KTP laser-resistant properties of the reinforced laryngeal mask airway

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Summary
We have assessed, in vitro, the effect of KTP laser strike on the reinforced laryngeal mask airway (RLMA) under a variety of conditions. At power densities normally encountered in clinical practice, using a divergent KTP laser beam, the RLMA could not be penetrated and did not ignite with laser strike. The RLMA was penetrated at a high power density of 6.94 W mm$^{-2}$ after 45–60 s. A flame appeared over the RLMA shaft at this power density after 12–35 s. The black marker line on the RLMA shaft was somewhat more vulnerable to the effects of laser strike. The flow of oxygen and nitrous oxide within the shaft did not appreciably alter the laser-resistant properties of the RLMA. The RLMA cuff was more vulnerable to laser strike than was the shaft and was penetrated at very low power densities. Filling the cuff with saline had a protective effect and penetration did not occur at power densities which caused penetration of air-filled cuffs (0.37 W mm$^{-2}$). (Br. J. Anaesth. 1997; 78: 594–600).

Key words

Laser surgery was introduced into otolaryngology in the early 1970s. Strong and Jako first used the carbon dioxide laser in laryngeal work. Since then the use of the laser has become widespread. The carbon dioxide laser is delivered by a bulky articulated arm or by coupling to an operating microscope. These delivery methods limit the manoeuvrability and access to tissue that the surgeon can achieve.

The Nd:Yag laser (yttrium-aluminium-garnet treated with neodymium ions pumped with a krypton arc lamp) was introduced in the 1980s. Its main advantage over the carbon dioxide laser is that it can be delivered by means of a more easily handled fiberoptic light cable. It has greater coagulative properties but less cutting ability than the carbon dioxide laser. Du Pont introduced the KTP laser in the 1980s. This laser uses an Nd:Yag laser to produce a beam at a wavelength of 1064 nm which is then passed through a potassium titanyl phosphate (KTP) crystal to produce visible green light at a wavelength of 532 nm. This light can be transmitted through a fiberoptic cable, producing a divergent beam, or through an operating microscope producing a coherent (parallel) beam. A divergent beam diffuses its energy over a progressively wider area as it travels away from the source, whereas a parallel beam imparts its total energy over the same area whatever the distance of the source from the target. Therefore, parallel KTP or carbon dioxide laser beams impart much higher power densities to the tissues they strike than does the divergent KTP laser. The KTP laser cuts better and faster than the Nd:Yag and coagulates better than the carbon dioxide laser. Tissues can therefore be cut, coagulated and vaporized with the same laser by varying power, exposure time and spot size. Unlike the Nd:Yag laser which needs an expensive shaped sapphire tip to produce good cutting, the KTP can achieve this using a bare fibre.

The KTP laser is now used extensively in ENT surgery for stapledectomy, tympanoplasty, reduction of turbinate and in functional endoscopic sinus surgery. Its greatest use is probably in oropharyngeal surgery where its vaporizing properties are more useful.

During laser surgery of the oral or laryngeal cavities, there is a serious risk of ignition of the tracheal tube. To avoid laser fire, special anaesthetic techniques and tracheal tubes have been designed, and several studies have examined the laser-resistant properties of such tracheal tubes.

Although the laryngeal mask airway (LMA) and the reinforced laryngeal mask airway (RLMA) are being used increasingly during laser surgery of the upper airway, there have been relatively few reports of their laser-resistant properties. Brimacombe and co-workers have reported on the incendiary properties of the RLMA to carbon dioxide lasers and found that it is resistant to penetration, ignition and combustion compared with PVC tracheal tubes.

To our knowledge, the incendiary characteristics of the RLMA to the KTP laser have not been studied previously. The main aim of this study was to assess if the RLMA is resistant in vitro to penetration and combustion using a divergent beam, at power densities normally encountered in our standard surgical practice. Second, we wished to determine the power density at which the RLMA would be penetrated or ignite.
Materials and methods

LASER SOURCE

A Laserscope KTP surgical laser system (Laserscope Inc, San Jose, CA, USA) was used to deliver the laser beam via a Laserscope Endostat optical delivery fibre (0.3 mm radius). This is a quartz thread covered by silicone cladding and a plastic-silicone jacket. The purpose of the cladding is to reflect light travelling within the fibre, and the jacket offers mechanical support. Before each experiment, the fibre was stripped and calibrated in accordance with the manufacturer’s instructions. The power output at source of the Laserscope surgical delivery system could be varied between 0 and 20 W.

