Radiofrequency Ablation of Advanced Head and Neck Cancer

Randall P. Owen, MD, MS; Sajid A. Khan, MD; Abdissa Negassa, PhD; Jonathan J. Beitler, MD, MBA; Jacqueline A. Bello, MD; Allan Brook, MD; Joaquim Farinhas, MD; Madhur K. Garg, MD; Missak Haigentz Jr, MD; Todd S. Miller, MD; Melody S. Hsu, MD; Thanjuvar S. Ravikumar, MD; Keivan Shifteh, MD; Richard V. Smith, MD; Carl E. Silver, MD

Objective: To determine if the application of radiofrequency ablation to advanced head and neck cancer (HNC) would result in local control of the tumor.

Design: Radiofrequency ablation was applied to advanced head and neck malignant tumors in the participants of this nonrandomized controlled trial.

Setting: Academic tertiary care medical center.

Participants: Twenty-one participants with recurrent and/or unresectable HNC who failed treatment with surgery, radiation, and/or chemotherapy were selected for the trial. Patients deemed appropriate for curative standard radiation or surgery were not accepted as participants.

Intervention: Radiofrequency ablation was applied to head and neck tumors under general anesthesia and computed tomographic scan guidance.

Main Outcome Measures: The primary end point was local control. Computed tomographic scan tumor measurements were used to assess response by standard response evaluation criteria in solid tumors (RECIST) guidelines. Secondary outcome measures included survival and quality of life.

Results: Eight of 13 participants had stable disease after intervention. Median survival was 127 days, and an improvement in University of Washington quality-of-life scores was noted. Adverse outcomes included 1 death due to carotid hemorrhage and 2 strokes.

Conclusion: Radiofrequency ablation is a palliative treatment alternative that shows promise in addressing the challenges of local control and quality of life in patients with incurable HNC who have failed standard curative treatment.

tumoral temperatures of up to 100°C are generated, resulting in protein denaturation and apoptosis, thereby producing a mass of inert, necrotic tumor debris. Radiofrequency ablation has been successfully used to treat unresectable malignant liver tumors with minimal complications and promising results. However, to our knowledge, prior to our series, this approach has not yet been applied to patients with unresectable HNCs. Over 4 years we developed and tested the application of RFA to recurrent or unresectable head and neck malignant tumors.

This single-institution study was performed at the Montefiore Medical Center (Bronx, New York), and the study protocol was approved by the Albert Einstein Comprehensive Cancer Center (Bronx) protocol review committee and the institutional review board. All aspects of care were in accordance with the ethical standards of these committees that oversee human experimentation at our institution, including adherence to all Health Insurance Portability and Accountability Act of 1996 rules. Participants were required to meet inclusion criteria that showed they had biopsy-proven recurrent disease, had received at least 1 prior standard treatment modality, and were ineligible for standard radiation and/or surgical interventions. Inclusion criteria included at least 1 of the following: (1) patient refusal of standard therapies, (2) prior irradiation, (3) medical comorbidities precluding surgery, or (4) judgment by a prospective multidisciplinary tumor board that the functional and/or cosmetic damage of standard surgical therapy warranted consideration of an alternative, albeit noncurative, approach. All participants gave informed consent before the procedure.

There were no absolute contraindications on the basis of tumor size or location. The RFA probes can ablate up to a 7-cm mass of tissue, and multiple ablations are also possible. Tumors near vital structures were still considered amenable to ablation, and great care was taken not to inflict collateral damage. Risk of damage to surrounding structures was carefully explained to each participant during the consent process.

Radiofrequency ablation umbrella probes were used (RITA Medical Systems Inc, Mountain View, California). Up to 100 W of energy was applied in an effort to achieve target temperatures of 100°C. Intratumoral temperatures of 60°C to 100°C for at least 10 minutes were achieved, and tissue temperature and impedance were tracked. Application of energy was continued until temperatures fell and impedance rose, implying no further conduction of energy into the tumor. General anesthesia was used in all cases, and surrounding structures were protected with moist gauze. The actual time of the procedure was usually about 20 to 30 minutes, although the time from induction of anesthesia to emergence was about 60 to 90 minutes.

