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What is This?
Coblation lesion formation in a porcine tongue model

Nathan L. Salinas, MD, and Jose E. Barrera, MD, Fort Sam Houston and Lackland Air Force Base, TX

Sponsorships or competing interests that may be relevant to content are disclosed at the end of this article.

ABSTRACT

OBJECTIVE: To investigate, in a porcine tongue model, the lesions created by coblation to define the optimal application of this method in treating the enlarged tongue base in patients with obstructive sleep apnea syndrome.

STUDY DESIGN: A prospective, experimental animal study.

SETTING: Military medical center.

SUBJECTS AND METHODS: Fifteen fresh porcine tongue specimens were injected with normal saline, and a single coblation probe was applied to the tongue specimens to create multiple submucosal lesions at specific energy settings. Control lesions were created without the use of saline injections. After creating the lesions, the porcine tongue specimens were sectioned and examined grossly. Size and character of lesions were recorded for each of the specimens and were compared across energy settings.

RESULTS: The energy applied at each setting was calculated on the basis of watts multiplied by treatment time. Coblation with saline injection created visible lesions with an average lesion area of 1.20 to 2.87 cm². The average lesion area increased as setting increased. Without saline injection, the average lesion area was 0.15 to 0.8 cm².

CONCLUSION: The porcine tongue model describes the relationship between lesion size and cold ablation device settings. Setting, but not time, significantly affects lesion size. The coblation setting and treatment time directly impact the amount of energy delivered. Additionally, submucosal normal saline injection significantly increases lesion size at all settings and application times. Given the average lesion diameter described in this study, placing lesions 1 cm apart will optimize the area affected by coblation while minimizing lesion overlap.

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Obstructive sleep apnea syndrome (OSAS) is thought to be caused by an anatomic narrowing of the upper airway during sleep, and one of the sites of obstruction in patients with OSAS can be an enlarged tongue base. Radiofrequency volumetric reduction of the tongue base is a widely used technique for treatment of OSAS.¹⁻⁴ Cold ablation (coblation), also known as plasma-mediated radiofrequency ablation, is a specific type of radiofrequency ablation available to address the enlarged tongue base in patients with OSAS.⁵ Coblation uses oscillating electrical current to disrupt surrounding tissue. This process begins when electrodes at the tip of the coblation probe emit radiofrequency energy within the target tissue. This energy is transmitted through a conductive medium, usually normal saline. The radiofrequency excites the saline solution, thereby creating a field of electrically active sodium ions that are able to dissociate tissue molecular bonds. Coblation generates relatively low tissue temperature (40-70°C) as compared with standard electrosurgery (400-600°C). Additionally, coblation operates at a much lower frequency (100 kHz) than conventional electrosurgery generators (350-2000 kHz).⁶,⁷ These properties allow ablation of targeted soft tissues with preservation of surrounding tissues.

Yucatan minipigs and Yorkshire land-raised cross (Sus scrofa) have similar tongue size and shape when compared with humans, and the porcine model has been used effectively to study percutaneous radiofrequency volumetric reduction of the tongue.¹⁻⁴ Coblation has been used for volumetric reduction of the tongue as well as soft palate and found to be a safe and effective surgical technique in humans.²⁻⁵,⁹,¹⁰ However, precise description of lesion formation with coblation has not been well studied in the tongue base. Therefore, it is important to investigate size and character of the submucosal lesion created to define the optimal surgical technique to reduce tongue volume by this method. The Coblator Reflex Ultra 65 Plasma Wand (ArthroCare ENT, Sunnyvale, CA) is a commercially available single-probe plasma-mediated radiofrequency ablation device designed for tongue base reduction. Detailed knowledge of the effect of this device is essential to establish evidence-based criteria for the application of this device. This article describes the lesions formed with coblation in a porcine tongue model.

Methods

This study was conducted at the Department of Otorhinolaryngology, Head, and Neck Surgery at Wilford Hall Medical Center, Lackland Air Force Base in Texas. Expedited
institutional review board approval was obtained through the 59th Medical Wing Clinical Research Division animal research center at Lackland Air Force Base.