The laser beam is divergent around the fibre core at 15° (that is 7.5° each side of the core). The fibre radius is 0.3 mm, so the area of laser strike at a distance d and thus the power density of the laser strike on the laryngeal mask is in accordance with equations (1–3) (personal communication, Rhys Llewellyn, European Marketing Manager, Laserscope):

\[
\text{Power density (W mm}^{-2}) = \frac{\text{power output of laser at source (W)}}{\text{area of laser strike (mm}^2)} \tag{1}
\]

\[
\text{Area of laser strike} = \pi(0.3 + x)^2 \tag{2}
\]

\[
x = d(\tan 7.5°) \tag{3}
\]

Therefore, on contact of the fibre with the shaft, the area of laser strike is 0.28 mm\(^2\); at a distance of 5 mm, the area is 2.88 mm\(^2\).

LARYNGEAL MASK AIRWAY

A set of RLMA (Intavent Ltd, Reading, UK) of standard dimensions were used: size 2.5, mean wall thickness 1.7 mm (range 1.55–1.85 mm; tolerance ±0.15 mm) and cuff wall thickness 0.55 mm (range 0.45–0.65 mm; tolerance ±0.1 mm). Each RLMA was labelled with its own identifying number (e.g. 031, 032, etc).

EXPERIMENTAL DESIGN

Each procedure was conducted under the same experimental design. The RLMA was held steady by a metal clamp on a metal stand. Gas flow through the RLMA was provided by attaching it to a standard co-axial breathing system from a Boyle’s machine. The laser-emitting fibre was held in place by a metal clamp on a second metal stand, allowing the distance (d) between the fibre and RLMA to be adjusted (eqn (3)). The laser beam was directed to the clear part of the shaft, between the metal rings. This was because the total area presented by the metal rings is relatively small and it was felt that under clinical conditions a laser would be more likely to involve the clear part of the tube. The metal rings were struck by the laser when the diameter of the area of laser strike exceeded the distance between the metal rings (i.e. greater than 1 mm). In each procedure, laser strike was continued either for a preset period of time (e.g. 20 s) or until an effect on the RLMA was seen. Video recordings of the experiments were made and any significant effects and the time at which they occurred were recorded.

The experimental procedures were designed to examine a sequence of questions.

EXPERIMENTAL PROCEDURES

Procedure A: at a power density normally encountered in standard practice, do different RLMA have similar laser-resistant characteristics?

This was the control to establish that the supply of RLMA was homogeneous. The RLMA was held free-standing in room air not attached to the anaesthetic system. Using a laser source power output of 10 W, the fibre was held at a distance of 5 mm from the shaft (power density 3.47 W mm\(^{-2}\)). Laser strike was maintained continuously for 20 s. A total of seven separate tubes were used, and each tube was subjected to at least two exposures at this power density.

Procedure B: what is the effect of increasing the power density by reducing the distance between the laser fibre tip and the RLMA shaft?

RLMA were held free-standing in room air. A laser source power output of 10 W was selected and laser strike was maintained continuously for 20 s. Tests were conducted at distances between the RLMA and laser fibre of 5 mm (power density 3.47 W mm\(^{-2}\)), 3 mm (power density 6.57 W mm\(^{-2}\)), 2 mm (power density 10 W mm\(^{-2}\)) and with the fibre in contact with the RLMA (power density 35.7 W mm\(^{-2}\)).

Procedure C: what is the effect if the laser strikes the radio-opaque black marker line on the RLMA shaft?

The RLMA was held free-standing in room air. A laser source power output of 10 W was selected with the fibre at a distance of 5 mm from the shaft (power density 3.47 W mm\(^{-2}\)). Laser strike was maintained continuously for 20 s with the laser aimed at the black line on the RLMA shaft.