Computed tomographic (CT) guidance allowed for optimal placement of the needle probe in tumors not easily seen by transoral visualization (Figure 1). Details of the imaging considerations for CT-guided RFA have been published. After induction of general anesthesia, a CT scan was performed. The RFA probe was then inserted, checked, and adjusted with as many CT scans as necessary to ensure accurate placement within the tumor, minimizing the likelihood of damage to surrounding structures. The probe was opened to varying sizes, allowing for ablations 1 to 7 cm in diameter. After placement of the probe tip into the tumor mass, ablation was performed in the CT suite. The participant was then brought to the recovery room and awakened. The same head and neck surgeon and neuroradiology team performed all 21 procedures.

Twenty-one participants were enrolled, and RFA was performed a total of 26 times. Tumor locations included the tongue (in 10 cases), oropharynx and hypopharynx (in 4 cases), floor of mouth (2), neck and thyroid (2), maxillary sinus (1), base of skull (1), and posterior neck (1) (Table 1). End points of tumor size and survival were measured relative to the first RFA procedure (4 participants had >1 RFA procedure). Eighteen tumors were squamous cell carcinoma of the oral cavity or oropharynx, and the remaining 3 were medullary thyroid carcinoma, basal cell carcinoma, and a posterior neck soft-tissue sarcoma. Seventeen of the 18 participants with SCC had RFA applied to the primary tumor of the upper aerodigestive tract. Only 1 patient had RFA applied to unresectable cervical nodes. In all other cases, RFA was applied only to a single lesion.

This phase II study had a 2-stage design. The end point of the study was determined to be response of the treated tumor as measured by comparison pre-RFA and post-RFA CT scans. Initially, a 3-dimensional local control index was devised to incorporate the unique characteristics of head and neck tumors; however, this was difficult to measure uniformly, and the measurements were incomparable with those of most studies that use standard RECIST measurements assessing for a binary outcome of either progressive disease or nonprogressive disease. The primary outcome of local control was measured and reported in this way for all participants. The RECIST system defines progressive disease as at least a 20% increase in the maximum diameter of the target lesion. Nonprogressive disease is therefore defined as less than a 20% increase in the maximum diameter of the target lesion.
Table 1. Clinical Characteristics and Treatments Received

<table>
<thead>
<tr>
<th>Patient No./Sex/Age, y</th>
<th>Tumor Site</th>
<th>Surgery</th>
<th>Radiation</th>
<th>Chemotherapy</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Tracheostomy/PEG</td>
<td>None</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Hardware removal (1999)</td>
<td>None</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(2-mo treatment break)</td>
<td>30-Gy HDR (2000)</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td>6/M/53 Tongue</td>
<td>R segmental mandibulectomy; L marginal mandibulectomy; near-total glossectomy; B modified neck dissection; tracheostomy; pectoralis major flap; gastrostomy; split-thick skin graft (2001)</td>
<td>Head and neck, 41.4 Gy; supraclavicle, 46.8 Gy</td>
<td>Docetaxel (2003)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Debridement and closure of exposed mandible (with RFA 2002)</td>
<td>30-Gy brachytherapy (2002)</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Composite resection with free flap, glossectomy</td>
<td>None</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Partial glossectomy, R modified neck dissection (2003), L modified radical neck dissection (2003)</td>
<td>None</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td>15/M/56 Tongue</td>
<td>Bilateral neck exploration, tracheostomy, aborted glossectomy/mandibulectomy (2003)</td>
<td>None</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Resection of recurrence/composite resection (2002)</td>
<td>None</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td>17/M/81 Base of skull (BCC)</td>
<td>Multiple (21) R ear (and surrounding tissue) procedures; temporal bone resection with rectus free flap (2002)</td>
<td>50 Gy (2003)</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Debulking of rectus free flap and recurrence (2003)</td>
<td>None</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td>18/M/36 Sarcoma</td>
<td>4 Surgical resections</td>
<td>None</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Administered but dose unknown (2000 not in the United States)</td>
<td>None</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td>19/M/79 Base of tongue</td>
<td>Total laryngectomy (1981), pharyngectomy with Pectoralis major flap (2004)</td>
<td>None</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Esophagel dilatation (2004)</td>
<td>None</td>
<td>None</td>
<td></td>
</tr>
</tbody>
</table>

