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CORRESPONDENCE

Changes in laryngeal airway patency in response to complete reversal of rocuronium-induced paralysis with sugammadex in small children with a supraglottic airway: protective effect of fentanyl?

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Editor—Insertion of supraglottic airway device as a conduit during general anaesthesia has become a standard for airway maintenance even in small children. Since supraglottic airways do not bypass the vocal cords, complications such as transient laryngospasm and mild stridor without desaturation are often encountered during emergence from general anaesthesia. Although rare, prolonged laryngospasm is a major respiratory cause of cardiac arrest in paediatric anaesthesia.[1]

Difficult Airway Society extubation guidelines recommend complete reversal of neuromuscular blocking agent to minimise postoperative respiratory complications caused by residual muscle paralysis.[2] Administration of an appropriate dose of sugammadex rapidly and completely antagonises rocuronium-induced muscle paralysis in anaesthetised children.[3] Despite the advantages of sugammadex, there remain extensive but unsolved arguments among anaesthesiologists regarding the possibility of sugammadex-induced laryngospasm, particularly in anaesthetised adult patients with a supraglottic airway device, mainly based on case report series and anecdotal evidences.[4] No doubt, laryngospasm occurred within a few minutes after sugammadex administration in these cases, but the Bailey manoeuvre for placement of a supraglottic airway was also performed immediately before administration of sugammadex. To date, it is unclear whether the laryngeal closure is caused by sugammadex *per se* or other mechanisms influencing the laryngeal reflex arc, such as mechanical airway receptor stimulation, level of anaesthesia and consciousness, chemical stimuli, or involvement of opioid-induced laryngeal rigidity.[5] Accordingly, we tested the hypothesis that injection of sugammadex for complete reversal of rocuronium-induced muscle paralysis decreases the vocal cord angle (primary variable) during emergence from general anaesthesia without stimulation of the airway receptors responsible for the laryngeal reflex arc in paediatric patients in which laryngospasm is of great clinical significance.

This prospective study was performed at Chiba University Hospital, Chiba, Japan and approved by our institutional review board (IRB #2471), and written informed consent was obtained from each of the parent(s) of all children participating in the trial (UMIN clinical trial registry: UMIN000025058). Based on a prior sample size calculation, 20 children undergoing sevoflurane anaesthesia with a supraglottic airway for inguinal hernia surgery and cryptorchidism surgery participated in the study. Inhalation induction with sevoflurane was performed, and an i.v. line was secured for injection of atropine 0.01 mg kg^{-1} (0.1 mg minimum and 0.5 mg maximum), propofol 1–2 mg kg^{-1}, and fentanyl 1–3 μg kg^{-1}. In accordance with the anaesthesia plan, rocuronium was either not used (non-paralysed group: 10 non-obese children, 58 [10] months old) or injected i.v. (0.89 [0.19] mg kg^{-1} in total) (sugammadex group: 10 non-obese children, 39 [15] months old). A disposable supraglottic airway (AuraGain™, Ambu®, Ballerup, Denmark) was inserted and anaesthesia was maintained by sevoflurane 1–2 vol% and remifentanil 0.2–0.5 μg kg^{-1} min^{-1}, which were discontinued at the end of surgery in both groups. In the sugammadex group, sugammadex (3.2 [1.2] mg kg^{-1}) was administered and complete neuromuscular recovery was confirmed by neuromuscular

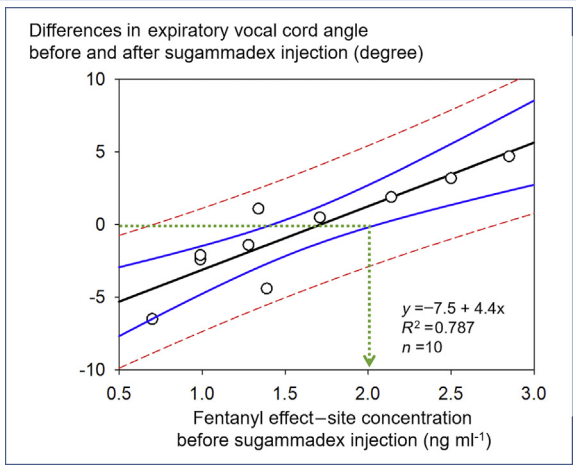

Fig 1. eRlationship of fentanyl effect-site concentration before sugammadex injection with the difference in vocal cord angle at the expiratory phase before and after injection of sugammadex. A linear regression model with 95% confidential intervals (blue lines) and 95% prediction intervals (dotted red lines) was obtained by multivariate analysis. As indicated by the green line, fentanyl effect-site concentration > 2 ng ml^{-1} is unnecessary to prevent vocal cord narrowing.

monitoring. Vocal cords were seen by a thin endoscope inserted through the supraglottic airway and respiratory variables were continuously recorded throughout anaesthesia management. The vocal cord angle, defined as the angle produced by lines connecting anterior and posterior commissures, was measured during inspiration and expiration.[6] Changes of vocal cord angle before and after sugammadex injection were assessed by the paired two-sided Student's *t*-test, and $P<0.05$ was considered statistically significant. Independent explanatory variables for differences of the expiratory vocal cord angle after sugammadex were determined using a multiple linear regression analysis in the sugammadex group. Statistical analyses were performed using SAS software version 9.4 (SAS Institute, Cary, NC, USA).