Procedure D: does oxygen and nitrous oxide flow within the RLMA have any effect on the laser-resistant properties of the shaft?

A laser source power output of 10 W was selected, the fibre at a distance of 5 mm from the RLMA shaft as in experimental procedure A (power density 3.47 W mm\(^{-2}\)). The RLMA was attached to the anaesthetic system with a flow of oxygen 2 litre min\(^{-1}\) and nitrous oxide 4 litre min\(^{-1}\). Laser strike was maintained continuously for 20 s.

Procedure E: at what power density can the RLMA be penetrated or ignite?

Three separate groups of experiments (E1, E2 and E3) were performed.
Experiment E1 (effect of increasing power output at a fixed distance). The RLMA was connected to the anaesthetic system with oxygen 2 litre min\(^{-1}\) and nitrous oxide 4 litre min\(^{-1}\) flowing through it. The laser fibre was held at a distance of 5 mm from the shaft. Laser strike was continuous for up to 60 s. The effects of power outputs of 10 W (power density 3.47 W mm\(^{-2}\)), 15 W (power density 5.21 W mm\(^{-2}\)) and 20 W (power density 6.94 W mm\(^{-2}\)) were observed.

Experiment E2 (effect of increasing power output with laser fibre in contact with RLMA). The RLMA was connected to the anaesthetic system with oxygen 2 litre min\(^{-1}\) and nitrous oxide 4 litre min\(^{-1}\) flowing through it. The laser fibre was held in contact with the RLMA shaft and laser strike was continuous until an effect was observed. The effects of power outputs of 10 W (power density 35.7 W mm\(^{-2}\)) and 20 W (power density 71.4 W mm\(^{-2}\)) were noted. The laser fibre was pushed through the damaged RLMA and 20 W of power reapplied with oxygen and nitrous oxide flowing through the system and RLMA shaft.

Experiment E3 (effect of oxygen and air mix flowing through the RLMA). The RLMA was connected to oxygen 2 litre min\(^{-1}\) and air 4 litre min\(^{-1}\) flowing through the anaesthetic system. The laser fibre was held in contact with the RLMA shaft and a power output of 20 W was applied (power density 71.4 W mm\(^{-2}\)). After 45 s the laser fibre was pushed through the damaged RLMA and the power output of 20 W was reapplied to assess the effects of laser within the oxygen and air gas stream.

Procedure F: what is the effect of the laser on the RLMA cuff filled with air?

The RLMA was held in its clamp, free-standing in room air. The laser power output at source was set to 10 W. The cuff was filled with 12 ml of saline. First, the laser fibre was held 10 mm from the cuff and laser strike continued for 20 s. Second, the fibre was held 35 mm from the cuff and laser strike was continued for 60 s. Finally, the fibre was held 40 mm from the cuff and laser strike continued for 60 s.

Results

The result of procedure A was that there was no discernible effect of laser strike on the clear part of the shaft after continuous firing for 20 s. In procedure B (table 1), there was no penetration of the shaft with the laser strike, even at relatively high power densities. At a power density of 10 W mm\(^{-2}\) the surface silica layer gave a yellow–green “flare” within 7 s of being struck by the laser, a layer of silica ash then formed which seemed to prevent further penetration of the shaft by the laser beam. Higher power densities (35.7 W mm\(^{-2}\)) caused the surface to flare within 1 s: a flame then burned along the plastic sheath of the laser fibre, but there was no fire on the RLMA and after 20 s there was no penetration of the shaft.

In procedure C (table 2), at a power density (3.47 W mm\(^{-2}\)) which had no effect on the clear part of the shaft (power density 1.22 W mm\(^{-2}\)) and laser strike was continued for 20 s. Second, the laser fibre was held 20 mm from the cuff (power density 0.37 W mm\(^{-2}\)) and laser strike continued for 20 s. Third, the fibre was held 35 mm from the cuff (power density 0.13 W mm\(^{-2}\)) and laser strike was continued for 60 s. Finally, the fibre was held 40 mm from the cuff (power density 0.10 W mm\(^{-2}\)) and laser strike continued for 60 s.

