What is the Safest Foil Tape for Endotracheal Tube Protection during Nd-YAG Laser Surgery? A Comparative Study

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Materials and Methods

In part 1, five red rubber (RR) Rusch (W. Germany) endotracheal tubes were wrapped with ¾-inch wide self adhesive metallic tape in an overlapping spiral fashion beginning at the cuffed end of the tube. RR endotracheal tubes were used because they are highly flammable when exposed to the Nd-YAG laser. Five liters per minute of 100% oxygen flowed through the tubes so that endotracheal tube perforation and combustion by the laser would be clearly seen. A second segment of each tube was wrapped with the same tape but with its adhesive side outward to determine the flammability of the adhesive, since the laser might contact it if aimed at the edge of the tape. The tapes used were: 1) Radio Shack (Tandy Corp., Ft. Worth, TX) no. 44-1155 tape; 2) 3M (Minneapolis, MN) no. 425 aluminum tape; 3) 3M no. 433 aluminum tape; 4) 3M no. 1430 aluminum tape; and 5) copper foil tape (1 mil thick) (Venture Tape Corp., Rockland, MA). An unwrapped RR endotracheal tube served as a control.

In part 2, RR tracheal tubes wrapped with 3M no. 425 and Venture copper foil tape were placed in a copper chamber that was flushed with oxygen. The concentration of oxygen was determined to be 98% both before and after laser discharge as measured on the tape with a catheter connected to a mass spectrometer. Each type of foil wrapping was evaluated five times.

A LaserSonics® (Santa Clara, CA) model 1700 CO2/Nd-YAG laser, in the Nd-YAG mode with a hand-held laser probe, was used in part 1 of this study. The laser’s output was set at 50 W in the continuous mode, with a beam diameter of 0.68 mm. The beam was directed perpendicularly at the shafts of the foil-wrapped endotracheal tubes and the laser’s emission was continued until vigorous combustion was noted or up to a maximum of 60 s. A blowtorch fire, if observed, was noted. In part 2, the laser was set to its maximum output of 110 W in the continuous mode of operation and was attached to a Zeiss (W. Germany) operating microscope with a 400-mm lens. It was directed perpendicularly at the wrapped tubes in the test chamber. Venture copper foil and 3M no. 425 tapes were each evaluated five times. The laser was operated until combustion occurred or until 1 min had elapsed.
Results

The results of part 1 of this study and a similar study published previously involving the CO$_2$ laser are summarized in table 1. The bare RR endotracheal tube burned with a blowtorch effect after 13 s of Nd-YAG laser contact. Combustion and a blowtorch fire occurred in 6 and 15 s, respectively, after laser contact with Radio Shack no. 44-1155 tape. Its reverse side was not tested. 3M no. 425 aluminum tape withstood 60 s of laser emission without any effect to its nonadhesive side. When its adhesive side was struck by the laser, smoking was noted immediately. After 60 s of laser contact, endotracheal tube combustion was noted beneath the tape. 3M no. 433 aluminum tape withstood 60 s of laser contact. When its adhesive side was exposed to the laser, it burned immediately, and a blowtorch fire was observed after 12 s. In the case of 3M no. 1430 aluminum tape, combustion occurred immediately after laser exposure to either side. The laser was discontinued after vigorous flames were observed, and the flames were extinguished, so no blowtorch effect was noted. Venture copper foil tape was not visibly changed after 1 min of laser radiation to its non-adhesive side. Smoking was noted after 5 s and flames in 15 s when the reverse side was struck with the laser. The nonadhesive sides of the 3M no. 425 tape and Venture tape was retested three more times with no affect from the laser.

In part 2, no evidence of combustion was noted in all five trials of RR tracheal tubes wrapped with 3M no. 425 or Venture copper foil tape in an atmosphere of 98% O$_2$ after 1 min of Nd-YAG laser fire at a power of 110 W.

Discussion

Both the CO$_2$ and the Nd-YAG lasers (unless frequency doubling or tripling is employed) emit radiation in the infrared region of the spectrum, and hence are invisible. The wavelength of the CO$_2$ laser is 1.06 μm while that of the Nd-YAG laser is 10.6 μm. The Nd-YAG laser is being employed increasingly in surgery because it offers important advantages over the CO$_2$ laser. These include its greater hemostatic effect, greater depth of tissue penetration, and the fact that it can be delivered via a fiber-optic bundle. This allows it to be used for the treatment of peripheral airway lesions. The Nd-YAG laser, unlike the CO$_2$ laser, is not absorbed by water. As with other types of lasers used for airway surgery, in Nd-YAG laser cases, the anesthesiologist and surgeon are frequently in competition for the airway. A case of life threatening endotracheal tube combustion has been reported during an Nd-YAG laser case.4

In our study, the nonadhesive side of the Venture copper tape afforded protection from Nd-YAG laser-induced endotracheal tube combustion; however, when the adhesive side was struck by the laser, combustion occurred. Radio Shack no. 44-1155 and 3M no. 1430 metallic tapes offered essentially no protection from combustion induced by this laser. 3M no. 433 and no. 425 aluminum foil tapes were only warmed slightly when exposed to 60 s of Nd-YAG radiation on their nonadhesive sides; however, the 3M no. 433 tape burned immediately with a blowtorch fire occurring after 12 s when its adhesive side was exposed. The reverse side of the 3M no. 425 tape smoked immediately with tube combustion noted at 60 s.

