A Comparison of Ocular Protective Measures During Carbon Dioxide Laser Laryngoscopy

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Objective: To determine the efficacy of various eye protection measures during carbon dioxide laser laryngoscopy.

Design: A standard medical mannequin was equipped with indicator paper over the eyes and subjected to multiple passes of direct carbon dioxide laser beam contact at 400-mm focal length with powers ranging from 2.5 to 4.0 W during simulated laser microlaryngoscopy. Several different eye protection materials, including silk tape, paper tape, cloth tape, occlusive dressing, and eye pads, were used to cover the eyes and tested for their degree of protection against the laser beam. Thermal injuries were quantified and compared among these protective materials.

Setting: Academic medical center.

Main Outcome Measure: Degree of eye protection against the laser beam injury on a scale of 0 to 4.

Results: The carbon dioxide laser beam at both 2.5 and 4.0 W produced considerable thermal damage to the indicator paper in the absence of any protective barrier. Among the adhesive protective barriers, moistened cloth tape was the most effective adhesive material against laser beam-induced thermal damage ($P<.001$). Silk tape and paper tape offered poor protection. Moist eye pads, although not adhesive and therefore unable to maintain eye closure, were very effective barriers against the laser beam. Dry paper tape and dry eye pads were imminently flammable.

Conclusion: A combination of moistened cloth tape to maintain eye closure coupled with placement of well-moistened cotton-based eye pads over the tape provides excellent eye protection during carbon dioxide laser laryngoscopy.

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Otolaryngologists frequently use a variety of lasers in a variety of otolaryngologic procedures. During microlaryngoscopy, the carbon dioxide laser has proved to be a valuable tool in the management of benign and malignant vocal cord lesions, subglottic stenosis, bilateral true vocal cord paralysis, supraglottic squamous cell carcinoma, and a variety of other specialized disease processes. The carbon dioxide laser has the advantage of being controlled from the microscope traveling in the form of a linear beam that projects into the laryngoscope while operating at some distance from the field. Using the micromanipulator, the laser beam can be aimed precisely with a variety of power settings, modes, and spot sizes to effect a controlled cutting or burning of the desired tissues with a relative sparing of surrounding tissues. However, the long length of the free beam from the microscope through the laryngoscope to the larynx also puts surrounding structures potentially at risk for inadvertent injury during laser laryngoscopy. Slight changes in microscope position or in the micromanipulator may lead to the beam aiming outside of the laryngoscope and onto the face or body of the patient. In some cases, the carbon dioxide laser beam may be reflected from instrumentation to surrounding parts of the patient’s body. While inadvertent contact between the laser beam and the facial skin may produce a burn, a much more potentially serious injury may arise from the laser beam contacting the patient’s eye. Carbon dioxide laser contact with the cornea may produce irreversible visual damage. Although such injuries are rarely reported, their effects are devastating.

Several methods have been suggested for protection of the eyes during carbon dioxide laser laryngoscopy. Some experts have recommended eye closure with paper tape or cloth tape while others have recommended against tape owing to the
fear of fire, favoring simple covering of the eyes with moistened cotton-based eye pads. Each of these different eye protection methods has advantages and disadvantages. However, to our knowledge, no systematic evaluation of different ocular protection methods with respect to the carbon dioxide laser beam during laryngoscopy has been reported. This study was specifically conducted to determine which of several methods afforded the best ocular protection during carbon dioxide laser laryngoscopy.

METHODS

In a standard operating room suite, a cardiopulmonary resuscitation mannequin was placed supine on the operating table in a standard surgical position for direct laryngoscopy (Figure 1). After exploration of potential materials sensitive to the effect of laser thermal injury, yellow card stock paper was identified as a suitable material because it showed this thermal injury with a high degree of visual contrast. To simulate the closed human eyelid complex, 1.5 × 2.0-cm segments of this yellow-high-contrast paper were then cut into ellipses.

