Incidence of Complications in Radiofrequency Treatment of the Upper Airway

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Objectives: To investigate the incidence of complications after temperature-controlled radiofrequency (TCRF) treatment of the inferior turbinate, palate, and tongue. To compare these complication rates with those reported in the literature. Study Design: Prospective, observational study. Methods: All patients treated with TCRF to the inferior turbinate, palate, and tongue during a 12-month period were included. Data were collected for parameters of energy delivery and the development of complications. Results: One hundred thirty-six patients were treated with a total of 470 TCRF lesions. The overall incidence of minor complications was 1.2% (6/470 lesions); there were no complications of moderate or major severity. Conclusion: The incidence of minor complications after TCRF in this series was low, and there were no complications of greater severity. These findings are in stark contrast with some previously published papers with higher complication rates. These significantly higher rates may be caused by a marked learning curve, problems in patient selection and the technique of application, excessive energy delivery, and perioperative management. Key Words: Sleep apnea, radiofrequency, inferior turbinate, palate, tongue.

INTRODUCTION

The application of temperature-controlled radiofrequency (TCRF) for tissue ablation in the upper airway was first reported by Powell et al. in the in vitro bovine model and in vivo porcine model. Because of this investigation, there has been a keen interest in the investigation and application of radiofrequency to the soft tissues of the upper airway. The peer-reviewed literature on the use of radiofrequency to the upper airway in humans and animals includes publications from 14 countries: the United States, France, the United Kingdom, Norway, Sweden, Finland, Germany, Turkey, Korea, Saudi Arabia, Brazil, Belgium, Canada, and Australia.

The initial evaluations focused on the efficacy and safety of this technology. Subsequently, TCRF has been shown by most centers to be safe and effective in treatment of the inferior turbinates, soft palate, and tongue in patients with snoring, sleep-disordered breathing (SDB) or nasal obstruction secondary to turbinate hypertrophy.

With the introduction of any technology, there are risks for complications. However, our goal in using TCRF in the upper airway was to achieve maximal efficacy while maintaining a minimal risk of complications. From our earliest in vitro work, there existed a subtle complexity to this technology that only became appreciated with continued experience. The existence of a significant learning curve was apparent. This was expected, and it is precisely why the initial investigation was not performed in humans but instead in animal models.

Unfortunately, the application of TCRF technology appears easy because the electrode is placed deep to the mucosa where there is essentially no visual evidence of the treatment effect below the surface. However, it is critical to have a basic understanding of the electrophysiologic principles of delivered radiofrequency energy to limit unwanted tissue damage and yet accomplish a positive treatment effect. This is accomplished more safely by carefully interpreting the real-time feedback information that is obtained concerning electrode temperature (degrees celsius), power (watts, W), tissue impedance (ohms, Ω), treatment time (seconds), and total energy delivered (joules, J, or watts × seconds). Fortunately, with patience, perseverance, and experience, risks and complications may be limited.

In preparation for this study, a review of the literature on complications after radiofrequency treatment of the upper airway was conducted. A search of the pub-
lished medical literature was performed using the MEDLINE database for English-language articles or abstracts. The search was based on the keywords radiofrequency, turbinates, sleep, and snoring. This included all articles reporting radiofrequency treatment of the upper airway in which the presence or absence of complications was described.

There are obvious, important differences between various types of complications. We classified these according to severity: minor (mucosal ulceration, mucosal crusting, or uvular sloughing), moderate (hemorrhage, palatal fistula, nerve paresis or paralysis, or significant dysphagia), or major (serious infection requiring drainage or other significant airway compromise). Articles were excluded if they did not specifically address the occurrence of complications of major and moderate severity.

The published literature results are reported separately for treatment of the turbinates, palate, and tongue in Tables I, II, and III, respectively. The precise estimates of incidence rates vary according to whether they are calculated as a fraction of the number of treated patients, radiofrequency treatment sessions, or radiofrequency lesions. By pooling the data from all studies, we estimated the combined incidence of complications of moderate and major severity as 0% (0/213 treatment sessions and 0/213 patients) for the turbinates, either 0.6% (8/1406 treatment sessions) or 1.2% (8/669 patients) for the palate, and either 2.7% (38/1392 treatment sessions) or 6.2% (33/614 patients) for the tongue. Several authors did not specifically report minor complications as defined here; therefore, it was not possible to calculate the overall incidence in this category.

