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An uncommon cause of endotracheal tube obstruction

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Keypoints

Although a rare occurrence, there are case reports describing endotracheal tubes kinking and failing inside patients during general anesthesia. Patients with severe scoliosis (a Cobb Angle > 120 degrees) are at an increased risk for this. We recommend the use of coiled-wire reinforced endotracheal tubes in this patient population, especially if they will be in the prone position for surgery.

Abstract

Scoliosis is defined as a three dimensional lateral and rotational deformity of the thoracolumbar spine. Traditionally, its severity has been determined by measuring the Cobb angle. A small amount of spinal curvature (<10 degrees) is considered a normal variation and isn't uncommon in the general population. Curvature greater than 120 degrees is classified as severe and may include such complications as failure to thrive, symptomatic lung disease, alveolar hypoventilation, right ventricular failure, cor pulmonale and in rare cases premature death. Despite the suspected causes of scoliosis, these patients often require anesthetic care for various surgical or procedural interventions. We report a 13-year-old with severe scoliosis (a Cobb angle of 180 degrees) whose endotracheal tube became obstructed during major orthopedic surgery, leading to complete failure to ventilate. Details of the case are discussed as well as a review of similar case reports.

Keywords: severe scoliosis, endotracheal tube obstruction, ventilatory failure

Introduction

Scoliosis, from the Greek words for "crooked" and "bending," is defined as a three dimensional lateral and rotational deformity of the thoracolumbar spine. It is a fairly common medical condition with an estimated prevalence of approximately 1 to 2% of the U.S. population being affected. Similar rates are seen throughout the world.[1] Scoliosis is classified by cause, being either idiopathic (with no known cause) or secondary. Idiopathic scoliosis is further subdivided into infantile (< 3 years old), juvenile (3 to 10 years old) and adolescent (> 10 years old). Causes of secondary scoliosis include congenital disorders, neuromuscular conditions, tumors or trauma.[2,3]

Traditionally, the severity of the curve has been determined by measuring the Cobb angle, with the derived value usually describing the concave side. The angle is

measured between a line drawn along the upper end plate of the superior vertebra and another along the lower end plate of the inferior vertebra.[2]

A small amount of spinal curvature (<10 degrees) is considered normal and isn't uncommon. Curvature greater than 120 degrees is classified as severe and may include such complications as failure to thrive, symptomatic lung disease, alveolar hypoventilation, right ventricular failure, cor pulmonale and in rare cases, early death.[4] Despite the suspected causes of scoliosis, these patients often require anesthetic care for various surgical or procedural interventions.

We report a 13-year-old with severe scoliosis (Cobb angle of 180 degrees) whose endotracheal tube became obstructed during major orthopedic surgery, leading to complete failure to ventilate. Details of the case are discussed as well as a review of similar case reports.

Case report

Institutional Review Board approval is not required by Nationwide Children's Hospital for presentation of single case reports. A 13-year-old, 35 kg male with severe scoliosis, secondary to a non-accidental traumatic brain injury sustained as an infant, presented for major orthopedic surgery. The case was scheduled for 8 hours. Planned surgical interventions included: bilateral proximal femoral resections with muscular interposition arthroplasties, bilateral anterior knee releases with quadriceps V-Y plasties, and a left knee posterior ulceration debridement and wound VAC application. The patient had a complex medical history including cerebral palsy, spastic quadriplegia, profound developmental delay, reactive airway disease and seizure disorder. The overall goal of surgery was to improve the patient's quality of life by enabling him to sit in a wheelchair, instead of being bed-ridden.

On physical examination, the patient was noted to be non-verbal, severely contracted, spastic and much smaller than patients of similar age. Due to his spinal curvature of 180 degrees, he was concave to the left, in a V position. His chin was nearly fused to his left shoulder. The patient was unable to move his head into a midline position, because of severe torticollis. He had developed a stage 4 skin ulceration over the left pelvic brim where his rib cage was compressing the area. The patient had dysmorphic facial features that were not syndrome related. Although he had normal mouth opening and a normal thyromental distance, he was treated as an anticipated difficult airway.

His pre-operative vital signs included a resting respiratory rate of 20 breaths/minute, a room-air oxygen saturation of 96% by pulse oximetry, a heart rate of 92 beats/min, and a blood pressure (BP) of 136/87 mmHg. The patient had a pre-existing PICC line in his right upper arm with maintenance IV fluids infusing. The patient was held *nil per os* for 8 hours (including tube feedings) and was transported to the operating room where routine monitors were applied. After pre-oxygenation, general anesthesia was induced by the administration of intravenous midazolam (2 mg), fentanyl (100 mcg) and propofol (100 mg). Sevoflurane was administered simultaneously and incrementally increased to 3%. Once it was determined that the patient could be adequately mask-ventilated, neuromuscular blockade was achieved by the administration of rocuronium (15 mg).

