CASE REPORT

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Endotracheal Tube Ignition by Electrocautery During Tracheostomy: Case Report with Autopsy Findings

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ABSTRACT: This case of upper airway tract fire resulting from the use of electrocautery during elective tracheostomy has significance for surgeons, anesthetists, and forensic pathologists alike. The major autopsy findings are described and illustrated. Suggestions that may help to prevent or minimize the risk of fire in this context are reviewed.

KEYWORDS: electrocautery, endotracheal tube fire, tracheostomy

Electrocautery and focused laser beams are used extensively in surgery and have advantages over more conventional cutting instruments. While the use of high-energy ignition of tissue may help provide a bloodless operative field, these methods are not without complications. Ignition of the endotracheal tube (ETT), with resultant airway damage, is potentially the most serious complication. The authors describe a case of endotracheal tube fire ignited by electrocautery during the creation of a tracheostomy stoma, which had eventual lethal consequences.

Case Report

A 72-year-old diabetic man was admitted to a hospital following a one-week history of "flu-like" symptoms and was diagnosed as having left lower lobe staphylococcal pneumonia. His deteriorating respiratory status required tracheal intubation and mechanical ventilation. The need for prolonged respiratory support then became evident and a

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tracheostomy was performed on the seventh day of hospitalization.

Anesthesia was induced and maintained with isoflurane in concentrations of 1 to 2% in oxygen via a semiclosed circle system with controlled ventilation at a rate of 8 breaths per minute. Electrocautery in the cutting mode was used to dissect to the trachea and to create the tracheostomy stoma. The electrocautery was still in operation while the ETT was being withdrawn to allow placement of the tracheostomy tube. As the tip of the ETT approached the tracheal stoma, a "puff" was heard, and immediately afterward a blue flame was observed emitting from the stoma. The fire was extinguished immediately by a towel placed over the stoma, and a saline flush was administered down the ETT. A tracheostomy tube was inserted within 1 min after complete removal of the ETT. After ventilation had been established through the tracheostomy, fiberoptic endoscopy was performed, which revealed small amounts of soot on the slightly edematous vocal cords. The tissues in the hypopharynx were edematous, and evidence of thermal inhalation injury was seen down to the level of the carina. Postoperative therapy included a short course of steroids for the burns to the airway. The period after the inhalation injury was associated with increased inspired oxygen and ventilatory requirements. Despite intensive medical therapy and ventilatory support, the patient's clinical status continued to deteriorate, and death occurred 13 days after the tracheostomy.

Postmortem examination identified a tracheostomy stoma in the lower anterior midline of the neck, surrounded by an irregular border of denuded red granulation tissue (Fig. 1). Histological sections from the tracheostomy track showed extensive necrosis, polymorphous inflammatory infiltration, early organization, numerous bacteria, and opaque particulate debris. The posterior pharyngeal mucosa was purplish and mottled, and the epiglottis, larynx, and upper trachea had white patches with embedded black material (Fig. 2). There was diffuse reddening of the mucosa of the trachea and both main-stem bronchi. The proximal bronchial tree had finely granular tan-brown mucosa and contained abundant exudate.

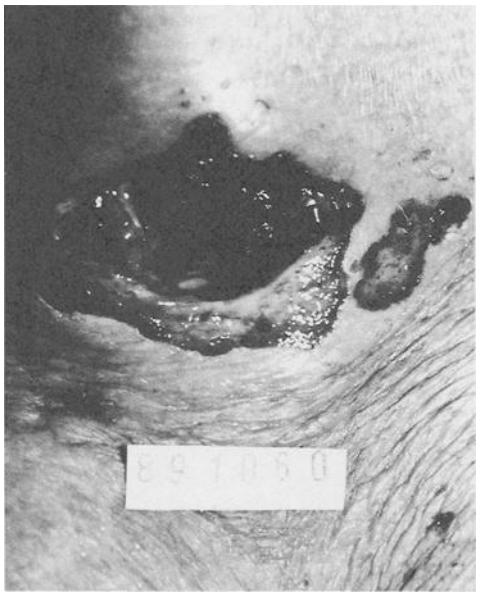

FIG. 1—*The tracheostomy stoma, surrounded by an elliptical zone of denuded skin and granulation tissue. A smaller denuded patch is seen to the left of the stoma, on the right side of the photograph.*

FIG. 2—*The edematous epiglottis, larynx, and upper trachea, mottled by white exudate with embedded black material.*

The extensively consolidated lungs had a combined weight of 2500 g. In the left upper lobe was a 7-cm focus of dark necrotic tissue. Limited areas of bronchiectasis were seen in the lingula and left lower lobe. The right lung had a 7-cm confluent area of bronchopneumonia in the superior segment of the lower lobe and three 0.5-cm abscesses in the middle lobe. The histological findings in the lungs included both bacterial (gram-positive cocci) and fungal (morphology consistent with *Aspergillus*) pneumonia, superimposed on a background of diffuse alveolar damage—the pathological correlate to adult respiratory distress syndrome.