The incidence to date of moderate and major complications after TCRF of the upper airway has been low, supporting the safety of this technology. However, there have been a few centers that have reported an unacceptably high number of moderate and major complications after application of TCRF.16,34 To date, there has been no specific response to these unusually high complication outcomes, and as a result, many physicians, especially in the medical field, have become hesitant to support the use of radiofrequency.

Our experience has been markedly different from that of these high complication centers and similar to that reported in the remainder of the literature. The objective of this study was to systematically evaluate our experience with a large, prospective study specifically designed to detect complications after TCRF treatment of the turbinates, palate, and tongue.

**MATERIALS AND METHODS**

This study was a prospective, observational study of all patients undergoing TCRF treatment of the turbinates, palate, or tongue from July 2002 through June 2003 in our center. This study was approved by the Stanford University School of Medicine Institutional Review Board.

All adult patients who underwent TCRF treatment to the soft tissues of the upper airway—whether in isolation or in conjunction with additional procedures—were included. Minors were excluded.

**Patient Selection**

Pretreatment evaluation was unaffected by the existence of this study. Polysomnography was required for patients with snoring or SDB to establish an accurate diagnosis and guide treatment planning. Patients with turbinate hypertrophy with or without SDB were required to have failed medical therapy. Patients were not offered TCRF if posttreatment edema was of significant concern or if they refused or were unable to use nasal continuous positive airway pressure (CPAP) for airway protection after treatment. Other contraindications included chronic alcoholism, pacemakers; coagulopathies; unstable psychiatric, cardiovascular, or pulmonary disorders; or any patient that was unable or refused to sign informed consent.

**Primary Outcome**

The primary outcome of interest was any complication in the immediate or delayed follow-up periods. All complications were documented, including but not limited to airway compromise, infection, mucosal ulceration, tissue loss, palatal fistula,

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**TABLE I.**

<table>
<thead>
<tr>
<th>Author(s)</th>
<th>Technology/Method of Delivery</th>
<th>Patients</th>
<th>Treatment Sessions</th>
<th>Total Lesions*</th>
<th>Energy (J/Lesion)*</th>
<th>Complications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Li 1998²</td>
<td>TCRF</td>
<td>22</td>
<td>22</td>
<td>43</td>
<td>382</td>
<td></td>
</tr>
<tr>
<td>Smith 1999⁵</td>
<td>TCRF</td>
<td>11</td>
<td>11</td>
<td>22</td>
<td>450</td>
<td></td>
</tr>
<tr>
<td>Utley 1999⁶</td>
<td>TCRF</td>
<td>10</td>
<td>10</td>
<td>40</td>
<td>450</td>
<td></td>
</tr>
<tr>
<td>Coste 2001¹⁴</td>
<td>TCRF</td>
<td>14</td>
<td>14</td>
<td>84</td>
<td>350</td>
<td></td>
</tr>
<tr>
<td>Powell 2001¹⁷</td>
<td>TCRF</td>
<td>17</td>
<td>17</td>
<td>34</td>
<td>350–500</td>
<td></td>
</tr>
<tr>
<td>Back 2002²¹</td>
<td>Coblation</td>
<td>19</td>
<td>19</td>
<td>99</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Bozkurt 2002²⁵</td>
<td>Unknown</td>
<td>20</td>
<td>20</td>
<td>60</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bhattacharya 2003²⁹</td>
<td>Coblation</td>
<td>24</td>
<td>24</td>
<td>96</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Seeger 2003³⁷</td>
<td>Celon</td>
<td>38</td>
<td>38</td>
<td>1–2 per session</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stuck 2003³⁸</td>
<td>TCRF</td>
<td>10</td>
<td>10</td>
<td>4–6 per session</td>
<td>500</td>
<td></td>
</tr>
<tr>
<td>Nease 2004⁴²</td>
<td>TCRF</td>
<td>28</td>
<td>28</td>
<td>56</td>
<td>500</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>213</td>
<td>213</td>
<td>5</td>
<td>5</td>
<td></td>
</tr>
</tbody>
</table>

*Left blank if unable to determine from available information.*
nerve injury, hemorrhage, and significant treatment site pain or dysphagia.