After induction and prior to intubation, an unsuccessful attempt was made to position the patient's head midline. Thought was also given as to the benefit of placing a shoulder-roll beneath the patient's scapula, to facilitate proper alignment of airway structures. But this measure proved unhelpful, due to his anatomy. Light cricoid pressure helped to bring the vocal cords into view (Cormack-Lehane score of I vs. IIa). Endotracheal intubation was easily achieved using a Macintosh 2 blade and a cuffed, styleted 5.5 endotracheal tube (ETT). The tube did have to be rotated towards the right, seeing that the patient's trachea was deviated that direction. Bilateral breath sounds were confirmed as well as a positive end tidal carbon dioxide (ETCO2) tracing. The endotra-

cheal tube was taped and secured at a depth of 16 cm at the teeth. The patient tolerated anesthetic induction and endotracheal intubation without adverse hemodynamic effects. Mechanical ventilation was initiated for the case.

Because the surgical plan involved multiple sites on the patient's bilateral lower extremities, frequent repositioning was required. The first part of the surgical procedure was performed with the patient in the supine position. During this time there were no observed issues with ventilation. It wasn't until the second part of surgery, with the patient in the right lateral decubitus position, that we experienced difficulty ventilating. The first indication was the audible peak-airway-pressure alarm on the anesthesia machine. It alarmed at 40 mmHg and reached as high as 52 mmHg. The second was an observable and rapid decrease in tidal volumes. The patient was removed from mechanical ventilation and manually ventilated by hand. The bag felt tight and required the adjustable-pressure-limiting (APL) valve to be adjusted to between 30-50 mm H20. Recruitment maneuvers were difficult, required high pressures on the part of the anesthetist and were only marginally successful. Upon auscultation, bilateral breath sounds were present, but diminished. The $ETCO_2$ tracing, via capnography, showed an appreciable slant in the expiratory limb. Considering the patient's history of reactive airway disease, a broncospasm was suspected. Six puffs of albuterol were given via the endotracheal tube. The inhaled concentration of sevoflurane was also increased, to deepen the plane of anesthesia.

Full muscle relaxation was confirmed by zero twitches present using a train-of-four monitor. During this time, the patient didn't desaturate, nor was the anesthetist ever unable to ventilate. All of the aforementioned measures helped. Mechanical ventilation was resumed. Once the surgeons finished operating on the patient's left side, the patient was then placed supine. Ventilatory parameters returned to normal.

Surgery was performed for another hour, still while in the supine position. During this time, the patient had no issues and all ventilatory parameters were within normal limits. The patient was then repositioned in the left lateral decubitus position. Due to his torso being shaped like a V, this proved problematic. The concavity of his left thoracic wall caused only his face and left hip to touch the bed. This made proper positioning problematic. His right chest wall projected upward, off of the OR table. This created an immediate problem with ventilation, similar as to what was experienced with the patient in the right-side-down position.

Again, peak airway pressures passed 50 mmHg, despite adequate muscle relaxation. Breath sounds were noted bilaterally, but sounded tight. Wheezes were also present. The $ETCO_2$ waveform became even more abnormal: there was an obvious slant in the up stroke and an increase in the alpha angle with a loss of the expiratory plateau. Tidal volumes were instantly reduced, from 250 ml's to 80 ml's. Another broncospasm was suspected. An additional 4 puffs of albuterol were administered, as well as IV epinephrine (20 mcg). Despite these difficulties, the patient's oxygen saturation never dropped below 98%.

Nevertheless, the decision was quickly made to reposition the patient back into the supine position, to allow for better ventilation so that surgery could be resumed. The problem briefly resolved but then continued. A differential diagnosis of anaphylaxis versus transfusion related acute lung injury (TRALI) was briefly considered as the patient had been recently transfused with two units of PRBC and also given albumin. This was thought to be unlikely, seeing that the patient had experienced a similar scenario while in the right-decubitus position prior to receiving any blood products. More epinephrine (a total of 40 mcg) was administered, but proved ineffective. Mechanical ventilation was discontinued since the ventilator was unable to generate enough pressure to function properly. The patient was again

hand ventilated, requiring extremely high pressures (> 50mmHg) just to inflate the lungs. Bilateral breath sounds were present. The ETT and breathing circuit were checked and found to have no kinks or external obstructions. The patient began to desaturate from 98% to 85%. $ETCO_2$ increased from 40 to 55 mmHg. A mucous plug was suspected, so the anesthesia staff attempted to pass a 10 French suction catheter down the ETT, but was unable to do so. Resistance was met at the distal end of the ETT. A 14 French suction catheter, which is more rigid, was successfully passed, albeit with some force and effort. No secretions were noted but upon catheter removal, the obstructive pattern on the ETCO2 waveform improved and peak airway pressures decreased.