### Table 1

<table>
<thead>
<tr>
<th>Power density (W mm(^{-2}))</th>
<th>Power at source (W)</th>
<th>Distance (mm)</th>
<th>Effect after 20 s</th>
<th>No. of separate RLMA tested</th>
<th>Total No. of tests</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.47</td>
<td>10</td>
<td>5</td>
<td>None</td>
<td>11</td>
<td>11</td>
</tr>
<tr>
<td>6.57</td>
<td>10</td>
<td>3</td>
<td>None</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>10.0</td>
<td>10</td>
<td>2</td>
<td>7 s: yellow-green flare</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>35.7</td>
<td>10</td>
<td>Contact</td>
<td>1 s: yellow-green flare</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>5–6 s: flame spread along plastic sheath of laser fibre (no flame or fire on RLMA)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>20 s: crater in tube wall filled with silica ash—no penetration of shaft</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Table 2

<table>
<thead>
<tr>
<th>Power density (W mm(^{-2}))</th>
<th>Power at source (W)</th>
<th>Distance (mm)</th>
<th>Effect after 20 s</th>
<th>No. of separate RLMA tested</th>
<th>Total No. of tests</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.47</td>
<td>10</td>
<td>5</td>
<td>1 s: instant flare</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>20 s: crater filled with silica ash, but no penetration</td>
<td></td>
<td></td>
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</tbody>
</table>
shaft (procedures A and B, table 1), laser strike on the black line caused an instant flare and after 20 s produced a crater filled with silica ash. This crater was similar to that produced at a power density of 10.0 W mm\(^{-2}\) on the clear part of the shaft (table 1), but subjectively, was somewhat deeper. There was no penetration of the RLMA.

In procedure D (table 3), at a power density of 3.47 W mm\(^{-2}\) (which had no effect in experimental procedures A and B), the flow of gases which support combustion within the tube did not change the laser-resistant properties of the shaft.

In procedure E (table 4), the RLMA shaft proved to be laser-resistant up to power densities of 5.21 W mm\(^{-2}\) for durations of 60 s.

In procedure E1, at a power density of 6.94 W mm\(^{-2}\), a yellow glow and smoke appeared over the surface of the shaft within 12 s, followed shortly by a flame along the laser fibre. At 35 s there was a yellow flame on the shaft; this did not spread away from the point of laser strike. The experiment was stopped after 45 s when a crust of silica ash had formed; this was removed to reveal that the shaft had been penetrated, with the metal rings broken.

In procedure E2, at a power density of 35.7 W mm\(^{-2}\), a flame appeared at 10 s spreading along the laser fibre, followed by a glow and a flame localized to the point of laser strike. A crust of silica ash formed. After 60 s when the experiment was stopped, examination revealed that when the crust of ash was removed, the shaft underwent penetration and the metal rings broken. At 71.4 W mm\(^{-2}\), there was an instant glow followed by a flame which spread over the surface of the shaft.

Simultaneously, smoke appeared within the lumen of the shaft. The experiment was stopped at 15 s when there was a spreading fire which was extinguished by a fire extinguisher. When the laser fibre was pushed through the hole in the RLMA, there was a near-instant conflagration with laser strike: the flame burned within the shaft both towards the cuff and retrogradely towards the anaesthetic machine. The cuff exploded with a loud bang. The gas flow was turned off and the fire extinguisher was applied, but despite this, an incandescent glow remained over the surface of the shaft for 45 s.

In procedure E3, at a power density of 71.4 W mm\(^{-2}\) with a mixture of oxygen and air flowing within the shaft, there was smoke within the shaft at 10–12 s, followed by a surface yellow flame and yellow glow inside the tube. At 45 s, the experiment was stopped: when the silica crust was removed, the tube was found to have been penetrated and the metal rings broken. Pushing the laser fibre through the hole in the shaft caused an instant glow and a flame at 10 s. It did not result in the conflagration seen when oxygen–nitrous oxide was used.

