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What is This?
The macroscopic and microscopic effects of radiofrequency injury in the porcine tongue: A pilot study

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

ABSTRACT

OBJECTIVE: Current treatment protocols for obstructive sleep apnea/hypopnea syndrome with radiofrequency ablation of the base of the tongue are empiric. Injecting local anesthetics and saline into the treatment site is believed to shorten treatment duration and improve results. Our objective is to compare lesions at different energy levels, both macroscopically and histologically, and to determine if electrolyte solution injection results in a larger lesion.

STUDY DESIGN: A prospective, experimental animal study.

SETTING: University-affiliated institution.

SUBJECTS AND METHODS: Five pigs each received four treatments on the right and four on the left side of the tongue. Three of four treatments were applied sequentially by increasing length of exposure (15, 30, or 60 seconds), and the fourth was conducted over 15 seconds after injecting 1 cc of a 1:1 local anesthetic-saline solution into the treatment site. The animals were recovered for three days and then sacrificed. Macroscopic measurements for each lesion were analyzed, and histological comparison was performed.

RESULTS: The average volume of the lesions was 57.36, 65.18, and 60.50 mm³ for treatment durations of 60, 30, and 15 seconds, respectively, and there was no significant difference. Lesion volume at sites where anesthetic-saline was injected had a mean volume of 36.72 mm³. Paired comparison against the three treatment durations revealed significantly smaller lesion volume size (P = 0.0041, 0.0007, 0.0047, respectively).

CONCLUSION: The lesions created with radiofrequency energy were consistent and predictable. The volumes of the lesions did not differ significantly with regard to different energy levels. The lesion was significantly smaller after injection of anesthetic-saline at the treatment site.

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Radiofrequency-based tools for volumetric tissue reduction have been successfully used in many surgical disciplines, such as urological, neurological, and cardiovascular surgery. In the treatment of obstructive sleep apnea/hypopnea syndrome (OSAHS), radiofrequency energy is delivered by applying either monopolar or bipolar electrodes to both the palate and the base of the tongue. A radiofrequency generator provides alternating current to the electrode configuration, which, in turn, generates low heat energy sufficient for promoting denaturation of tissue protein. Ablation using radiofrequency-based instruments, similar to laser-based technology, can be performed under local anesthesia in an office setting, and induces minimal perioperative and postoperative discomfort. Although long-term effectiveness is yet to be determined, the safety and efficacy of this treatment modality have been established as a stand-alone modality for the base of the tongue and as part of a multilevel surgical approach. Criticisms of use of radiofrequency ablation for tissue reduction in treating OSA have revolved around its expense and the necessity of multiple treatment sessions, although these shortcomings could potentially be addressed by optimizing procedure efficiency and by decreasing the duration required of each treatment.

Current protocols for treating the base of tongue using a monopolar or bipolar electrode array configuration are based on little data with regard to the number of treatment sites, energy application, or effects of concurrent in situ saline use. The purpose of this study was, therefore, to revisit the threshold for duration of time necessary for effective clinical application of radiofrequency energy using a bipolar electrode for base of tongue reduction. In this study we evaluated lesion volume induced with application of radiofrequency energy—generated, plasmainduced electrosurgery over 15, 30, and 60 seconds in porcine tongue tissue. In addition, the effects of injecting saline and local anesthetics into the treatment site were also examined to study the effects on the time required for effective delivery of radiofrequency energy. The porcine animal model was selected for this study because tongue size is similar to that found in humans.
MATERIALS AND METHODS

The experimental protocol was approved by the Institutional Animal Care Use and Advisory Committee at the University of California, Davis, prior to initiation of the study. All investigators and technical staff had completed an animal anesthesia and handling course required by the university to participate in investigations of this nature.

