An evaluation of carbon dioxide laser reflectivity from laser-resistant endotracheal tubes and wraps

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This study compared Mallinckrodt® Laser-Flex™ with polyvinyl chloride endotracheal tubes (ETTs) wrapped with aluminum foil tape, copper foil tape, or Merocel® Laser-Guard laser-resistant wrap to determine if specular reflection occurred during exposure to a carbon dioxide (CO₂) laser. The ETTs were straightened and centered within cardboard cylinders and exposed to a laser set at 25 W for a maximum of 60 seconds in the continuous and intermittent modes. The laser sighting beam was directed at the ETT at a 45-degree angle. Time to reflectivity was measured when discoloration formed on the cardboard cylinder following laser activation.

Measurements revealed that the Laser-Flex ETT was most resistant to reflection damage in both the continuous (21.3 seconds) and intermittent (50.8 seconds) modes compared with Laser-Guard (4.8 seconds and 10.6 seconds), aluminum (1.0 seconds and 1.6 seconds) and the copper (1.1 seconds and 1.7 seconds) groups respectively. We concluded that the Mallinckrodt Laser-Flex and the Merocel Laser-Guard were less reflective of incident CO₂ laser radiation than the copper or aluminum foil wrapped tracheal tubes.

Key words: Carbon dioxide laser, endotracheal tubes, reflection.

Introduction
The carbon dioxide (CO₂) laser has long been considered an effective device for treatment of certain disorders of the upper airway. However, the high energy density of the laser may result in the ignition of the endotracheal tube (ETT).1,2 To decrease the likelihood of such an occurrence, various wraps and laser-resistant ETTs have been developed.3,4 Although these products are effective in reducing ignition, they may reflect the incident laser beam as verified in vitro by Sosis and Dillon.5 In the clinical setting, this reflection could result in a potential risk to the patient and surgical personnel. The purpose of this study was to compare the reflectivity of a laser-resistant endotracheal tube with polyvinyl chloride (PVC) endotracheal tubes, wrapped with either aluminum, copper foil, or Merocel® Laser-Guard laser resistant wrap.

Materials and methods
Ten stainless steel Mallinckrodt® Laser-Flex™ ETTs (8.0-mm internal diameter) and 30 Sheridan™ HVT™ cuffed PVC ETTs (8.0-mm internal diameter) were divided into four groups (Laser-Flex, aluminum, copper, and Laser-Guard). The PVC endotracheal tubes were wrapped with either aluminum adhesive foil tape (No. 425, 3M Corp., St. Paul, Minnesota), 1-millimeter (thickness) copper adhesive foil tape (Venture Tape, Rockland, Massachusetts), or Laser-Guard (Merocel Corp., Mystic, Connecticut) protective wrap. The Laser-Guard wrap is a self-adhesive, corrugated silver foil sheet bounded to a thin, absorbent sponge layer, which is saturated with water after application to the ETT.
The ETTs were straightened with a stylet and suspended vertically by a ring stand. A cardboard cylinder, measuring 45 mm in diameter by 115 mm in length, was centered around each tube and attached to the ring stand. A Sharplan 1060 CO2 laser (Laser Industries, Tel Aviv, Israel) connected to a Zeiss (Jena, Germany) Universal S2 operating microscope and 400-mm objective lens was placed 2 feet from the endotracheal tube with the laser sighting beam aimed at the distal third of the tube to reflect at a 45-degree angle (Figure 1). Laser output was set at 25 W with one half the trials in the intermittent mode and one half in the continuous mode. All trials were conducted in room air and limited to 60 seconds measured on a stop watch. Reflection of laser energy was determined when discoloration (ignition) appeared on the cardboard cylinder following laser activation. A new cardboard cylinder was used for each trial. Mean time to reflection was measured for each group in seconds. An analysis of variance (ANOVA) for repeated measures was used to compare times until ignition with a $P < 0.01$ set for statistical significance.

**Results**

Ignition of the cardboard cylinders resulting from laser reflectivity was noted in all groups. Visual damage was noted on the exterior of the Laser-Flex (brownish discoloration) and Laser-Guard (penetration of external sponge layer but none on the corrugated silver foil sheet). No visual damage was apparent on either the aluminum or copper foil wrap.

The Laser-Flex group had the greatest time (in seconds) to reflection in both the continuous ($21.3 \pm 21.4$ (± SD) and intermittent modes ($50.8 \pm 14.4$). The Laser-Guard wrapped tubes were less effective in preventing ignition of the cardboard cylinder (continuous = $4.8 \pm 2.3$ and intermittent = $10.6 \pm 5.0$) than the Laser-Flex group, but more effective than the aluminum and copper groups whose mean times to ignition for the continuous mode were $1.0 \pm 0.5$ and $1.6 \pm 1.1$, and for the intermittent mode $1.1 \pm 0.5$ and $1.7 \pm 1.2$, respectively (Table I). Analysis of variance revealed significance ($P < 0.01$) between the Laser-Flex and all other groups.