**TCRF Treatment**

A TCRF generator and 10 mm active tip electrode with a protective sheath (Somnus Medical Technologies, Gyrus ENT LLC, Bartlett, TN) was used for all treatments. Data were collected related to the parameters of radiofrequency energy delivery: energy delivered for each lesion (joules, J), maximum electrode temperature (degrees celsius), treatment time, power (watts, W), and tissue impedance (ohms, Ω). The algorithm of energy delivery has been described previously.3

All surgeons had extensive experience with TCRF and an understanding of the electrophysiologic principles of radiofrequency and patient selection criteria. All followed strict treatment protocols for all three regions (turbinate, palate, and tongue) that we have previously reported.2–4,33 Only a brief description is presented here.

**Turbinates**

The anterior inferior turbinate was treated. No sedatives, corticosteroids, or antibiotics were used if the turbinates were treated alone. Follow-up evaluation was performed with an office visit at 1 week and a second visit from 4 to 6 weeks after the procedure. Specific attention was devoted on follow-up to any pain, bleeding, crusting, dryness, odor, infection, or change in smell.

**Palate**

The soft palate was treated either with a single midline lesion, two paramedian lesions, or a midline lesion combined with two lateral lesions. The number of lesions and pattern of energy delivery was based on an assessment of patient anatomy, especially palate thickness, and were not altered by this observational study. No sedatives, corticosteroids, or antibiotics were used if the palate was treated alone or in conjunction with turbinate treatment. All patients were instructed to use their CPAP starting the first night after treatment and sleep with the head of the bed elevated at least 30 degrees from the horizontal for 3 days. Office follow-up evaluation was performed at 1 and 4 weeks after the procedure.

**Tongue**

The tongue was treated using either one midline or two paramedian lesions each at the tongue base/circumvallate papillae or the ventral tongue as outlined in an earlier publication.33 The protocol that we have used over the past 6 years includes the use of 500 to 750 J of TCRF energy per lesion at the initial tongue treatment session to assess the inflammatory response and the potential for airway compromise. Future treatments were based on the edematous response associated with this initial session (of note, during the 12-month period of this study, some patients underwent their initial and subsequent tongue TCRF treatments, and others had undergone this initial treatment before the start of the study period). If TCRF alone was performed (including

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### TABLE II. Reported Incidence of Complications after Radiofrequency Treatment of the Soft Palate.