A series of control “injuries” was obtained by first taping the yellow indicator paper to the eyes of the mannequin. Then, using the carbon dioxide laser (IL Med Unilase CO2 laser; Laser Solutions Inc, Basking Ridge, NJ) mounted on a Zeiss microscope (model No. OPMI Vario S8; Carl Zeiss Inc, Thornwood, NY) outfitted for standard microlaryngoscopy surgery, a laser beam (model No. OPMI Vario S8; Carl Zeiss Inc, Thornwood, NY) mounted on a Zeiss microsurgical system with a focal length of 400 mm was directed onto the protective material covering the yellow card stock eyelid prior to experimental laser burn. In each case, the right eye was subjected to a series of experimental laser burns at 2.5 W at the same focal length of 400 mm directed onto the protective material/indicator paper combination. For the same protective material, the left eye was subjected to a series of 4 laser burns at a power setting of 4.0 W. High-quality digital photographs were then taken of each protective material over the yellow card stock eyelid after the series of experimental burns and cataloged. This sequence was repeated for each protective material type.

At the conclusion of the experiments, each combination protective material covering the yellow card stock eyelid was then inspected for the severity of the laser burn through the protective material and/or onto or through the yellow card stock eyelid. The degree of burn to the yellow eyelid was rated on a scale of 0 to 4 as presented here.

<table>
<thead>
<tr>
<th>Injury Grade</th>
<th>Description</th>
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<tbody>
<tr>
<td>0</td>
<td>No visible damage to protective material or indicator paper.</td>
</tr>
<tr>
<td>1</td>
<td>Superficial damage to protective material.</td>
</tr>
<tr>
<td>2</td>
<td>Deep damage to protective material without evidence of indicator paper damage.</td>
</tr>
<tr>
<td>3</td>
<td>Damage penetrating protective material with damage to indicator paper (without complete penetration).</td>
</tr>
<tr>
<td>4</td>
<td>Damage to protective material with complete penetration of the indicator paper.</td>
</tr>
</tbody>
</table>

In addition, at the conclusion of each experimental burn, the mannequin itself was evaluated for laser injury (ie, penetration of the beam through the protective material, through the card stock, and into the plastic of the mannequin).

Results were tabulated in Microsoft Excel (Microsoft Corp, Redmond, Wash) and exported into SPSS version 10.0 (SPSS Inc, Chicago, Ill). The differences in severity of the laser burns for each of the protective methods were then statistically compared with the χ² test with exact Monte Carlo significance set at P<.05.

RESULTS

The composite results of the laser burn experiments according to each protective material type are displayed in the Table. Among the materials suitable to maintain eyelid closure, the cloth tape superficially moistened with water provided the best protection against laser injury for both the 2.5-W and 4.0-W power settings (P<.001 for both power settings). Paper tape provided the least effective barrier protection to the eye, easily transmitting the thermal energy of the laser beam through the tape to the deeper layer of yellow indicator paper, among the methods tested. Figure 1 and Figure 2 illustrate the typical laser burn injuries for various materials.
In addition, the cotton eye pad without water was a completely ineffective barrier protection from the laser. In fact, during the testing with the dry eye pad, the 4.0-W beam penetrated the full thickness of the dry eye pad, the full thickness of the yellow indicator paper, and even the full thickness of the mannequin “skin” during a single firing. This points out the potential serious danger from the laser beam during laser laryngoscopy. A small flame with plume induced by the laser was noted for both paper tape and for the dry eye pad, indicating tendency toward flammability. The completely moistened eye pad provided an extremely capable barrier against carbon dioxide laser penetration. Further testing illustrated the capability of the moist eye pad to withstand power settings up to 10.0 W.

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The eye may be in close proximity to the laser beam during several laser-based surgical procedures. These include laser facial skin resurfacing, laser resection of oral cavity lesions, and laser hair removal as well as laser laryngoscopy. While no ocular protection method may be universally adaptable to this wide variety of surgical procedures, it is clear that some form of eye protection is absolutely mandatory during all laser procedures. This applies to both the patient and operating room personnel. Serious ocular injuries have been reported for inadvertent contact between the laser beam in the eye in both patients and operating room staff even several feet away from the origin of the laser beam. In some cases, these injuries may be serious and irreversible.