Fifteen fresh Yucatan minipigs and Yorkshire land-raised cross (*Sus scrofa*) tongue specimens were obtained from the 59th Clinical Research Division animal laboratory from animals that were euthanized. A submucosal injection of 1 to 2 mL of normal saline was made into the base of each porcine tongue specimen at each lesion site immediately before coblation was applied. The probe of the Coblator Reflex Ultra 65 Plasma Wand was inserted submucosally at multiple positions in each tongue: 1 cm posterior and anterior to the circumvallate papillae on each side of the midline (Fig 1). The control lesion was the final site created in the mid-tongue. The probe was inserted to similar depth for each of the specimens as judged when the mucosa contacted the plastic stop. The Coblator II generator (ArthroCare ENT) produces energy at five settings: 2, 3, 4, 5, and 6. This energy was applied for a specific treatment time (10, 15, or 30 seconds) through the coblation probe to create each lesion. For each setting and time, applying coblation without preinjection of normal saline created a control lesion. Watts for each setting based on manufacturer setting information ranged from 50 to 190, as shown in Table 1.11

After creating the lesions, the pig tongue specimens were immediately sectioned in the sagittal plane and examined grossly. Lesion diameter (maximal anterior to posterior distance in millimeters) and lesion depth (maximal dorsal to ventral height in millimeters) were measured and recorded in an electronic spreadsheet program. By treating each lesion as a rectangle, the average area of each lesion was calculated as the product of depth (mm) and diameter (mm). This calculation was converted to cm² by dividing this product by 100. Because only one control lesion was created for each time and setting, results were analyzed with the Mann-Whitney *U* test, nonparametrically comparing the spread of data in saline and control groups. The null hypothesis described the lesion size as being no different between groups. Analysis of variance (ANOVA) was also performed to analyze time and setting to determine if these variables showed a difference in relation to lesion size. Statistical significance was established as *P* < 0.05. Additionally, subjective findings (e.g., heterogeneity, homogeneity, color change) were noted for each of the specimens. Digital photography was used to document the lesions.

### Results

#### Gross Findings

Submucosal lesion color change from pink to homogenous whitish color was noted after the lesions were formed with the coblation device (Fig 2). The lesions appeared elliptical, centered at the probe tip, and did not involve the mucosal surface of the tongue specimens.

#### Energy

Joules were calculated as the product of estimated watts at each setting and the time in seconds. The approximate amount of energy in joules for each setting and time is shown in Table 1.

#### Lesion Size

Tables 2 to 4 show the mean submucosal lesion depth, diameter, and area, respectively, at each setting for each treatment time. Corresponding control (no saline group) lesion depth, diameter, and area were recorded as well. The saline injection group demonstrated lesion depths ranging from 20 to 30 mm (average 22.7±2.8 mm), lesion diameter ranging from 4 to 12 mm (average 5.3±1.1 mm), and lesion area ranging from 0.80 to 3.24 cm² (average 1.20±0.87 cm²). The lesion size increased as coblator setting increased, with maximal lesion area seen at setting 6 for 15 seconds: average lesion area at this setting 2.87 cm². Increased treatment time did not significantly affect the average lesion size. The control group demonstrated lesion depth ranging from 12 to 20 mm, lesion diameter ranging from 1 to 4 mm, and lesion area ranging from 0.15 to 0.80 cm². The differences be-

![Figure 1](https://example.com/figure1.png) **Figure 1** Dorsal view of porcine tongue specimen with the planned lesions marked immediately before lesion formation anterior and posterior to circumvallate papilla (arrowhead). The epiglottis is seen at 12-o’clock position, with the anterior tongue at the 6-o’clock position.
When we used the Mann-Whitney U test to compare saline and no saline (control) groups, we found that the saline injection was associated with statistically greater differences in lesion depth ($P < 0.0001$), diameter ($P < 0.0001$), and area ($P < 0.0001$).

Using area as the outcome variable, we performed a two-factor ANOVA to evaluate the effect of time and setting. There was no significant main effect of time ($P < 0.082$), but there was a significant main effect of setting on lesion size ($P < 0.0001$). There was no significant interaction term ($P < 0.113$).

Applying a Bonferroni correction, alpha was set at 0.017 rather than 0.05 to account for multiple comparisons as single factor ANOVA was used to more closely examine the effect of setting at the different treatment times. These ANOVAs revealed no significant effect of setting when the treatment time was 10 seconds ($P < 0.086$); however, there was a significant main effect when the treatment time was 15 seconds ($P < 0.003$) and 30 seconds ($P < 0.012$). Post hoc analysis showed that at 15 seconds’ treatment time, setting 6 was different from settings 2, 3, 4, and 5, whereas at 30 seconds’ treatment time, setting 6 was different from settings 2, 3, and 4, but not 5.