<table>
<thead>
<tr>
<th>Author(s)</th>
<th>Method of Delivery</th>
<th>Patients</th>
<th>Treatment Sessions</th>
<th>Total Lesions*</th>
<th>Energy (J)/Lesion*</th>
<th>Antibiotics*</th>
<th>Postoperative Steroids*</th>
<th>Total Minor</th>
<th>Moderate</th>
<th>Major</th>
<th>Complications Incidence of Moderate and Major (#/sessions)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Powell 1998</td>
<td>TCRF</td>
<td>22</td>
<td>80</td>
<td>117</td>
<td>688</td>
<td>N</td>
<td>N</td>
<td>11</td>
<td>11</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Boudevyns 2000</td>
<td>TCRF</td>
<td>45</td>
<td>122</td>
<td>122</td>
<td>700</td>
<td>N</td>
<td>N</td>
<td>24</td>
<td>21</td>
<td>3</td>
<td>2.5%</td>
</tr>
<tr>
<td>Coleman 2000</td>
<td>TCRF</td>
<td>12</td>
<td>28</td>
<td>28</td>
<td>700</td>
<td>N</td>
<td>N</td>
<td>6</td>
<td>6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Emery 2000</td>
<td>TCRF</td>
<td>43</td>
<td>104</td>
<td>188</td>
<td>600–700/300</td>
<td>N</td>
<td>N</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>1.0%</td>
</tr>
<tr>
<td>Hukins 2000</td>
<td>TCRF</td>
<td>20</td>
<td>60</td>
<td>60</td>
<td>650</td>
<td>N</td>
<td>N</td>
<td>3</td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Li 2000</td>
<td>TCRF</td>
<td>22</td>
<td>79</td>
<td>79</td>
<td></td>
<td>N</td>
<td>N</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Back 2001</td>
<td>VidaMed</td>
<td>20</td>
<td>43</td>
<td>86</td>
<td>300–600</td>
<td>N</td>
<td>N</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Brown 2001</td>
<td>TCRF</td>
<td>12</td>
<td>36</td>
<td>108</td>
<td>300–600</td>
<td>N</td>
<td>N</td>
<td>3</td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fergusson 2001</td>
<td>TCRF</td>
<td>47</td>
<td>98</td>
<td>235</td>
<td>500–700</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pazing 2001</td>
<td>TCRF</td>
<td>26</td>
<td>26</td>
<td>78</td>
<td>650/300</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sher 2001</td>
<td>TCRF</td>
<td>105</td>
<td>252</td>
<td>1–3 per session</td>
<td>650/300</td>
<td></td>
<td></td>
<td></td>
<td>7</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>Tenis 2000</td>
<td>TCRF</td>
<td>23</td>
<td>54</td>
<td>162</td>
<td>600/300</td>
<td>N</td>
<td>Y</td>
<td>27</td>
<td>27</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Back 2002</td>
<td>Coblation</td>
<td>20</td>
<td>20</td>
<td>60</td>
<td></td>
<td>N</td>
<td>N</td>
<td>4</td>
<td>4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blumen 2002</td>
<td>TCRF</td>
<td>15</td>
<td>31</td>
<td>93</td>
<td>300–750</td>
<td>N</td>
<td>N</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bozkurt 2002</td>
<td>Coblation</td>
<td>18</td>
<td>18</td>
<td>72</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Haraldsson 2002</td>
<td>TCRF</td>
<td>16</td>
<td>48</td>
<td>144</td>
<td>300–600</td>
<td>N</td>
<td>Y</td>
<td>2</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fischer 2003</td>
<td>TCRF</td>
<td>16</td>
<td>16</td>
<td>80</td>
<td></td>
<td>N</td>
<td>N</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>5.6%</td>
</tr>
<tr>
<td>Rombaux 2003</td>
<td>Coblation</td>
<td>17</td>
<td>17</td>
<td>4–6 per session</td>
<td></td>
<td>N</td>
<td>N</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>5.9%</td>
</tr>
<tr>
<td>Stuck 2003</td>
<td>TCRF</td>
<td>91</td>
<td>127</td>
<td>3–4 per session</td>
<td>450–600</td>
<td>N</td>
<td>N</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tatla 2003</td>
<td>Celon</td>
<td>10</td>
<td>20</td>
<td>120</td>
<td></td>
<td>N</td>
<td>N</td>
<td>2</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Woodson 2003</td>
<td>TCRF</td>
<td>26</td>
<td>39</td>
<td>105</td>
<td>300–650</td>
<td>N</td>
<td>N</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kania 2004</td>
<td>TCRF</td>
<td>43</td>
<td>88</td>
<td>264</td>
<td>350–800</td>
<td>N</td>
<td>N</td>
<td>9</td>
<td>9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>669</td>
<td>1406</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>119</td>
<td>111</td>
<td>7</td>
</tr>
</tbody>
</table>

*Left blank if unable to determine from available information.*
treatment of the tongue with other sites), no corticosteroids or sedatives were used; however, these patients were treated with antibiotics (oral cephalexin 500 4 times a day for 3 days). If other upper airway procedures were performed such as tonsillectomy, palate surgery, or genioglossus advancement, the patient received a single dose of 8 mg of intravenous dexamethasone at the time of surgery and up to two doses of 8 mg of intravenous dexamethasone every 8 hours postoperatively; in these cases, the patients received intravenous cefazolin followed by oral cephalexin for a total of 5 days of therapy. All patients were instructed to use their CPAP starting the first night after treatment and sleep with the head of the bed elevated at least 30 degrees from the horizontal for 3 days. Follow-up evaluation was performed at 1 and 4 weeks after the procedure. Additional follow-up appointments were made as needed.

