We present a case of polyvinyl chloride (PVC) endotracheal (ET) tube kinking and discuss the airway pressure changes, implications, and ventilation-based methods to functionally remedy the situation. The kink developed in the intraoral portion of an 8.5-cm PVC ET tube in a patient undergoing T3-T5 laminectomy in the prone position, heralded by a sudden increase in peak airway pressure. The kink was confirmed by attempted intratubal suction. Adequate ventilation was achieved with conversion to pressure control (PC) mode with an inspiratory-expiratory time (I:E) ratio of 1:1.

An experiment was conducted using 8.5-cm PVC ET tube, ventilating a 2-L reservoir bag. A kink was artificially created on the ET tube and ventilated with volume control (VC) and then PC mode. Both modes delivered equal tidal volumes at equal plateau pressures, with higher peak pressures in VC mode. The PC mode with I:E 1:1 delivered higher tidal volume than I:E 1:2 and 2:1 at equal plateau pressures. Whereas previous reports of intraoperative ET tube kinking discussed the detection, diagnosis, cause, and management in scenarios where the tube is readily accessible, we highlight airway pressure characteristics and ventilator management of such a situation when an ET tube was not amenable to remedial solutions.

Keywords: Anesthesia, endotracheal tube, kinking, ventilation, ventilatory management.

Polyvinyl chloride (PVC) endotracheal (ET) tube kinking is a relatively uncommon but important and easily remediable complication. The kinking is common in 2 areas: the joining point of the connector to the main body of the tube (usually due to weight of the circuit) and the intraoral/intranasal portion proximal to the glottis (primarily due to excessive flexion/rotation and thermal tube softening).1,2 With this report we present a representative case and focus on airway pressure characteristics in such cases.

Written consent of the patient was obtained before this report was written.

Case Summary

A 28-year-old man (weight of 50 kg, height of 155 cm) with no medical comorbidities had a diagnosis of thoracic (T) levels 3 through 5 intradural extramedullary spinal tumor. He was scheduled to undergo T2-T6 laminectomy and decompression of the lesion in the prone position. Airway examination revealed an adequate mouth opening (> 3 cm) and cervical range of motion with a thyromental distance of 6 cm and Mallampati grade 1 airway.

For induction of anesthesia, the patient was intubated with an 8.5-cm cuffed PVC ET tube, fixed at 21 cm after auscultation for bilateral equal air entry. He was ventilated using a Draeger Fabius (Draeger) ventilator in volume control (VC) mode with a target tidal volume (VT) of 400 mL and rate of 12/min targeted to maintain end-tidal carbon dioxide (ETCO₂) of 32 to 35 cm H₂O. One hour after positioning, peak airway pressures rose suddenly from 14 cm H₂O to 46 cm H₂O, triggering the high-pressure alarm and decreasing the delivered VT from 400 to 160 mL. Auscultation of the lung base revealed no additional sounds (wheeze or crepitations). A check of the ventilation circuit revealed no causative factors. Suctioning was attempted, but the catheter could not be navigated beyond the intraoral portion of the ET tube, suggesting ET tube kinking. A C-arm roentgenogram confirmed a kinked ET tube in the oropharynx (Figure 1A).

Because of prone positioning of the patient using Mayfield skull pins (Integra LifeSciences Corp), a change of the ET tube could not be attempted. For maximal ventilation with minimal pressure, the ventilation mode was changed to pressure control, with the inspiratory pressure set at 17 cm H₂O above a positive end-expiratory pressure (PEEP) of 5 cm H₂O and the delivered VT increased to 210 mL. We then found that if we kept the same parameters and switched to pressure support mode, we had a further increase in VT to above 350 mL. The patient maintained ETCO₂ within normal range, and arterial blood gas analysis revealed PaCO₂ to be 33 mm Hg. The operation was successfully completed.
Discussion

To account for the large discrepancy between the 2 ventilatory modes of pressure and volume control, we scrutinized their pressure-time waveforms postoperatively. We believe the difference lies in how each mode cycles between inspiration and expiration. Although the pressure support mode supports flow-triggered cycling as default, under apneic conditions such as in this case, it reverts to time-cycling with an inspiratory-expiratory time (I:E) ratio of 1:1, as opposed to a 1:2 ratio setting in pressure control mode. This increase in inspiratory time of the pressure support mode relative to the pressure control mode coupled with a decelerating flow pattern led to a higher VT delivery by the end of inspiration. Our impression was that the decelerating flow pattern of pressure support mode probably reduced the resistance offered by the tube kink at lower flows because of more laminar flow. A nonclinical experiment was conducted to validate this hypothesis.

- **Experiment.** A 2-L reservoir bag was used as the test lung and was ventilated via an 8.5-cm ET tube using the Draeger Fabius ventilator (Figure 1B). The ventilation was conducted in VC mode with a target VT of 400 mL and a rate of 15/min, and pressures were noted (Figure 2A). Then the ET tube was kinked manually at the site of the pilot balloon inflation line exit, and the kink angle was adjusted to achieve a peak pressure of 40 cm H₂O. The delivered VT was reduced to 310 mL with plateau pressure of 32 cm H₂O (Figure 2B). Changing the mode to pressure control with inspiratory pressure of 32 cm H₂O led to the same VT being delivered, with peak and plateau pressures being 32 cm H₂O (Figure 2C). An increase in the inspiratory time by making the I:E ratio 1:1 increased the delivered VT to 370 mL (Figure 2D). However, changing the I:E ratio to 1.5:1 and 2:1 (Figure 2E) decreased the VT to 350 mL and 310 mL, respectively. The cause for this decreased VT with changed I:E ratio was probably inadequate expiratory time, leading to intrinsic PEEP.

- **Postinspiratory Pause.** An interesting finding was the application of postinspiratory pause in the VC mode.
to assist in the diagnosis of airway obstruction signaled by increased airway pressures. Based on our previous unpublished findings, a 40% postinspiratory pause applied to anesthetized patients with no airway abnormality led to a peak-plateau pressure difference (Ppeak-plateau) of 4 to 5 cm H2O. In the current case and in our experiment (Figure 2F), the Ppeak-plateau increased to greater than 16 cm H2O after ET tube kinking.

We believe this finding reflects the dynamic airflow resistance due to the kink as follows: turbulent flow caused by the kink creates more resistance than does smooth laminar flow. It also demonstrates, via the low plateau pressure, that the airways and alveoli are spared exposure to the high peak pressures shown on the ventilator side of the kink.

Thus, application of a 40% postinspiratory pause may help differentiate the cause of increased airway pressure between increased airway resistance vs increases in lung and chest compliance.

Conclusion

Previous reports of intraoperative ET tube kinking discuss the detection, diagnosis, cause and management in scenarios where the ET tube was readily accessible.1-3 With this report we highlight the airway pressure characteristics and ventilator management of such a situation when ET tube was not amenable to remedial solutions. It might be worthwhile to explore ventilatory options, especially pressure control mode with an I:E ratio of 1:1 and optimum pressure to achieve adequate VT. Coupled with ETCO2 monitoring to rule out inadequate ventilation, the outlined method could help ease the management of a potentially life-threatening solution without resorting to extraordinary measures.

REFERENCES


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DISCLOSURES

The authors declare they have no financial relationships with any commercial entity related to the content of this article. The authors did not discuss off-label use within the article.