In procedure F (table 5), the air-filled cuff ruptured within 6 s at power densities as low as 0.37 W mm\(^{-2}\) (accompanied by a characteristic "pop" and cuff deflation). Continued firing of the laser (at 1.22 W mm\(^{-2}\) for up to 20 s) did not cause the ruptured cuff to ignite. With very low power densities (0.13 W mm\(^{-2}\)), the area of cuff struck by the laser darkened and slowly formed an "aneurysm": after 60 s of continuous firing, this area was found to be extremely brittle and disintegrated with the slightest manipulation. At the lowest power density (0.10 W mm\(^{-2}\) for

### Table 3 Experimental procedure D: effect of oxygen 2 litre min\(^{-1}\) and nitrous oxide 4 litre min\(^{-1}\) flow within the tube on the laser-resistant properties of RLMA

<table>
<thead>
<tr>
<th>Power density (W mm(^{-2}))</th>
<th>Power at source (W)</th>
<th>Distance (mm)</th>
<th>Effect after 20 s</th>
<th>No. of separate RLMA tested</th>
<th>Total No. of tests</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.47</td>
<td>10</td>
<td>5</td>
<td>None</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>5.21</td>
<td>15</td>
<td>5</td>
<td>No effect after 60 s</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>6.94</td>
<td>20</td>
<td>5</td>
<td>See text for description</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

### Table 4 Experimental procedure E: effect of high laser power densities on RLMA. *With laser fibre then pushed through hole made (see text); †oxygen 2 litre min\(^{-1}\), nitrous oxide 4 litre min\(^{-1}\); ‡oxygen 2 litre min\(^{-1}\) and air 4 litre min\(^{-1}\)

<table>
<thead>
<tr>
<th>Power density (W mm(^{-2}))</th>
<th>Power output at laser source (W)</th>
<th>Distance (mm)</th>
<th>Gas flow within RLMA</th>
<th>Effect</th>
<th>No. of separate RLMA tested</th>
<th>Total No. of tests</th>
</tr>
</thead>
<tbody>
<tr>
<td>Procedure E1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.47</td>
<td>10</td>
<td>5</td>
<td>O(_2)/N(_2)O(\uparrow)</td>
<td>No effect after 60 s</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>5.21</td>
<td>15</td>
<td>5</td>
<td>O(_2)/N(_2)O(\uparrow)</td>
<td>No effect after 60 s</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>6.94</td>
<td>20</td>
<td>5</td>
<td>O(_2)/N(_2)O(\uparrow)</td>
<td>See text for description</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Procedure E2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>35.7</td>
<td>10</td>
<td>Contact</td>
<td>O(_2)/N(_2)O(\uparrow)</td>
<td>See text for description</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>71.4</td>
<td>20*</td>
<td>Contact</td>
<td>O(_2)/N(_2)O(\uparrow)</td>
<td>See text for description</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Procedure E3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>71.4</td>
<td>20*</td>
<td>Contact</td>
<td>O(_2)/air(\uparrow)</td>
<td>See text for description</td>
<td>1</td>
<td>1</td>
</tr>
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</table>

### Table 5 Experimental procedure F: effect of laser on RLMA cuff filled with air. RLMA held free-standing in room air

<table>
<thead>
<tr>
<th>Power density (W mm(^{-2}))</th>
<th>Power at source (W)</th>
<th>Distance (mm)</th>
<th>Cuff filled with</th>
<th>Time to penetration (s)</th>
<th>Effect</th>
<th>No. of separate RLMA tested</th>
<th>Total No. of tests</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.22</td>
<td>10</td>
<td>10</td>
<td>Air</td>
<td>1–3</td>
<td>Rupture</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>0.37</td>
<td>10</td>
<td>20</td>
<td>Air</td>
<td>6</td>
<td>Rupture</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>0.13</td>
<td>10</td>
<td>35</td>
<td>Air</td>
<td>60</td>
<td>See text</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>0.10</td>
<td>10</td>
<td>40</td>
<td>Air</td>
<td>—</td>
<td>See text</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>
60 s), this aneurysmal area formed but was not brittle and did not disintegrate.