During laser microlaryngoscopy, several equipment and operating factors may increase the chance of inadvertent injury to the patient’s eye. First, a carbon dioxide laser beam originates at a far distance, often 400 mm or more from the target tissue. As such, this laser beam must traverse free air from the microscope to the larynx. Should the beam become erroneously aimed or should it reflect from other structures, the patient or operating room personnel may be harmed by the beam. In addition, during laser microlaryngoscopy, the operating room is commonly darkened and the surgeon operates through the binocular microscope, intensely concentrating on the microscopic image. Other operating room personnel also frequently look through microscope oculars or at the display monitor. Thus, visual attention, and therefore to some degree vigilance, is likely to be focused away from the beam. A high degree of awareness is required in these cases to prevent accidental laser beam injury.

Several different methods of protecting the eyes during laser laryngoscopy have been proposed. All laser safety experts agree that some barrier must be placed over the closed eyelid such that if the laser beam were aimed at the eye, the barrier would absorb and therefore neutralize the laser beam. However, the type of barrier or protection method is not universally agreed on. First of all, some form of tape is usually required to maintain the lid in a closed position. Failure to mechanically close the lid and the placement of a barrier (such as the wet eye pad) on the surface of the eye may lead to corneal abrasion or exposure keratitis during the surgical case with equally disastrous consequences. However, placement of tape over the eyelid itself may be problematic because the tape is a potentially flammable material. Moistening the tape may also add to the degree of protection afforded by the tape, but it also may loosen the adhesive properties of the tape. Similarly, a completely occlusive plastic dressing such as Tegaderm provides an excellent seal over the eye because it is a configurable plastic sheetlike product, but because Tegaderm cannot hold moisture, it may subsequently be a flammable object in the path of the laser beam. If Tegaderm were

### Table. Thermal Injury Scores for Experimental Carbon Dioxide Laser Laryngoscopy Burns

<table>
<thead>
<tr>
<th>Protective Method</th>
<th>Mean Thermal Injury Rating*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2.5 W</td>
</tr>
<tr>
<td>Control</td>
<td>4.0</td>
</tr>
<tr>
<td>Tegaderm†</td>
<td>2.8</td>
</tr>
<tr>
<td>Durapore† tape (single layer)</td>
<td>2.0</td>
</tr>
<tr>
<td>Durapore tape (double layer)</td>
<td>2.0</td>
</tr>
<tr>
<td>Micropore† tape (dry)</td>
<td>3.0</td>
</tr>
<tr>
<td>Micropore tape (wet)</td>
<td>3.0</td>
</tr>
<tr>
<td>Cloth adhesive tape (dry)</td>
<td>2.0</td>
</tr>
<tr>
<td>Cloth adhesive tape (wet)</td>
<td>1.0</td>
</tr>
<tr>
<td>Curity‡ eye pad (dry)</td>
<td>2.0</td>
</tr>
<tr>
<td>Curity eye pad (wet)</td>
<td>0.0</td>
</tr>
</tbody>
</table>

*Four passes per setting.
†3M Healthcare, St Paul, Minn.
‡Tyco Healthcare Group LP, Mansfield, Mass.

**Figure 2.** Patterns of carbon dioxide laser injury for silk tape (A), cloth tape (B), and eye pad (C) methods. OD indicates right eye; OS, left eye.
to become ignited after beam contact, it would be very difficult to quickly remove from the eye given its extremely adhesive properties. Suggestions have been made to place paper tape over the eye to facilitate quick removal should a laser fire occur. However, again, the paper-based tape may be flammable and affords little eye protection because it is so thin as demonstrated by our data.

