Anesthesiology
72:553–555, 1990

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

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Metallic tapes have been shown to protect combustible endotracheal tubes from the CO_2 laser; however, no adequate means of protecting such tubes from the Nd-YAG laser has yet been found. In this investigation, five different metallic tapes were evaluated as protection for red rubber endotracheal tubes from an Nd-YAG laser set to 50 W. Radio Shack no. 44-1155 and 3M no. 1430 were quickly perforated by the laser. Laser contact with the adhesive side of 3M no. 433 resulted in combustion. The nonadhesive side of the Venture copper tape was not affected by the laser; however, when its adhesive side was struck, a fire occurred. 3M no. 425 tape provided the best protection: no effect was seen when the laser was aimed at its nonadhesive side for 1 min, with only smoking of the tape evident when its adhesive side was tested. Finally, 3M no. 425 and Venture copper foil tapes were shown to be resistant to an Nd-YAG laser set to 110 watts in an atmosphere of 98% O_2. (Key words: Laser, combustion: fires. Complication: Nd-YAG.)

THE NEODYMIUM-YTTRIUM-ALUMINUM-GARNET (Nd-YAG) laser is being used in a variety of otolaryngologic and thoracic airway procedures. The advantages of this laser, as compared with the CO_2 laser, include its superior hemostatic action, greater depth of penetration, and the fact that it can be propagated through a fiber-optic bundle. It has been used for upper-airway surgery such as tonsillectomies as well as for the treatment of obstructing tracheobronchial tumors. A catastrophic complication reported with the use of the Nd-YAG laser during airway surgery was ignition of the endotracheal tube.[1] Excellent protection of endotracheal tubes from the CO_2 laser using the proper metallic foil tapes has been demonstrated.[2] However, since no safe technique for endotracheal tube protection has yet been found with the Nd-YAG laser operating at 50 W,[3] this study was undertaken to determine if commercially available metallic adhesive tapes[2] could prevent Nd-YAG laser ignition of combustible endotracheal tubes both in an air and in an oxygen-rich environment.

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Received from the Department of Anesthesia, Indiana University School of Medicine, Indianapolis, Indiana. Accepted for publication September 25, 1989. Presented in part at the 63rd Congress of the International Anesthesia Research Society, Orlando, Florida, March 1989.

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Materials and Methods

In part 1, five red rubber (RR) Rusch (W. Germany) endotracheal tubes were wrapped with ¼-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.[3] 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 CO_2/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[2] 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 nonadhesive 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 fiberoptic bundle.[4] 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.[1]

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 1. Effect of CO_2 and Nd-YAG Laser Radiation on Foil Wrapped Endotracheal Tubes

Tape Studied	Nd-YAG Laser*		CO_2 Laser†	
	Nonadhesive Side	Adhesive Side	Nonadhesive Side	Adhesive Side
Radio Shack no. 44-1155	6-s combustion 15-s blowtorch fire	Not tested	7-s tube penetration 14-s combustion	Ignition and perforation ≤0.1 s
3M no. 425	No effect by 60 s	Immediate smoking Tube combustion at 60 s	No effect by 25 s	Smoking at 2 s. No flames or perforation
3M no. 433	No effect by 60 s	Immediate combustion and blowtorch fire after 12 s	No effect by 25 s	Ignition and perforation ≤0.1 s
3M no. 1430	Immediate combustion	Immediate combustion	7-s tube penetration 14-s combustion	Flaming of adhesive at 1 s No penetration
Venture copper foil	No effect by 60 s	Smoking at 5 s Flames at 15 s	No effect by 25 s	Flaming of adhesive at 1 s No penetration

* 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[2] (table 1) has demonstrated that Radio Shack no. 44-1155 tape and 3M no. 1430 tape offer little protection from the 70 W continuous CO_2 laser and readily combusted. Also, after exposure to 70-W CO_2 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 CO_2 laser.[2] Venture copper foil tape's adhesive backing flamed but was not penetrated by the 70 W CO_2 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[5] 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[7] 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 $F_{I_{O_2}}$ required should be administered with the remainder of the inspired mixture comprised of nitrogen or helium.

The authors wish to thank Sherry Heller, R.N. for assistance in completing this study.

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