In procedure G (table 6), a power density which had caused explosive cuff rupture within 6 s in the air-filled cuff (0.37 W mm$^{-2}$), had no effect after 60 s of continuous firing on the saline-filled cuff. At the highest power density used which had caused explosive rupture of the air-filled cuff within 3 s (1.22 W mm$^{-2}$), the saline-filled cuffs lasted between 5 and 11 s before (non-explosive) penetration caused saline to leak out in a small jet. There was less subsequent deflation compared with the air-filled cuff, as some saline remained in the cuff.

### Discussion

At laser power outputs and at distances of the laser fibre tip from the RLMA normally encountered in clinical practice, the RLMA was not penetrated or ignited by KTP laser strike. While some surface changes did occur, the layer of silica ash which formed appeared to protect the RLMA shaft from further damage (procedure B; table 1). However, the black line and lettering on the RLMA shaft were more vulnerable to the effects of the laser. Longer exposures to laser strike had a detrimental effect: a power density of 6.57 W mm$^{-2}$ for 20 s had no effect (table 1), but a slightly higher power density of 6.94 W mm$^{-2}$ for 60 s caused shaft penetration (table 4). Similarly, a power density of 35.7 W mm$^{-2}$ for 20 s caused only surface changes (table 1), but after 60 s caused penetration (table 4). The air-filled cuff ruptured rapidly on laser contact at very low power density of 250 W mm$^{-2}$, but a slightly higher power density of 6.94 W mm$^{-2}$ caused penetration (table 4). The air-filled cuff ruptured rapidly on laser contact at very low power density of 250 W mm$^{-2}$, but a slightly higher power density of 6.94 W mm$^{-2}$ caused penetration (table 4).

Fried, Mallampati and Caminear$^{10}$ studied the effects of KTP laser strike on a selection of tracheal tubes. Using only one (extremely high) power density of 250 W mm$^{-2}$ for 60 s, they found the following tubes to ignite within 31 s: unwrapped PVC tubes (Sheridan and Mallinckrodt), unwrapped red rubber tubes (Rusch) and metallic-coated silicone tubes (Xomed Laser Shield). Only red rubber tubes wrapped with aluminium foil and corrugated stainless steel tubes (Mallinckrodt Laser-Flex) were resistant to the laser at this power density (although the silicone-covered corrugated steel tubes (Bivona Fome-Cuff) did suffer surface changes). The power density used in this study was different from that used in our study and direct comparison is therefore difficult, but the fact that red rubber tubes wrapped with aluminium foil and corrugated stainless steel tubes did not ignite suggests that these may be somewhat safer than the RLMA to laser strike. It is interesting that Fried, Mallampati and Caminear$^{10}$ also found the black marker line of the tracheal tubes to be less laser-resistant than the shaft.

Brimacombe and colleagues$^{12,13}$ tested the incendiary properties of the RLMA to carbon dioxide laser strike, and the results were similar to ours, although the relevant power densities differed with the different laser used. At 23.5 W mm$^{-2}$, the shaft was penetrated after 20–30 s but there was no ignition. Brimacombe and colleagues noted a layer of silica ash sitting on top of the crater, apparently “protecting” the shaft from further penetration or ignition (similar to our results in table 1). However, at very high powers (980 W mm$^{-2}$), the RLMA did ignite almost immediately. The cuff was also found to be less resistant, being penetrated within 5 s, but Brimacombe and co-workers did not test the effect of saline in the cuff or of laser on the black marker line.

Our study was an in vitro bench study. In the clinical situation, the risk of flammability may be affected by the presence of surrounding tissue or small particles of blood which may act to absorb laser energy and so cause ignition at lower power densities than the RLMA itself.

Our study provides no direct comparison of the RLMA with tracheal tubes to laser strike. There is controversy as to which tracheal tube is the most laser-resistant and which should ideally be compared with the RLMA.$^{6–10}$ Recognizing that RLMA are used by many anaesthetists in laser surgery of the upper airway, our main purpose was to document the laser-resistant properties of the RLMA alone, by using several experimental procedures in repeated studies. Further experiments of a different design are needed to compare the RLMA with tracheal tubes.