A radiofrequency generator with the ReFlex Ultra 55 Wand (ArthroCare Corp, Austin, TX) was used to perform plasma-mediated electrosurgery tissue reduction (Fig 1) in the base of the tongue of five pigs. The generator (controller) was set at a set point of six (which corresponds to an energy level of 153% ± 20% W, according to the manufacturer). Data were collected from five pigs. Prior to the procedure, the animals were anesthetized with tiletamine–zolazepam (Telazol, Wyeth, Madison, NJ) 4.4 mg/kg intramuscular administration for induction, and isoflurane in oxygen was administered via face mask. No antibiotics or corticosteroids were given at any time during the study. During the surgery the tongue was pulled forward to expose the circumvallate papilla at the junction between the base of the tongue and the oral tongue. At each treatment site, the needle electrode wand was inserted into the tongue, as shown in Figure 2, for energy delivery. The duration of treatment was recorded for each application site.

Each pig received eight radiofrequency energy plasma-mediated electrosurgery treatments, four on the right side of the tongue and four on the left. The four treatments on each side of the tongue varied by duration of time of exposure and injection into the treatment site. Three treatments were applied in sequentially increasing time of exposure (15, 30, or 60 seconds), and the fourth was conducted over 15 seconds after injecting 1 cc of a 1:1 local anesthetic-saline solution into the treatment site. The application of radiofrequency energy was performed immediately after the injection. The animals were allowed to recover for three days.

On postoperative day three, the animals were sacrificed by intravenous administration of pentobarbital 90 mg/kg. The tongues were harvested. Macroscopic measurements for each treatment site were obtained (Fig 3). Each specimen was fixated in 10 percent buffered formalin for three days and then polymerized in resin for two weeks before being sectioned with a diamond saw. Each section was mounted on a glass slide with cyanocrylate and then sanded with a diamond-saw sanding machine to approximately 5-μm thickness. The slides were then used for histological evaluation.

Data were collected in an electronic spreadsheet program, and results between groups were analyzed with EViews (Quantitative Micro Software, Irvine, CA). Owing to the small sample size, results were subdivided into groups and analyzed with a rank-based nonparametric test to test for equality of medians between series; in this case Kruskal-Wallis one way analysis of variance was used. The null hypothesis was established for the subgroups having the same general distribution, against the alternative of at least one subgroup having a different distribution. Statistical significance was established for \( P < 0.05 \).
RESULTS

Cell necrosis was histologically consistent for all treatment groups (Fig 4). The average lesion volumes were 57.36, 65.18, and 60.50 mm³ for treatment durations of 60, 30, and 15 seconds, respectively. Table 1 lists the different groups and compares them in terms of the median, mean, and standard deviation of the lesion size. Table 2 contains the pair-wise comparison between groups, with P values. Lesion volume did not differ significantly for the three treatment groups without injection of the local anesthetic-normal saline solution. Lesion volume at sites where this solution was injected was smaller, with a mean volume of 36.72 mm³. Values differed significantly from those without the injection at 60-, 30-, and 15-second treatment duration (P = 0.0041, 0.0007, 0.0047, respectively). One treatment site developed infection at the site where the lateral mucosal surface of the tongue was violated. This infection was associated with a lesion site that was injected with the local anesthetic-saline solution. This value was therefore excluded from data analysis. All calculations were performed with a total sample size of nine, after eliminating the values for the lesions created on the right side of the tongue of pig #2.

DISCUSSION

The effectiveness of surgical treatment of OSAHS relies on the ability to reduce the collapsibility of the upper airway during inspiration, without impacting normal function. Although initially the soft palate was the focus of attention for surgical therapy, it has become increasingly clear that the effectiveness of surgical intervention relies on the ability to stabilize the airway in a multilevel fashion. The base of the tongue is a very important component in this multilevel approach. Several studies have looked at the base of the tongue and its contribution to upper airway obstruction during sleep. Davidson et al4 studied the relationship of the volume of lingual fat and the body mass index in autopsy specimens. Obese individuals, more likely to suffer from OSAHS, had a higher tongue weight at the expense of increased amounts of fat in the posterior tongue and the sublingual tissue. The percentage of posterior tongue fat was found to correlate with higher height, weight, thickness of anterior abdominal wall fat, and body mass index. As pointed out by the authors, an increased tongue size results in higher Friedman tongue position, which correlates with higher prevalence and severity of OSAHS. Patients with upper airway obstruction caused predominantly by the base of the tongue are more likely to fail surgical treatment if the base of the tongue is not reduced.5