Some investigators have advocated the placement of the plastic scleral shell for corneal and ocular protection. However, placement of scleral shell is also not without potential complication, including corneal abrasion or the possibility of a retained scleral shell as a foreign body. The scleral shell has also been found to be relatively poor protective material against laser injury in that it may melt and transfer significant thermal energy from the beam to the eye.8

During the present experimental protocol, cloth tape in particular afforded excellent protection from laser beam penetration. In the dry state, that cloth tape did not ignite with either laser power setting. In addition, the cloth tape held moisture fairly well and when moistened, afforded even greater protection from the thermal injury of the laser beam. Thus, we believe that cloth tape is the preferred method of maintaining the eyelids in the closed position. Furthermore, the moistened cloth tape maintained its adhesive properties despite the placement of water on its surface, and this moisture added a second layer of laser protection.

In addition to maintaining eyelid closure with moistened cloth tape, we recommend that the eyes be covered by a new layer of water-soaked, cotton-based eye pads. During the procedure, care must be taken to make sure that the eye pads remain moist. This is especially evident given that a dry eye pad had a tendency to ignite into flame and afforded almost no protection from the laser beam: the laser beam at the 4.0-W setting completely penetrated the eye pad and caused subsequent severe deeper damage. Moist eye pads should not necessarily be used alone because they do not guarantee eyelid closure and may subject the cornea to abrasion. Furthermore, it is sometimes difficult to secure the position of the moist eye pads because tape does not stick particularly well to them. Therefore, a deeper layer of secondary protection, preferably with moistened cloth tape, is advisable.

Several factors should be considered when interpreting our data. First, some of these eye protection materials may be somewhat more flammable during the actual surgical procedure because there may be a leak of relatively higher concentrations of oxygen near the patient’s face during laser laryngoscopy procedures. This is especially true during Venturi jet ventilation cases. This higher concentration of oxygen in the air may lead to increased flammability of materials in the face of the laser beam. Second, we tested 2 power settings commonly used during our practice of laser laryngoscopy. Other higher power settings may be significantly more apt to cause thermal injury or penetrate eye protection methods. Beam intensity is a major factor in laser injury, and additional protective measures may be required when higher laser power levels are in use. Furthermore, we chose a pulse duration of 0.5 seconds, which is slightly higher than the usual range of 0.2 to 0.4 seconds used in the clinical setting. We purposely chose a longer pulse duration to exaggerate the estimation of potential ocular injury, accounting for variability in equipment and even temporary laser settings. Thus, the effectiveness of protective measures as detailed previously has an additional margin of safety attached to their recommendation.

One potential limitation of this study is the use of paper to simulate a cutaneous or corneal burn. Although we did not measure the exact temperature of the paper as it “burned,” paper will typically ignite at approximately 456°F (236°C), and on several occasions during the experiments an imminent ignition of the paper was noted. This implies that a significant amount of heat was transferred to create the visible “burn” in the card stock, thus implying a significant potential for cutaneous or corneal injury as evidenced by the card stock.

Eye protection during laser laryngoscopy must achieve 3 goals: (1) maintenance of eyelid closure during the case to prevent exposure keratitis, (2) protection of the cornea from abrasion from protective layers placed over the eye, and (3) formation of a barrier to laser beam penetration over the eye. The use of the eyelid closure maintained by moistened cloth tape covered by moistened eye pads offers 3 levels of protection for the cornea and globe from inadvertent carbon dioxide laser injury: the eyelid, the layer of tape, and the moistened eye pad. We believe that this triple barrier provides the greatest safety advantage among the available methods of eye protection during carbon dioxide laser laryngoscopy. In this era of high patient expectations and an emphasis on error prevention, otolaryngologists and all physicians using lasers in the office or operating room setting must be intimately familiar with laser safety protocols. Sustained vigilance, education of all operating room personnel, and continued critical evaluation of laser safety protocols offer the best protection against inadvertent ocular injury during laser laryngoscopy and during laser procedures in general.

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