Abbreviations: B, bilateral; BCC, basal cell carcinoma; CHOP, cyclophosphamide, doxorubicin, vincristine, prednisolone; EBRT, external beam radiation therapy; HDR, high dose rate; I & D, incision and drainage; L, left; MAID, mesna, adriamycin, ifosphamid dacarbazine; MRND, modified radical neck dissection; off-chord, sparing the vocal cords; PEG, percutaneous endoscopic gastrostomy; Pt, patient; R, right; RFA, radiofrequency ablation; TEP, tracheo-esophageal puncture.
A reference group was identified in a somewhat similar group of patients who received reirradiation for advanced HNCs and achieved a 37% response rate. An improvement over the radiation protocol of 20%, implying a 57% response rate, was thought to be clinically interesting.

A 2-stage design was selected to address the primary objective of this study. The optimum design at \( \alpha = 0.05 \) and a study power at 80% called for 15 eligible participants at the first stage. If there were 7 or more responses, then accrual would continue for a total of 47 eligible participants. Otherwise, the study would be terminated. If 23 or more participants responded at the planned end of the study, then RFA would be considered promising for further investigation. This design had a 0.70 probability of early termination if the true response rate was 37% or less.

Secondary end points included survival and QOL as measured by the University of Washington (UW) Head and Neck Quality of Life questionnaire. Continuous variables are summarized as means with 95% confidence intervals (CIs). Categorical variables are summarized as percentages with exact 95% CIs. Survival experience was summarized using the Kaplan-Meier estimator.

---

**Table 2. Response to Radiofrequency Ablation (RFA)**

<table>
<thead>
<tr>
<th>Participant</th>
<th>RECIST Criteria, cm</th>
<th>Category of Response (NP vs PD)</th>
<th>Survival, No. of Days</th>
<th>Quality of Life</th>
<th>LOS Post-RFA, d</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>8.1</td>
<td>NP</td>
<td>879</td>
<td>24.4</td>
<td>35</td>
</tr>
<tr>
<td>2</td>
<td>3.9</td>
<td>PD</td>
<td>559</td>
<td>55.6</td>
<td>58.3</td>
</tr>
<tr>
<td>3</td>
<td>ND</td>
<td>ND</td>
<td>31</td>
<td>8.3</td>
<td>2.8</td>
</tr>
<tr>
<td>4</td>
<td>ND</td>
<td>ND</td>
<td>63</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td>5</td>
<td>5.7</td>
<td>NP</td>
<td>143</td>
<td>28.1</td>
<td>33.3</td>
</tr>
<tr>
<td>6</td>
<td>5.3</td>
<td>NP</td>
<td>366</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td>7</td>
<td>6.2</td>
<td>NP</td>
<td>131</td>
<td>25.0</td>
<td>28</td>
</tr>
<tr>
<td>8</td>
<td>7.5</td>
<td>NP</td>
<td>87</td>
<td>33.3</td>
<td>53.3</td>
</tr>
<tr>
<td>9</td>
<td>11.2</td>
<td>NP</td>
<td>62</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td>10</td>
<td>6.0</td>
<td>PD</td>
<td>140</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td>11</td>
<td>12.5</td>
<td>NP</td>
<td>44</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td>12</td>
<td>ND</td>
<td>ND</td>
<td>229</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td>13</td>
<td>7.5</td>
<td>PD</td>
<td>449</td>
<td>49.4</td>
<td>46.7</td>
</tr>
<tr>
<td>14</td>
<td>7.9</td>
<td>NP</td>
<td>79</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td>15</td>
<td>8.5</td>
<td>PD</td>
<td>40</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td>16</td>
<td>ND</td>
<td>ND</td>
<td>182</td>
<td>43.9</td>
<td>48.9</td>
</tr>
<tr>
<td>17</td>
<td>3.9</td>
<td>PD</td>
<td>896</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td>18</td>
<td>10.2</td>
<td>NP</td>
<td>123</td>
<td>46.1</td>
<td>46.7</td>
</tr>
<tr>
<td>19</td>
<td>ND</td>
<td>ND</td>
<td>20</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td>20</td>
<td>ND</td>
<td>ND</td>
<td>216</td>
<td>47.3</td>
<td>27.2</td>
</tr>
<tr>
<td>21</td>
<td>ND</td>
<td>ND</td>
<td>87</td>
<td>39.3</td>
<td>30.6</td>
</tr>
</tbody>
</table>