<table>
<thead>
<tr>
<th>Table I</th>
<th>Mean time for laser reflection (mean seconds ± SD)</th>
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<tbody>
<tr>
<td></td>
<td>Continuous</td>
</tr>
<tr>
<td>Laser-Flex™</td>
<td>$21.3 \pm 21.4$</td>
</tr>
<tr>
<td>Laser-Guard</td>
<td>$4.8 \pm 2.3$</td>
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<tr>
<td>Aluminum</td>
<td>$1.0 \pm 0.5$</td>
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<tr>
<td>Copper</td>
<td>$1.1 \pm 0.5$</td>
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**Discussion**

One of the unique properties of laser light is its collimation or lack of divergence, allowing for the concentration of its energy into a small diameter laser light spot. Consequently, if a laser beam strikes a polished surface (e.g., metallic foil wraps), the energy may be redirected onto other surfaces (e.g., tissue, sponges, instruments) which can be damaged or ignited. Typically, instruments used...
in laser surgery have a matte, burnished, or blackened finish to minimize this type of reflection. We questioned whether the metallic foil tape commonly used to cover the surface of flammable endotracheal tubes\(^6\) would significantly reflect or absorb laser energy. In addition, we asked whether products specially designed for laser resistance would minimize reflection.

Reflection is defined as the turning back of a beam of light, sound, or heat when it strikes a surface that it does not penetrate. The degree of reflection that occurs must take into account variables such as structure of the compound, thermal capacity, reflectivity coefficient, surface finish (polished, matte, or oxidized), and the characteristics of the reflected light. With the wavelength of CO\(_2\) in the infrared region (10,600 nm), it is estimated that the degree of reflectivity is similar for aluminum, copper, and silver, and somewhat lower for stainless steel.\(^7\) This would explain the similar responses of the ETT groups wrapped in aluminum or copper, but not those of the Laser-Guard group. The probable reason for the difference is that the Laser-Guard is externally covered with a watersaturated sponge layer that absorbs laser energy and inhibits reflection. The Laser-Flex group showed the longest time to reflection, probably because the stainless steel surface has a matte finish, thus scattering the laser energy. In addition, the greater thickness of the metal confers a greater heat capacitance than do the metallic foil wrappings.

Sosis and Dillon were the first to report laser reflectivity of laser-resistant products. They examined Rusch red rubber tracheal tubes wrapped with 3M No. 425 aluminum foil tape and Venture copper foil tape, a PVC tracheal tube wrapped with Laser-Guard protective coating, and a Mallinkrodt Laser-Flex tracheal tube. The tubes were straightened and centered within cardboard cylinders and the CO\(_2\) laser set to 40 W in the continuous mode. Based upon the times (seconds) to perforation of the cardboard cylinders in response to laser reflection, they concluded that the Laser-Guard (5.7 ± 2.18) and Laser-Flex (9.2 ± 3.4) tracheal tubes were less reflective than the copper (1.7 ± 0.9) or aluminum (1.4 ± 0.5) foil wrapped red rubber tracheal tubes.

We used the Sosis and Dillon study as a model with the following modifications: PVC tracheal tubes were used with the foil wraps, the wattage was lowered to 25 W, and the testing time to ignition was measured in both the continuous and intermittent laser modes. The results demonstrated that laser reflectivity, as measured by ignition of the cardboard cylinder, occurred with all test products. Even though the wattage used by Sosis and Dillon was almost double that used in our study, the times to ignition were similar, with the exception of the Laser-Flex tube in which we found the time to ignition by the reflected beam to be at least twice as long (Figure 2). It is important to note that in the Laser-Flex group, 7 out of 10 trials in the intermittent mode and 2 out of 10 trials in the continuous mode reached the preset time limit of 60 seconds without ignition occurring.

![Figure 2](image-url)

These results would indicate that the aluminum and copper foil tapes have a high degree of reflectivity for infrared wavelengths with more rapid reflection of the laser energy leading to ignition.\(^8\) The corrugated silver foil of the Laser-Guard and the thick stainless steel shaft of the Laser-Flex tracheal tube are both noted to have greater thermal capacity, thereby resulting in greater absorption and scattering of laser energy, and therefore, less reflection.\(^7\) Nevertheless, it should be noted that some degree of reflection did occur with each product, thus highlighting the fact that no tube currently marketed is totally nonreflective.

In clinical procedures where laser reflectivity is likely to occur, it seems prudent to use a product that possesses a greater resistance to CO\(_2\) laser reflectivity. It is our conclusion that the Mallinkrodt Laser-Flex endotracheal tube or the Merocel Laser-Guard laser-resistant wrap provide better protection against reflectivity.
REFERENCES


AUTHORS

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