Our study was limited in that not every combination of conditions was tested. For example, the black marker line was tested at only one power density (table 2), and the effect of oxygen–nitrous oxide on laser strike on the cuff was not assessed. However, we feel that designing the experimental procedures to answer a sequence of questions enabled us to draw more practical conclusions from the study. For example, we can conclude with confidence that at a power density which does not affect the shaft (table 1), striking the black line increased the vulnerability of the RLMA (table 2); oxygen–nitrous oxide did not have such a marked effect (table 3).

We have attempted to emulate the laser strike which might normally occur in clinical practice. We have also been careful to express our results in terms of the incident laser power density which we believe is the relevant variable that determines outcome. Some previous studies have not adhered to this approach so rigorously.$^{9,13}$ Thus in most of the experiments, submaximal power outputs were used at distances of
2–5 mm from the shaft and 10–20 mm from the cuff. Most other studies also appear to have examined a different question, namely: “Does the RLMA or tracheal tube ignite at all?”

We do not think that this is a very useful question if the RLMA is then examined at power densities not found in clinical practice. We did, in fact, examine the effects under more extreme conditions and our conclusion does not differ in this respect from that which might be predicted: virtually any device will ignite or be penetrated if the laser strike is powerful enough.

Based on our findings, several recommendations may be made on the safe use of the RLMA in the presence of the divergent KTP laser.

1. The surgeon should clearly exercise caution and avoid direct laser strike on the RLMA shaft or cuff. This risk is minimized if a Boyle–Davis gag without the Doughty modification is used and the gag is opened as widely as possible: in this situation neither the RLMA cuff nor the shaft can be seen.

The risk of airway obstruction using an unmodified gag might, however, be high, and if this is the case then it would be sensible to use a modified gag and to protect the RLMA shaft by covering the slit with a dampened gauze or swab. The power output used should be the minimum required and laser duration should be limited. In this way, the risk of penetration of the shaft by the laser (which occurred in this study after 45–60 s at a power output of 6.94 W mm⁻² and higher; table 4) is minimized.

2. Consideration should be given by the manufacturers to produce RLMA in which there is no black marker line or lettering, or in which this is placed much higher up the shaft than it is at present. The purpose of the lettering is to identify the device as an RLMA (probably unnecessary), but more importantly, to identify its size. The purpose of the black line is to identify the midline of the shaft: when the device is inserted, this line should ideally be central and point cranially. It might at first be thought that this line serves a very important function. However, in a reinforced laryngeal mask, which has a flexible shaft, the portion of the shaft and so also the black line lying outside the mouth varies considerably and as such cannot accurately indicate the way in which the shaft or cuff is lying inside the mouth. The benefits of retaining the black line and lettering appear to be outweighed by the reduced ability of the RLMA to resist laser strike (table 2). Therefore, it is our contention that, for use with laser surgery to the head and neck, RLMA without the black line should be used.

3. This study lends no direct support to the notion that the use of gases which support combustion (i.e. oxygen and nitrous oxide) markedly reduced the laser-resistant properties of the RLMA (table 3). It is clear that under some, extreme circumstances ignition can occur and it would therefore be prudent to consider using only air–oxygen mixtures rather than oxygen–nitrous oxide during maintenance of anaesthesia, unless there is a compelling reason to use nitrous oxide.

4. The cuff is more vulnerable to laser strike than the shaft (table 5). Filling the cuff with saline affords protection and therefore is the safe method in the presence of lasers. Consideration might also be given to the use of methylene blue or a coloured inert indicator so that the operator knows if the cuff has ruptured. The disadvantages of using saline in the cuff are that the manufacturers only recommend filling the cuff with air and as not all of the saline can be withdrawn from the cuff after use, this may cause cuff rupture during autoclaving. The cost-benefit balance of using saline thus remains to be determined.

5. With the increasing use of lasers in clinical practice and especially with regard to tubes marketed specifically for use in laser surgery, it would be desirable that in future, manufacturers tested for and published tolerance levels of their devices to laser strike from a variety of lasers at different power densities.

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References


