesthesiol Scand 2019; 63: 187-94.

16. Gasteiger L, Oswald E, Keplinger M, et al. Randomised trial comparing the Ambu® Aura-i™ and the Ambu® Aura Gain™ laryngeal mask as conduit for tracheal intubation in children. Minerva Anestesiol 2020; 86: 1143-50.

17. Takenaka I, Aoyama K. Optimizing endotracheal tube size and length for tracheal intubation through single-use supraglottic airway devices. Can J Anaesth 2010; 57: 389-90.

18. Atherton DP, O’Sullivan E, Lowe D, Charters P. A ventilation-exchange bougie for fibreoptic intubations with the laryngeal mask airway. Anaesthesia 1996; 51: 1123-6.

19. Danha RF, Thompson JI, Popat MT, Pandit JJ. Comparison of fibreoptic-guided orotracheal intubation through classic and single-use laryngeal mask airways. Anaesthesia 2005; 60: 184-8.

20. Wong DT, McGuire GP. Endotracheal intubation through a laryngeal mask/supraglottic airway. Can J Anaesth 2007; 54: 489-91.

21. Black AE, Flynn PE, Smith HL, et al. Development of a guideline for the management of the unanticipated difficult airway in pediatric practice. Paediatr Anaesth 2015; 25: 346-62.

22. Kemper M, Haas T, Imach S, Weiss M. Intubation with a tube exchanger on an intubation trainer. Influence of tube tip position on successful intubation (German). Anaesthesist 2014; 63: 563-7.

23. Higgs A, McGrath BA, Goddard C, et al. Guidelines for the management of tracheal intubation in critically ill adults. Br J Anaesth 2018; 120: 323-52.

24. Lee JH, Park S, Jang YE, Kim EH, Kim HS, Kim JT. The distance between the glottis and the cuff of a tracheal tube placed through three supraglottic airway devices in children: a randomised controlled trial. Eur J Anaesthesiol 2019; 36: 721-7.

25. Teleflex®. INSTRUCTIONS FOR USE – LMA Fastrach™. In: Teleflex Medical IDA Business and Technology Park Dublin Road ACW, Ireland. Teleflex Medical; 2015.

26. Brain AI, Verghese C, Addy EV, Kapila A. The intubating laryngeal mask: 1. development of a new device for intubation of the trachea. Br J Anaesth 1997; 79: 699-703.

27. Sudheesh K, Chethana GM, Chaitali H, Nethra SS, Devikaran D, Shwetha G. A new second-generation supraglottic airway device (Ambu® AuraGain) versus intubating laryngeal mask airway as conduits for blind intubation - a prospective, randomised trial. Indian J Anaesth 2019; 63: 558-64.

Publisher’s Note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.