The 8-cm polyvinyl chloride ETT (Mallinckrodt) involved in the fire was extensively charred from the proximal end of the cuff to the distal end of the tube, with blackening of the tube for several centimetres above the area of charring (Fig. 3). Probable remnants of the thin plastic balloon were identified, although there was marked distortion and black charring of the remainder of the plastic tube at that site (Fig. 4).

Death was attributed to bronchopneumonia with laryngotracheal burns as a contributory cause.

Discussion

An endotracheal tube fire is a well-recognized complication of upper aerodigestive tract procedures using lasers [*1*] and electrocautery [*2*], with the published cases of fires ignited by lasers outnumbering those that inculpate electrocautery. Rita and Seleny [*3*] reported ETT ignition during tracheal stoma revision in a 2-year-old boy. Halothane and 50% nitrous oxide were being administered through a polyvinyl chloride ETT inserted through a chronic tracheostomy stoma. A urethral resectoscope was being used to remove

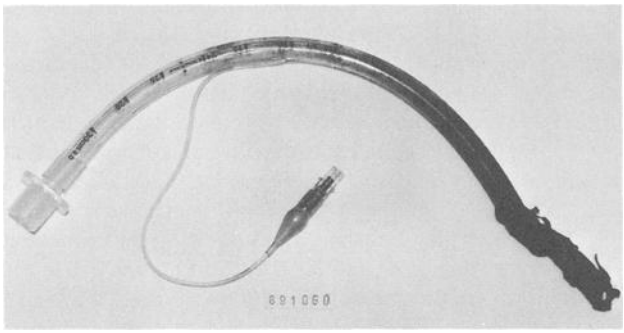

FIG. 3—*The polyvinyl chloride endotracheal tube, showing extensive charring of the cuffed end with destruction of the balloon.*

granulation tissue at the tracheostomy site in the area above the ETT when smoke suddenly escaped from the child's mouth and a flash was seen at the tracheostomy site. Simpson and Wolf [*2*] documented a case of ETT fire during elective adenoidectomy and tonsillectomy in a 4-year-old boy. Suction electrocautery set at the "spray" mode (coagulation) was being used to control bleeding in the right tonsillar fossa. After approximately 30 s of cautery, fire erupted in the pharynx. Before the beginning of the surgery, a retrograde leak of gases had been noted around the tube at the larynx. A more recent account by Bowdle et al. [*4*] involved cutting mode electrocautery, which was used in conjunction with an emergency tracheostomy performed during percutaneous transtracheal ventilation with 100% oxygen. A 14-gauge intravenous catheter inserted via the cricothyroid membrane into the trachea was used to ventilate the patient. As the thyroid isthmus was divided by electrocautery, a flash of light was seen in the surgical field and appeared to travel rostrally beneath the surgical drapes. When the patient's head was uncovered, flames were seen on the surgical drapes along the right side of the neck. The emergency airway circumstances in this case had allowed oxygen exhaled from the mouth to collect beneath the drapes near the surgical field, resulting in ignition of the surgical drapes and burns to the neck.

The tracheostomy scenario of the case reported in this paper shares some features with Bowdle's case in that cutting mode electrocautery was kept in operation at the stomal site during the brief period of exposure to 100% oxygen. During removal of the ETT, which brought the oxygen stream past the stoma and the electrocautery, the ETT ignited and our patient sustained burns to the airway. The electrocautery provided the source of ignition, the oxygen functioned as the oxidant, and the polyvinyl chloride ETT became the fuel.