**Discussion**

On the basis of these results, coblation produces predictable lesions in the porcine tongue model. The lesions that were formed could be distinguished from surrounding unablated tissue by the color change from pink to white. With a greater depth than diameter, the lesions formed an elliptical or rectangular shape, which correlates with other descriptions of the lesions that radiofrequency devices create.

In the porcine tongue model, saline injection is associated with a statistically significant difference in lesion size across all settings and times ($P < 0.0001$) compared with...
control lesions formed without saline injection. The increased effect gained by the addition of saline is likely the result of the coblation device’s mechanism of action, which uses a conductive medium to create a field of active ions to dissociate molecular bonds and, therefore, ablate soft tissue. Absence of this medium could potentially limit the effectiveness of coblation and result in suboptimal lesion formation.

ANOVA showed a significant main effect of setting but not time on lesion area. Post hoc analysis identified the significant effect of setting at 15 and 30 seconds but no significant effect of setting at the shorter ablation time of 10 seconds. Setting 6 demonstrated statistically significant larger lesion sizes at the higher treatment times. The maximal lesion area was achieved at setting 6 for 15 seconds (2.87 cm²). Setting 6 at 15 seconds delivers approximately 2850 J to each lesion site as described in Table 1. Without saline, maximal lesion area (0.80 cm²) was achieved at settings 4 and 5 for 15 seconds, which deliver 1650 and 2250 J, respectively.

As seen in the current study, a distinct advantage of coblation is that different settings and treatment times can be manipulated to generate predictable lesion size, which is important for understanding optimal application of coblation to the tongue base. The only publication describing single-probe coblation to the tongue base in humans used the Coblator II generator with the Reflex Ultra 55 Plasma Wand to apply energy at setting 6 for 20 seconds at 6 to 10 sites in the tongue base. Additional treatment sessions were performed based on the surgeon’s clinical judgment.

### Table 3
Mean lesion diameter for saline groups and the lesion diameter for the control groups at each setting and time

<table>
<thead>
<tr>
<th>Setting</th>
<th>Time (seconds)</th>
<th>Saline diameter, mm</th>
<th>Control diameter, mm</th>
<th>Difference</th>
<th>95% confidence interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>10</td>
<td>6</td>
<td>2</td>
<td>4</td>
<td>1.40-6.60</td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>7.75</td>
<td>3</td>
<td>4.75</td>
<td>0.57-8.93</td>
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<tr>
<td></td>
<td>30</td>
<td>6.5</td>
<td>2</td>
<td>4.5</td>
<td>1.45-7.55</td>
</tr>
<tr>
<td>3</td>
<td>10</td>
<td>7.25</td>
<td>2</td>
<td>5.25</td>
<td>3.73-6.77</td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>7</td>
<td>3</td>
<td>4</td>
<td>1.75-6.25</td>
</tr>
<tr>
<td></td>
<td>30</td>
<td>5.25</td>
<td>2</td>
<td>3.25</td>
<td>2.45-4.05</td>
</tr>
<tr>
<td>4</td>
<td>10</td>
<td>7.5</td>
<td>3</td>
<td>4.5</td>
<td>2.91-6.09</td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>5.5</td>
<td>4</td>
<td>1.5</td>
<td>-0.55 to 3.55</td>
</tr>
<tr>
<td></td>
<td>30</td>
<td>6</td>
<td>2</td>
<td>4</td>
<td>1.75-6.25</td>
</tr>
<tr>
<td>5</td>
<td>10</td>
<td>7.75</td>
<td>2</td>
<td>5.5</td>
<td>3.36-8.14</td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>7.5</td>
<td>4</td>
<td>3.5</td>
<td>1.91-5.09</td>
</tr>
<tr>
<td></td>
<td>30</td>
<td>6.5</td>
<td>2</td>
<td>4.5</td>
<td>1.74-7.26</td>
</tr>
<tr>
<td>6</td>
<td>10</td>
<td>7.75</td>
<td>2</td>
<td>5.75</td>
<td>2.47-9.03</td>
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<tr>
<td></td>
<td>15</td>
<td>11</td>
<td>1</td>
<td>10</td>
<td>8.70-11.30</td>
</tr>
<tr>
<td></td>
<td>30</td>
<td>9.75</td>
<td>2</td>
<td>7.75</td>
<td>5.75-9.25</td>
</tr>
</tbody>
</table>

Difference represents the mean difference between the lesion diameters and the control lesion diameter.