RESULTS
One hundred thirty-six patients were treated with a total of 470 lesions created during 224 treatment sessions. The mean age was 45.3 ± 11.4 years, and 81% of the subjects were males. In the subset of patients with SDB, the Epworth Sleepiness Scale before treatment was 9.4. Because the majority of these patients did not complete all treatment sessions within the time period under study, posttreatment scores are not reported. For those patients who underwent sleep studies (n = 103), the body mass index was 28.0 ± 4.0, neck circumference was 40.4 ± 3.4 cm, and apnea-hypopnea index was 24.5 ± 22.3.

Turbinate Results
Eighty-nine patients underwent treatment of the inferior turbinates with 183 lesions created in 93 treatment sessions. Radiofrequency energy (385 ± 71 J) was delivered over 1.06 ± 0.24 minutes, and the maximum temperature reached during treatment was 83.2 ± 2.8°C. Tissue impedance was 142 ± 16 Ω, and the maximum power was 7.8 ± 2.1 W. There was one minor complication of crusting at follow-up.

Palate Results
For the palate, 25 patients with simple snoring or SDB underwent treatment by receiving 73 TCRF lesions in 37 sessions. For the midline and paramedian lesions (n = 45), 523 ± 143 J of TCRF energy were delivered over 2.0 ± 0.7 minutes, and the maximum electrode temperature was 84.4 ± 1.9°C. Impedance of the tissues was 143 ± 6 Ω, and the maximum power delivery was 7.8 ± 2.4 W. For lateral lesions (n = 28), 334 ± 43 J of TCRF energy were delivered; other parameters of energy delivery (maximum electrode temperature, tissue impedance, and rate of delivery) were similar to midline and paramedian lesions. There were three minor complications of small (2, 5, and 6 mm), self-limited mucosal ulcerations in these patients. One of these occurred in the midline, and two were located laterally. There were no other complications.

Tongue Results
Fifty-one patients underwent tongue TCRF treatment with the creation of 214 lesions in 94 sessions. For the tongue base lesions (n = 148), 697 ± 156 J of radiofrequency energy per lesion were delivered over 2.3 ± 0.6 minutes, and the maximum temperature was 85.0 ±
0.9°C. Tissue impedance was $144 \pm 20 \Omega$, and the maximum power delivery was $7.7 \pm 2.4$ W. For the ventral tongue lesions ($n=66$), $648 \pm 97$ J of radiofrequency energy per lesion were delivered over $2.3 \pm 0.6$ minutes, and the maximum electrode temperature was $85.0 \pm 1.1$°C. Impedance of the tissues was $136 \pm 17$ $\Omega$, and the maximum rate of energy delivery was $9.0 \pm 2.0$ W. There were two minor complications of small (4 and 6 mm), self-limited mucosal ulcerations of the tongue base in these patients. There were no other complications.

Overall (turbinates, palate, and tongue), there were no complications of moderate or major severity. The overall rate of minor complications was either 1.3% (6/470 lesions) or 4.4% (6/137 patients), depending on the metric used for this calculation.

**DISCUSSION**

The incidence of minor complications in this investigation was low. The incidence of complications of greater severity (0%) was even lower than the pooled data (0%) for turbinates, 0.6% for the palate, and 2.7% for the tongue) would suggest. Some authors have suggested that much of the reported literature on radiofrequency is focused on effectiveness rather than complications and therefore cannot provide accurate assessment of complication rates. We address this concern by reviewing only those papers that specifically report moderate and major complications; the experience across many centers supports a low complication rate after radiofrequency. We also present a prospective study specifically addressing complications over a 1 year period after TCRF treatment according to our standard protocol as outlined in this study; we report no moderate or major complications in a large series.

Particularly striking are the high reported complication rates in two papers describing TCRF treatment of the tongue. The rates of complication reported in these two papers are so much higher than we and others have experienced that it is alarming. Furthermore, their outlier status is not explained by any information provided in the investigations.