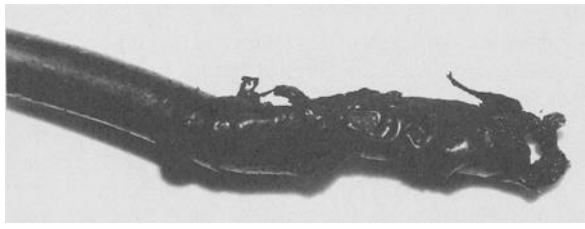

FIG. 4—*The cuffed end of the endotracheal tube, extensively charred. The few protruding barbs may be residual fragments of the balloon.*

Electrocautery delivers a current with an alternating sine wave at a radio frequency of 20 000 to 500 000 cycles/s (20 to 500 kHz) [5]. Continuous current is employed for the cutting mode, in which the production of intense heat explodes cellular water into steam at the cautery tip. The tissues are therefore divided before deeper layers are affected by the heat. Intermittent pulsing of the current on the coagulation mode produces heat and charring within the tissue, thus effecting hemostasis by coagulating the tissues and blood. The limited literature available suggests that the cutting mode of electrocautery may be associated with a greater risk of igniting a fire than the coagulation mode.

Higher concentrations of oxygen enhance combustion [4] and concomitantly increase the risk of fire. One means of minimizing this risk (for patients not in acute respiratory failure) is to lower the inspired oxygen concentration to a level that will still ensure the patient's safety (between 30% [6] and 50% [7]), and replace it proportionally with a nonflammable, noncombustible gas such as nitrogen. Lower oxygen concentrations, when combined with nitrogen, decreased the risk of fire in all the endotracheal tubes tested by Hayes et al. [6]. However, a lower inspired oxygen concentration will not completely erase the risk of fire, because many tubes will burn in as little as 25% oxygen [8]. The substitution of nitrous oxide (N_2O) for oxygen, on the other hand, provides little benefit as N_2O supports combustion almost as readily as oxygen [6,8].

The various types of ETTs differ in their incendiary mechanisms and in the amount of volatile gas produced on ignition. A burning red rubber ETT produces relatively small amounts of volatile gas; however, there is a danger that the ventilated oxygen may blow the flame to produce a torch effect, or that the gas mixture passing over the flame may create a Venturi effect. Polyvinyl chloride tubes melt at relatively low temperatures and vaporize at high temperatures. The toxic gas produced may result in more severe lung injury than would occur with other tubes of different materials, particularly when inhaled in the manner observed in our patient. Polyvinyl chloride gas ignited in a high-oxygen environment produces violent explosions and "resembles the flame of a poorly ignited, large, acetylene torch" [9]. Hayes et al. [6] studied the incendiary characteristics of a silicone (laser-resistant) ETT (Xomed, Inc., Laser Shield, Jacksonville, Florida) in comparison with polyvinyl chloride and red rubber ETTs. They found that the silicone tube could not be penetrated by a single laser pulse, regardless of the laser energy or gas composition, whereas polyvinyl chloride and red rubber tubes were readily ignited, depending on the oxygen concentration and laser energy. Polyvinyl chloride tubes are popular because of their low implant toxicity, pliability, and lack of complications during prolonged use. However, in situations in which there is a high risk of ignition, as in upper aerodigestive tract surgery, perhaps less flammable tubes should be used routinely.

Sommer [10] suggested several techniques for reducing the risk of pharyngeal fire. A moist, occlusive pharyngeal pack would reduce leakage of flammable gases into the oral cavity. If leakage occurs, the anesthetic/oxidizing agent could be diluted by insufflating the oral cavity with a gas that does not support combustion, such as nitrogen, helium, or carbon dioxide. Sommer's third recommendation was that bipolar rather than unipolar cautery be used, as bipolar cautery would reduce leakage of electrical current to the surrounding tissues.

Finally, we emphasize the concerns of Bowdle et al. [4] and advise against the use of electrocautery in situations in which the surgical field is in close proximity to an oxygen source. If the use of electrocautery is deemed necessary in airway surgery, an ignition-resistant tube, or a tube which, on ignition, does not produce abundant toxic gases, should be considered.

A recent report by Bailey et al. [11] documents the only other case of electrocautery-induced fire occurring during elective tracheostomy, and lists recommendations for the prevention of fire during this procedure.

Although our patient had existing respiratory impairment, the airway burns and in-

halation of potentially toxic fumes may have contributed to the progression of his underlying bacterial and fungal infection and prompted the development of diffuse alveolar damage.

In summary, this case of ETT fire punctuates a latent danger inherent in the use of electrocautery during airway surgery. Suggestions that may help prevent or minimize the risk of fire are reviewed.

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