### Table 4
Mean lesion area across saline groups and lesion area across control groups at each setting and time

<table>
<thead>
<tr>
<th>Setting</th>
<th>Time (seconds)</th>
<th>Saline area, cm²</th>
<th>Control area, cm²</th>
<th>Difference</th>
<th>95% confidence interval</th>
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</thead>
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<tr>
<td>2</td>
<td>10</td>
<td>1.36</td>
<td>0.30</td>
<td>1.056</td>
<td>0.50-1.61</td>
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<td></td>
<td>15</td>
<td>1.90</td>
<td>0.36</td>
<td>1.54</td>
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<td></td>
<td>30</td>
<td>1.45</td>
<td>0.36</td>
<td>1.09</td>
<td>0.29-1.89</td>
</tr>
<tr>
<td>3</td>
<td>10</td>
<td>1.70</td>
<td>0.24</td>
<td>1.46</td>
<td>1.12-1.80</td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>1.71</td>
<td>0.36</td>
<td>1.35</td>
<td>0.42-2.78</td>
</tr>
<tr>
<td></td>
<td>30</td>
<td>1.20</td>
<td>0.28</td>
<td>0.92</td>
<td>0.58-1.26</td>
</tr>
<tr>
<td>4</td>
<td>10</td>
<td>1.91</td>
<td>0.60</td>
<td>1.31</td>
<td>0.93-1.86</td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>1.33</td>
<td>0.80</td>
<td>0.5325</td>
<td>-0.70 to 3.11</td>
</tr>
<tr>
<td></td>
<td>30</td>
<td>1.53</td>
<td>0.34</td>
<td>1.19</td>
<td>0.58-1.80</td>
</tr>
<tr>
<td>5</td>
<td>10</td>
<td>2.11</td>
<td>0.32</td>
<td>1.7875</td>
<td>0.99-2.58</td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>1.96</td>
<td>0.80</td>
<td>1.155</td>
<td>0.65-1.66</td>
</tr>
<tr>
<td></td>
<td>30</td>
<td>1.76</td>
<td>0.36</td>
<td>1.4</td>
<td>0.73-2.07</td>
</tr>
<tr>
<td>6</td>
<td>10</td>
<td>2.16</td>
<td>0.36</td>
<td>1.8</td>
<td>0.81-2.80</td>
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<tr>
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<td>2.87</td>
<td>0.15</td>
<td>2.715</td>
<td>2.23-3.20</td>
</tr>
<tr>
<td></td>
<td>30</td>
<td>2.32</td>
<td>0.24</td>
<td>2.08</td>
<td>1.48-2.68</td>
</tr>
</tbody>
</table>

Difference represents the mean difference between the saline lesion area and the control lesion area.
amount of energy that this regimen delivers is not reported but based on our calculations would be somewhere between 22,800 J (setting 6 for 20 seconds at 6 sites) and 38,000 J (setting 6 for 20 seconds at 10 sites) because setting 6 uses approximately 190 W (Table 1). In Greene’s series of 250 patients treated with coblation of the tongue base, there were no reported perioperative complications, including sensory or motor defects, even when the lesions were occasionally less than 10 mm apart.

However, as described in our current study, submucosal saline injection has a significant effect on lesion size. Although Greene injected the tongue with an unspecified amount of one percent lidocaine with epinephrine and saline gel was applied to the probe tip before the probe was inserted, no submucosal saline injections were described with this treatment regimen. Given the decreased lesion size in the absence of concomitant submucosal saline injection seen in our study, it is likely that the lesions created using Greene’s protocol did not actually overlap even when probe insertion sites were closer than 10 mm.

At the same time, although Greene states that tongue base coblation decreased snoring and daytime somnolence as well as improved apnea-hypopnea index (AHI), he does not describe a specific rate of success. Furthermore, tongue base coblation was often used in conjunction with uvulopalatopharyngoplasty or surgery to relieve nasal obstruction. Therefore, the optimal energy delivery as a primary or adjunctive procedure is not known for this treatment modality, and Greene acknowledges that further study is necessary to define an optimal protocol for energy delivery.