Submucosal radiofrequency reduction of the tongue base is currently a popular, minimally invasive approach to ad-
dress obstruction at the hypopharyngeal level. It is easy to perform, well tolerated by patients, and can be performed under local anesthesia on an outpatient basis. Although the success rate in reducing apnea-hypopnea index varies depending on the energy level settings used (high vs low energy) and the number of sessions performed (single vs multiple), and is somewhat lower compared with newer, more invasive techniques, radiofrequency tongue base reduction remains a popular procedure with good success rates, particularly in appropriately selected individuals and in combination with other procedures.

This study demonstrates that the radiofrequency energy with plasma-mediated electrosurgery system used in this study creates predictable tissue necrosis. The volume of the lesions appeared to be stabilized within 15 seconds of each application. Prolonged treatment did not produce bigger lesions, nor did it cause uncontrolled damage to the surrounding tissue. This constitutes a safety feature of radiofrequency energy delivery through self-limited tissue destruction after excessive energy delivery. Radiofrequency transmits energy by alternating the direction of current in the electrode, which in turn causes ions in the surrounding tissue to change in direction. This ionic motion creates energy, which increases the temperature in the tissue surrounding the electrode. Just as the temperature approaches the boiling point of water, desiccation of the tissues ensues and the transmission of energy is interrupted. Use of plasma-mediated electrosurgery with a bipolar wand thus limits the energy transmission to a defined area.

Radiofrequency energy–based, plasma-mediated electrosurgery fundamentally differs from electrocautery and other radiofrequency-based technologies. Plasma has enough energy to induce molecular dissociation, leading to breakage of the tissues’ molecular bonds. The overall effect is tissue ablation and localized removal or reduction of tissue volume. The heat dissipated in this plasma-mediated process ranges between 45°C to 85°C, which is significantly lower than that of traditional radiofrequency techniques.

In a pilot study of radiofrequency tongue base reduction, Powell and colleagues used a Somnus (Somnus Medical Technologies, Sunnyvale, CA) radiofrequency generator at 1000 J per site for two sites and subsequently reduced the energy level to 600 to 750 J owing to the referred pain in some patients. Their rationale for using such energy levels was based on the data obtained from one animal in their porcine model of radiofrequency base of tongue reduction. Other measurements were made with much higher levels of radiofrequency energy delivered to the treatment sites.

A multi-institutional study of radiofrequency volumetric tissue reduction for OSAHS has shown that electrolyte solution injection (local anesthetic with or without saline solution) made treatment results more predictable and overall better, significantly decreasing the time required for each treatment. It is hypothesized that saline and local anesthetic injection might increase the concentration of ions surrounding the electrode, which would make the energy transfer more efficient. Our study, however, showed that injecting a local anesthetic and saline solution to the treatment sites resulted in significantly smaller lesions. Fluid can disperse rapidly into surrounding tissues, and we did not study different time intervals between injection and application of radiofrequency energy, or different volumes of injection. Further studies could determine if these variables have an impact in the histological as well clinical results in OSAHS patients with obstruction at the level of the base of the tongue.

CONCLUSIONS

Lesions created with radiofrequency energy–based, plasma-mediated electrosurgery of the base of the tongue in an animal model were consistent and predictable. The volumes of the lesions did not differ significantly when the porcine tongues were treated over durations of 15, 30, or 60 seconds. Lesions, however, were significantly smaller when a local anesthetic-normal saline solution was previously injected into the treatment site.

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AUTHOR CONTRIBUTIONS

Norman N. Ge, study design, data collection and analysis, writer; Paul Schalch, writer, revision; Craig W. Senders, study design, data collection and analysis.

DISCLOSURES

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