Results

Nonprogressive: 8

Progressive: 5

127 (median) 95% CI, 61-217

Median, 3.0

Mean, 2.7

Results Nonprogressive: 8 127 (median) 95% CI, 61-217 Median, 3.0 Mean, 2.7

Abbreviations: CI, confidence interval; LOS, length of stay; ND, no data obtained; NP, nonprogression; PD, progressive disease; RECIST, response evaluation criteria in solid tumors.

a Twenty-one participants were accrued for this study for a total of 26 ablations.

b Denotes participant who underwent more than 1 ablation.

---

**RESULTS**

Completed data were obtained in 13 patients who underwent both preprocedural and postprocedural CT scans (Table 2). Eight of 13 patients (62%; exact 95% CI, 0.33-0.83) were shown to have nonprogressive disease.

The median survival was 127 days (95% CI, 61-217 days) (Figure 2). The median length of hospital stay following the procedure was 3.0 days (interquartile range [IQR], 2.0-6.5 days), with shorter stays following the more recently performed procedures.

The UW QOL surveys in 11 participants showed an index increase by a median of 3.0 percentage points (mean, 2.7 percentage points), with 8 of 11 (73%) showing improvement. Difficulty obtaining consistent patient follow-up in this population precluded our complete collection of QOL data. It should be noted that over half of the participants reported subjective improvement in pain, function, and/or appearance at various intervals after they received RFA.

Adverse events associated with the procedure included 1 carotid hemorrhage resulting in death, 2 strokes, 1 increase in size of a preexisting orocutaneous fistula, 2 cases of cellulitis, 1 central venous catheter infection, and 2 instances of pneumonia. Besides the death and 1 of the strokes, the other adverse events were transient and had no lasting effect on the participants. The 2 major adverse events are further described as follows.
Patient 19 had a recurrent tumor of the oropharynx overlying the carotid artery. This was treated effectively with RFA. Eighteen days after the procedure, the patient had a massive carotid hemorrhage and died. We postulate that with the tumor ablated, the carotid artery was exposed to the saliva of the pharynx, which eroded the carotid wall.

Patient 20 also had a recurrence of the oropharynx, which was treated with some modification (more distance [1 cm] from the carotid artery and less energy [80 W instead of 100 W]). However, an immediate postoperative scan indicated tumor destruction with carotid artery exposure. In an effort to avoid the complication of carotid hemorrhage in this patient, the carotid artery was coil embolized. This did prevent the complication of carotid hemorrhage; however, the patient suffered an ipsilateral stroke with resultant hemiparesis despite having passed balloon test occlusion of this vessel. We conclude from these 2 cases that tumors on or near the carotid artery should not be treated with RFA at the energy levels used. Further research, perhaps in animals, is necessary to determine if a lower level of energy would be safe and effective for such tumors.

Nonprogression of disease in 8 of 13 patients achieved the goal of 7 or more responses for the primary outcome of local control (albeit with revision to the RECIST system and to an end point of nonprogression rather than partial or complete response). This would then have led us to continue the study to a total accrual of 47 patients. However, the 2 major adverse events, the need to change the original criteria for assessing tumor response, and the difficulty in obtaining long-term follow-up, caused us to conclude the study.

The primary problem in completing the study as planned was the inability of a number of these patients to follow through with the planned posttreatment imaging. Many patients were quite debilitated from their prior treatments as well as from their recurrent disease. Many also had social constraints preventing them from proper follow-up. Therefore, only 13 of 21 patients obtained postintervention scans, and these ranged from 17 to 392 days after RFA (median, 44 days; IQR, 22.5-103.5 days).