More extensive studies in which the authors used tongue base radiofrequency have been performed and should be considered when discussing the treatment regimen for coblation tongue base reduction. Three different treatment approaches for tongue base radiofrequency ablation have been described: single session treatment, multiple session treatment, and transcervical high-energy treatment.

Nelson and Barrera described 10,500 J as an effective single treatment dose when radiofrequency is used for tongue base volumetric reduction. Improvement in AHI, Epworth Sleepiness Scale scores, supine AHI, oxygenation, percentage of rapid eye movement sleep, and respiratory arousal index was found with a minimal complication rate described as superficial mucosal ulcers and taste alterations in 2 percent of patients. The overall response rate was 45 percent, with a 58 percent response rate in moderate OSA. Woodson et al13 delivered an average 13,994 ± 5459 J of total energy to individual patients over multiple treatment sessions and reported significant reduction in AHI in 20 percent of the subjects. This regimen was associated with multiple albeit transitory complications, including tongue edema, mucosal erosion, tinnitus, paresthesias, and referred pain. Additionally, Blumen et al14 applied transcervical radiofrequency energy to the tongue base with a mean of 14,288 ± 3251 J per session. This study showed improvement in AHI, mean oxygenation, and sleepiness, but it was noted that additional studies are needed to correlate objective clinical efficacy with the dose per lesion site and the number of lesion sites per session.

Our study addresses dose per lesion at a given energy setting and treatment time. In addition, setting and size of lesion are correlated. This novel finding can be applied to optimize clinical efficacy using coblation. In addition, by defining how much energy is applied with each setting and treatment time, care can be taken to avoid overtreating the tongue base because this could result in complications without additional benefit. Optimal application of coblation should maximize lesion size while minimizing energy delivery. For instance, more than 10,500 J, considered a potentially excessive amount of energy in radiofrequency literature, would be delivered when forming four lesions at setting 6 for 15 seconds (11,400 J), at setting 4 for 30 seconds (13,200 J), at setting 5 for 30 seconds (18,000 J), or at setting 6 for 30 seconds (22,800 J). Although no gross complications were observed at any of the treatment doses described in this porcine tongue model, excessive radiofrequency energy to the tongue base may result in previously published complications. Therefore, setting 6 for 10 seconds appears to be an optimal dose to maximize lesion area while avoiding excessive energy delivery to the tongue base. Additionally, setting 6 for 15 seconds achieves maximal lesion area, although energy delivery would be slightly more than 10,500 J.

A limitation of this study is that the tongue specimens were removed from the pigs before coblation and sectioning was performed immediately instead of after a delay interval, which prevents comment on lesion changes over time. Future study to evaluate the evolution of the lesion within a live porcine model would be valuable in order to determine the clinical significance of the findings described in this study.

Another limitation of this study is that only four treatment lesions were created in each porcine tongue specimen, centered on the circumvallate papillae, rather than multiple lesions dorsal to this landmark as is more commonly performed in clinical practice. Although the goal of this study was not to direct exact placement of lesions across the tongue, our study of these four lesions can infer the pathophysiology of lesion formation occurring further dorsal in the tongue base.

Finally, because only one control lesion was created for each setting and time, comparison between saline lesions and control lesions within groups is limited. However, across the groups, saline injection is associated with statistically higher differences in lesion depth, diameter and area, which may be explained by the pathophysiology of lesion formation with coblation.

Conclusion

The porcine tongue model describes the relationship between lesion size and cold ablation device settings. Setting, but not time, significantly affects lesion size. The coblation
setting and treatment time directly impact the amount of energy delivered. Creating lesions with coblation at setting 6 for 10 or 15 seconds would maximize lesion area while minimizing energy delivery to the tongue base. Given the potential morbidity associated with excessive energy, greater energy delivery does not appear to be justified in this porcine tongue model. Additionally, submucosal normal saline injection significantly increases lesion size at all settings and application times. Given the average lesion diameter described in this study, placing lesions one centimeter apart will optimize the area affected by coblation while minimizing lesion overlap.

Acknowledgments

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Author Contributions

Nathan L. Salinas, conception, acquisition, analysis, interpretation, drafting, revising; Jose E. Barrera, conception, design, analysis, revising, final approval.

Disclosures

Competing interests: Jose E. Barrera, owner: Endomir Sleep Solutions, LLC; royalty agreement as inventor for Sleep MRI: Stanford University.

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