<table>
<thead>
<tr>
<th>Tape Studied</th>
<th>Nd-YAG Laser*</th>
<th>CO$_2$ Laser†</th>
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<tbody>
<tr>
<td></td>
<td>Nonadhesive Side</td>
<td>Adhesive Side</td>
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<tr>
<td>Radio Shack no. 44-1155</td>
<td>6-s combustion 15-s blowtorch fire</td>
<td>Not tested</td>
</tr>
<tr>
<td>3M no. 425</td>
<td>No effect by 60 s</td>
<td>Immediate smoking</td>
</tr>
<tr>
<td>3M no. 433</td>
<td>No effect by 60 s</td>
<td>Tube combustion at 60 s</td>
</tr>
<tr>
<td>3M no. 1430</td>
<td>Immediate combustion</td>
<td>Immediate combusiton and blowtorch fire after 12 s</td>
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<tr>
<td>Venture copper foil</td>
<td>No effect by 60 s</td>
<td>Smoking at 5 s</td>
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<td></td>
<td>Flames at 15 s</td>
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* Present study: Red rubber endotracheal tubes studied with 5 l/min oxygen flowing through them. The Nd-YAG laser was set to 50 W with a beam diameter of 0.68 mm in the continuous mode for up to 60 s.
† Polyvinylchloride endotracheal tubes studied with 5 l/min oxygen flowing through them. The CO$_2$ laser was set to 70 W with a 0.68-mm beam diameter in the continuous mode for up to 25 s. Source: Reference 2.
In common with the present Nd-YAG laser study, previous work (1) has demonstrated that Radio Shack no. 44-1155 tape and 3M no. 1430 tape offer little protection from the 70 W continuous CO₂ laser and readily combusted. Also, after exposure to 70-W CO₂ laser radiation, as in the present study, the nonadhesive side of 3M no. 425, no. 433, and Venture 1 mil copper foil tape, were unaffected. The backing of Radio Shack no. 44-1155 and 3M no. 433 tape burned and were perforated on exposure to the CO₂ laser. (2) Venture copper foil tape’s adhesive backing burned but was not penetrated by the 70 W CO₂ laser. The Nd-YAG laser also rapidly ignited its adhesive backing.

Geffin et al. (3) evaluated endotracheal tube flammability during Nd-YAG laser application at power levels up to 50 W in the continuous mode. They reported that RR endotracheal tubes were not protected from Nd-YAG laser-induced combustion by Radio Shack no. 49-502 aluminum foil tape. However, they tested no other types of tape. They also observed that the clear, unmarked portions of polyvinylchloride endotracheal tubes offer protection from the Nd-YAG laser at low power; however, they were unable to find any endotracheal tube that was safe for use with the Nd-YAG laser operating at 50 W in the continuous mode. In our study 3M no. 425 tape and Venture copper foil tape protected the exterior of the shaft of a flammable RR endotracheal tube from 1 min of 110 W Nd-YAG laser radiation to the nonadhesive side of the tape. The fact that combustion occurred at 15 s after laser contact with the adhesive side of the Venture copper tape suggests an advantage of the 3M no. 425 tape. The spot diameter of 0.68 mm used in the present study results in a much greater power density (power/area) than that used in the study Geffin et al. which employed a 2-mm spot diameter.

Our findings regarding the use of 3M no. 425 tape for endotracheal tube protection mark the first report of a method providing adequate protection of the exterior aspect of a combustible endotracheal tube from the Nd-YAG laser at 110 W and a duration of 1 min. It should be noted, however, that foil wrapping will not protect combustible endotracheal tubes from indirect combustion due to sparks or a high temperature secondary to tissue combustion. The lumen of the endotracheal tube is also unprotected and thus combustion could be initiated via a fiber-optic filament. It is recommended that a rigid metal bronchoscope be used for major airway surgery when a fiberoptic bundle is used to conduct the laser. (6) The protection afforded by the 3M no. 425 and Venture copper foil tapes in an atmosphere with an increased fraction of oxygen (98%), such as may occur if an uncuffed endotracheal tube is used, has been shown to be excellent especially considering that the laser was set to 110 W with a duration of continuous operation of 1 min.

The cuffs of the endotracheal tubes used in laser airway surgery are easily damaged by the laser and cannot be protected with foil tape. They should be filled with saline to which a small amount of dye such as methylene blue has been added to signal cuff perforation. Extra protection of the cuff can be obtained by packing it off with wet pledgets that are moistened periodically. As a further safety measure, only the minimum FiO₂ required should be administered with the remainder of the inspired mixture comprised of nitrogen or helium.

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References