Vocal cord angle both during expiration and inspiration did not significantly differ before and after injection of sugammadex for rocuronium-induced muscle paralysis (expiration: 36.4 [6.9] to 35.9 [5.4] degrees, 95% confidence interval [CI] of difference of means −1.9 to 3.0 degrees, $P=0.634$; inspiration: 36.2 [7.1] to 35.8 [5.6] degrees, 95% CI of difference of means −1.6 to 2.5 degrees, $P=0.638$). However, differences in expiratory vocal cord angle before and after sugammadex injection varied between −6.5 and 4.7 degrees (Fig. 1). Multiple linear regression analysis identified lower fentanyl effect-site concentration before sugammadex injection as a single independent risk factor for decreasing the expiratory vocal cord angle after injection of sugammadex. No vocal cord angle changes were observed in non-paralysed children during emergence from anaesthesia.

Laryngeal patency is determined by a balance of forces between the abductor and adductor muscles. Either laryngeal reflex or abrupt recovery of laryngeal muscles have been considered possible mechanisms for laryngeal closure after sugammadex injection.[4] Induction of the laryngeal reflex requires afferent stimuli such as extrinsic mechanical or chemical stimulation of airway mucosal receptors.[5] In this study, an endoscope was kept within the supraglottic airway device without any airway interventions, in order to avoid afferent mechanical airway receptor stimulation, indicating that sugammadex-induced laryngeal reflex was unlikely. We speculate that abrupt restoration of muscle tonus with sugammadex occurs earlier in the adductor muscles, the major tonic laryngeal muscles, than the abductor muscle, resulting in laryngeal narrowing particularly under light anaesthesia, while spontaneous slow recovery from muscle paralysis occurs first in the abductor muscle, followed by the laryngeal adductors.[7] In either mechanism, our results suggest that higher fentanyl effect-site concentration prevents laryngeal narrowing in agreement with previous work showing dose-dependent depression of laryngeal reflexes[8] and upper airway muscle activity[9] by fentanyl. However, intraoperative fentanyl dosage needs to be optimised because of its U-shaped dose-response relationship for postoperative respiratory complications.[10] As shown by the green line in Figure 1, fentanyl effect-site concentration >2 ng ml^{-1} may not be necessary to prevent laryngeal narrowing after sugammadex. Our results suggest that sugammadex should be administered under deep anaesthesia for complete reversal of muscle paralysis in small children with a supraglottic airway device until future randomised controlled studies to avoid potential confounders such as opioid dose, anaesthesia depth, strength of muscle paralysis and recovery speed from muscle paralysis provide conclusive evidence on this clinically important issue.

Authors' contributions

Study design: KI, YK, SI
Data collection: KI, YK, SK, MS, YSakaguchi
Data analysis: KI, SK
Statistical analysis and advice: YSato, SI
Writing of the draft manuscript: KI, YK, SI, YSato
Approval of the final version: KI, YJ, MS, YS, YS, SI

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Declaration of interest

The authors declare that they have no conflicts of interest.

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Training anaesthetists in cricothyrotomy techniques using video demonstrations and a hands-on practice session: a shift towards preferred surgical approaches

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Editor—The cannot intubate, cannot oxygenate (CICO) situation should lead to a lifesaving cricothyrotomy. Cricothyrotomy techniques are broadly categorised as closed 'percutaneous' or open 'surgical', the latter including both the 'classic surgical' technique and the 'scalpel–bougie–tube' technique popularised by the Difficult Airway Society (DAS).[1] Many studies suggest that surgical approaches yield better results.[2–6] However, the fourth National Audit Project (NAP4) and a Canadian survey, before publication of the DAS guidelines, both highlighted that the first-choice technique in a CICO situation is the percutaneous option for a large proportion of anaesthetists.[6,7] We hypothesised that this paradoxical choice might result from a lack of confidence in performing surgical techniques and that a formal cricothyrotomy training program could reverse this trend. We designed a training program and evaluated its effect on the level of confidence in being able to perform a cricothyrotomy and whether this training would modify the anaesthetist's first-choice technique in a CICO situation. This study does not fulfil the definition of Clinical Research according to the International Committee of Medical Journal Editors, and hence has not been registered in a public trial registry. However, it was approved by our institution's Ethics Committee (Comité d'éthique de la recherche du CIUSSS de l'Estrie – CHUS, FWA #00005894 and IRB00003849) under reference number 2017-1517.

Subjects were recruited among participants in a workshop at both the October 2016 and March 2017 Quebec Association of Anaesthetists' Meetings. Participants provided written consent and data collection was anonymous. Initially, an online survey was completed by the participants, composed of questions assessing confidence and preference for each cricothyrotomy technique (baseline survey, n=44). Then, participants visualised unbiased educational videos produced by the authors demonstrating three cricothyrotomy techniques ('scalpel–bougie–tube', 'classic surgical', and 'percutaneous') on cadavers (available at http://cricotraining.com). Participants then repeated the same survey (post-video survey, n=38). The last step of the program involved live demonstration and practice of the three cricothyrotomy techniques during a 50 min workshop, with a learner to skilled instructor ratio of 3:1. We used manikins and a porcine model based on previous publications.[8,9] Porcine larynxes were purchased from a local abattoir (£2.40 each), stabilised with foam, and