Surgery resumed, but after a few minutes of resolution, the peak airway pressure increased and the EtCO2 waveform became abnormal again. A stat intra-op chest x-ray was ordered. Anesthesia staff also requested a flexible bronchoscope to the OR to ascertain if the ETT was in the right mainstem bronchus or had somehow become occluded again. During this time the on-call Pediatric Otolaryngologist, who had just finished operating in the adjacent OR, came into the room to offer assistance. The flexible bronchoscope was placed, with some difficulty, through the patient's ETT, but due to the patient's body habitus, anatomy of the tracheobronchial tree was grossly abnormal. The carina was not apparent and it was difficult to discern the trachea from the bronchus. It was recommended that the ETT be pulled back until symptoms resolved. But when the ETT was carefully retracted from 16 cm to 10 cm, under direct visualization of the bronchoscope, without resolution of symptoms, we were completely unable to ventilate the patient. The ETT had become supraglottic and was immediately removed. The patient was able to be mask ventilated easily and oxygenation was maintained this way. The patient was then quickly reintubated with a new ETT of the same size, using a C-Mac video laryngoscope, with the Pediatric Otolaryngologist standing by. A brief discussion between anesthesia and ENT then took place as to what the likely causes were and what should happen next. It was thought that the distal end of the ETT had kinked inside the patient's trachea. By this point, surgery had been going on for approximately 6 hours and the ETT had most likely warmed to the patient's body temperature, making it more pliable. Also, the acute angle of his scoliosis in the upper thoracic region made this seem plausible. This was confirmed by our x-ray findings, which in fact demonstrated a kinked ETT. See Fig.1

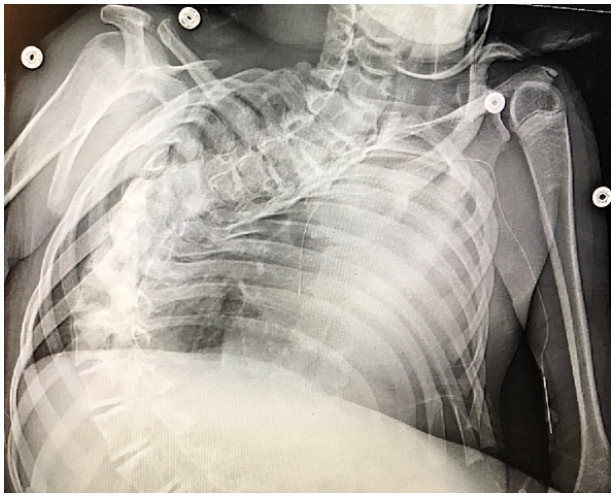

Figure 1. Acute angle of scoliosis in the upper thoracic region.

The decision was made to reintubate the patient using a coiled-wire reinforced ETT. This was accomplished by using a Cook exchange catheter. The 2nd ETT was removed and replaced with the coiled-wire cuffed reinforced ETT of the same size. Success was confirmed by a positive $EtCO_2$ waveform, equal bilateral breath sounds, and visualization of what we thought was the carina with the bronchoscope. Due to all of the difficulties with adequately ventilating the patient, the surgical team decided to postpone the rest of the planned surgical interventions and to take the patient to the pediatric ICU.

Discussion

Although intra-operative obstruction of an endotracheal

tube is a fairly rare occurrence, it does happen. Anesthesia providers should therefore be able to quickly identify and readily treat an obstruction should it occur in order to prevent a potentially fatal outcome.

During our review of literature, we were only able to find a handful of reports that described intra-tracheal kinking of the endotracheal tube while under general anesthesia and none that described this phenomenon in a pediatric scoliosis patient. While reviewing similar case reports of obstructed ETT's it quickly became apparent that the presentation of a severe broncospasm and the presentation of an obstruction are virtually identical and that anesthesia providers typically treated the latter as the prior.