In an attempt to identify risk factors for complication, Tables II and III also present aspects of treatment and perioperative management that varied among the studies for treatment of the palate and tongue, respectively. These factors include the method of radiofrequency energy delivery, amount of energy delivered per lesion, and the use of routine postoperative antibiotics. The rates of complication vary markedly for treatment of the tongue, and therefore it is most useful to begin with examination of these papers. Because the rate of complication is so low (2.7%), it would require a large study to systematically address the role of each specific factor on the incidence of complications in a randomized, controlled trial. For example, to have 90% power for detecting whether any single one of these factors was associated with a doubling of the rate of serious complications in tongue radiofrequency, a study would require 9,500 patients. It is unlikely that such a study of this magnitude will ever be conducted.

Another approach is a simplified version of meta-analysis to consider specific potential risk factors for complication. Dividing the tongue radiofrequency papers according to whether routine postoperative corticosteroids were used, the combined rates of moderate and major complications were 6.1% (15/246 treatment sessions) when corticosteroids were used and 1.0% (7/674 treatment sessions) when steroids were not used. Student’s t test for proportions revealed that this difference was statistically significant ($P < .001$). The same analysis was performed for the use of perioperative antibiotics in tongue treatment and for both corticosteroids and antibiotics in palate treatment, and the results were not statistically significant. One paper identified earlier reporting high rates of complication incorporated routine use of postoperative corticosteroids for 5 days in their treatment protocol. This may or may not account for the differences in their results from this study and other results reported in the literature. Although we have experienced low complication rates with the use of cephalexin, we believe that other antibiotics that provide coverage against the most common oral and pharyngeal flora can be used with similar results.

Complications after TCRF treatment may be related to several other factors. These include the learning curve associated with the use of this technology and especially understanding of the electrophysiology of lesion generation for the various devices and treatment sites, the number and location of lesions created during each treatment session, and aspects of perioperative management other than corticosteroid use. For example, the other of the two papers cited earlier as outliers with higher complication rates described a novel technique of radiofrequency energy delivery. Ultrasound was used to localize the hypoglossal nerve and lingual neurovascular bundle before treating the base of tongue using the coblation technology. The paper describes several unique aspects of their technique including the need for general anesthesia and continuous intubation for several hours after the procedure and treatment of the entire tongue base up to 5 mm of these identified structures. The authors describe their complications as “minimal,” but Table III suggests that their rate is clearly higher than with other technologies and techniques. It is likely that their higher complication rate is related to the unique aspects of their procedure, especially their more aggressive treatment of the tongue base.

A final, critical aspect of TCRF treatment is patient selection and tailoring treatment to patient anatomy. Treatment of the palate is markedly different from treatment of the tongue based in part on the anatomic character of the tissues (i.e., the tongue is thick, homogeneous muscle, and the palate is relatively thin with diminutive muscle). Tissue bulk and consistency should be evaluated carefully, and one of the most important variables for palatal treatment is thickness. The midline palate is the safest region to treat because the musculus uvulae provides the greatest bulk of the palate. The thickness of the palate decreases rapidly as one moves away from the median and paramedian region. Palate thickness varies significantly in patients, as was seen in our first TCRF palate publication in which the thickness in the midline by cephalometric radiographs was $10.5 \pm 2.3$ mm, if the...
palate is thin, the total energy delivery must be limited or damaged to the mucosa will occur more frequently. Treatment to the lateral region of the palate should be undertaken only when it is established that the tissue thickness is appropriate. Lateral cephalograms can be used to measure the palate thickness in the midline, and the lateral regions of the soft palate are thinner to varying degrees and must be evaluated clinically. Clinical judgment must be used for optimal treatment planning. We have developed and have reviewed in this paper a conservative protocol to limit risks and improve safety when using TCRF in the upper airway. We constantly revise it on the basis of our experience and the results of others in personal communication and as reported in the peer reviewed literature.

CONCLUSIONS

The incidence of complications, minor, moderate, and major, after TCRF in this investigation is low. These figures are somewhat lower than the rate of significant complications suggested by a review of the literature. Complication rates that markedly and chronically exceed these rates should alert the surgeon to consider re-evaluating their personal techniques or center’s treatment protocols for the use of TCRF. Several factors may influence the rate of complications, including a learning curve associated with the use of this technology, the amount of energy delivered per lesion, the temperature selection, the number and location of lesions created during each treatment session, and perioperative management of patients with special emphasis on airway control.

BIBLIOGRAPHY