Park and colleagues describe a nasally intubated patient that experienced ventilatory failure while undergoing general anesthesia for dental work, due to endotracheal tube obstruction. The initial presentation of gradually increasing peak airway pressures and CO2 levels were initially interpreted as a broncospasm and treated as such. After a satisfactory circuit and machine check, the patient was given epinephrine, hydrocortisone, an in-circuit nebulizer treatment and pheniramine maleate, in addition to deepening the inhaled Sevoflurane concentration. It wasn't until a flexible bronchoscope was used through the ETT that it became apparent there was a large blood clot occluding the end of the ETT distal to the Murphy eye. Upon successful dislodgement of the ETT, the patient's ventilatory parameters returned to normal and surgery was resumed.[5]

In another case report by Lee and colleagues, a 20-year-old male presented for right mandibular fracture repair. The initial intubation attempt, with a cuffed 7.0 ETT, was unsuccessful. The 7.0 ETT was too large and wouldn't pass through the nasal cavity. A size 6.5 ETT was then chosen. It was placed in warm water, making it more pliable, prior to use. After successful nasal intubation, neither breath nor epigastric sounds were heard. A peak airway pressure of 50 cm H20 generated no $ETCO_2$. A quick review of the anesthesia circuit and ETT revealed no abnormalities. The tube was retracted until it was above the vocal cords and then reinserted into the trachea. After successful confirmation via direct visualization, but no return of ETCO2 or breath sounds, a broncospasm was suspected. Although the article doesn't describe the details, treatment for a broncospasm was initiated. SPO2 dropped from 99% to 70%. A fiber optic bronchoscope wasn't able to be passed through the ETT and the diagnosis of obstruction was made. The authors believe that by passing the pre-warmed ETT through the nasal passages, the structural integrity of the ETT may have been compromised and thus kinked at some point. In addition, the prior intubation attempt with the 7.0 ETT may have caused nasal trauma that led to the development of the blood clot. The patient was extubated and immediately intubated with a new ETT. Surgery resumed without any complications.[6]

Defective endotracheal tubes have also been cited as a cause of intra-tracheal kinking. Chua and Ng describe a 9-year-old boy presenting for pacemaker insertion. The patient was intubated without incident, but an hour into surgery decreased tidal volumes and increased ETCO2 levels were noted. A quick review of the anesthesia circuit and ETT didn't reveal anything awry. The anesthesia team then proceeded to treat the patient for a suspected broncospasm. Manual ventilation was initiated. A bronchodilator (ventolin 2 puffs) was administered and an attempt was made to pass a suction catheter down the ETT. These measures proved marginally successful. Tidal volumes briefly increased but then later decreased. $ETCO_2$ rose to 90 mmHg secondary to hypoventilation. One more attempt was made to pass a suction catheter through the ETT, but this time it wouldn't pass through the oral section of the tube. Intra-oral kinking of the ETT was ruled out as a possibility by digital exam. It wasn't until surgery was halted and a direct laryngoscopy was performed that the anesthesia team noticed a se-

vere kink in the tube just proximal to where it enters the trachea. The patient was extubated and reintubated with a new tube. The remainder of surgery went as planned without any untoward events. The defective ETT was examined. Apparently there was a manufacturing defect at the junction of where the inflation tube is attached to the wall of the ETT, causing a V shape. This kink probably became more pronounced the longer the case went on, as the ETT had more time to warm to the patient's body temperature.[7]

Similar cases have been described by Arai et al, as far back as 1983. Their article describes three incidents of ETT kinking during neurosurgery. All occurred at the junction where the cuff inflation tube joins the wall of the ETT, regardless of head position.[8]

Early warning signs of a broncospasm and an obstruction in the intubated patient are identical: decreasing tidal volumes, increasing peak airway pressures, an increasing and persistently high ETCO2 and a potential decrease in arterial oxygen saturations. Add to this the fact that the ETCO2 waveform patterns for each condition also look identical, it is no wonder that providers often choose to treat a ventilatory issue as a broncospasm rather than an obstruction. But by doing so, are we wasting valuable time, time that could be spent reintubating the patient?

Conclusion

In conclusion, whenever a patient with severe scoliosis (Cobb angle greater than 120 degrees) requires endotracheal intubation for surgery, consider the use of a reinforced ETT, especially if the patient will be prone. The reinforced tube will hopefully prevent intra-tracheal kinking and subsequent failure, although it will not protect from other more common causes of obstructions.

If difficulty ventilating a successfully intubated patient arises, consider using a fiberoptic bronchoscope before the patient decompensates and it becomes an emergency; treating the wrong problem only wastes valuable time, time that could be spent reintubating the patient.

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