Positron emission tomography (PET) imaging was useful in identifying a persistent tumor after RFA in 1 participant, though this was not part of the study protocol. Positron emission tomographic imaging has been increasingly used for surveillance of liver tumors treated with RFA, and PET imaging studies may be a helpful adjunct for future study to determine if post-RFA tumor masses seen on conventional imaging harbor a viable tumor.

Success or failure in a chemotherapy or radiation trial is generally based on the number of complete and partial responses observed. The effect of RFA is dissimilar to that of standard chemotherapy or radiation in that tumors do not shrink but are instead converted into a mass of necrotic, nonviable tissue. Therefore, the determination of success or failure with respect to RFA must be defined by nonprogression rather than shrinkage of the tumor. Thirteen participants had both preprocedure and postprocedure imaging studies, making them evaluable for the primary end point of the study. Eight of 13 participants in our trial were shown to have stable (nonprogressive) disease, suggesting potential benefit afforded by RFA in terms of local control of tumors. This did not translate into a survival advantage in our study, which likely indicates the multifactorial nature of death in this highly complex patient population with comorbidities and the debilitating effects of long-term cancer.

Eight of 11 patients who completed preprocedure and postprocedure questionnaires recorded an improved QOL score, indicating a potentially promising area for future study. Based on the limited data that we collected, subjective and QOL improvements after RFA were gratifying. The data were insufficient to quantitatively identify predictors of improved QOL. However, those with lower initial QOL scores, particularly when related to pain at the site of the tumor, seemed to benefit the most.

The 2 durable adverse events, 1 death and 1 stroke, were the most troubling outcomes of the study. Although it was understood by the investigators and the participants that RFA in the head and neck was a novel technique, that no other good treatment option was available, and that unforeseen complications were possible, these 2 outcomes caused us to reconsider the potential for harm. In fact, many unresectable cancer recurrences in the head and neck are near the carotid artery. Therefore, further studies, perhaps best performed in animals, are warranted to test the efficacy vs the tumor and the preservation of carotid integrity with decreased RFA energy.

Patients with recurrent and/or unresectable HNC who fail standard therapeutic options have very limited treatment alternatives. Despite advances in palliative chemotherapy and supportive care, these patients have a median survival of 7 months. Reirradiation has been increasingly studied, and some encouraging outcomes indicate that this therapeutic option should be a strong consideration in selected patients with locoregionally recurrent HNC. Aggressive free flap reconstruction can be very successful in addressing the inevitable complications, such as osteoradionecrosis and fistula formation. Still, the high morbidity and adverse effects on QOL that reirradiation causes must be discussed with each patient and a joint decision made as to whether it is an appropriate choice of therapy.

Radiofrequency ablation should not be considered an alternative to potentially curative salvage surgery or reirradiation. If a potential candidate for this trial was a candidate for curative salvage surgery or reirradiation and was willing to proceed despite the risks, RFA was not presented as an alternative. Radiofrequency ablation is in its infancy as a potential modality to treat HNC, with this article presenting the first substantial investigational series. Therefore, the participants in this study were either considered unfit for reirradiation or other curative therapies, or they were presented with these options and refused. Only then was the patient enrolled in our study as a participant.

The most challenging aspect of this study was the difficulty in obtaining consistent participant follow-up. Four
participants came from considerable distances, making in-
person follow up very difficult. However, the realities of
their end-stage disease made it very challenging to ar-
range for and complete follow-up imaging and office vis-
its. Nevertheless, efforts were made to contact partici-
pants and their local physicians to follow their status. Based
on these conversations, uncontrolled locoregional dis-
ease was the exception rather than the rule for the par-
ticipants. Therefore, it would seem unfair to assume that
all participants who did not follow up properly were un-
able to do so because of progressive locoregional disease.

Although the missing data make interpretation of the results more difficult, the data generated by this study form an important foundation for further study of RFA as a palliative modality. It should be noted that even if
one were to assume the worst case of the 8 participants without follow-up scans having progression of disease, then still 8 of 21 (38%) would have shown nonprogres-
sion of disease, an equivalent proportion compared with the reirradiation historical control group. One advan-
tage of RFA compared with reirradiation is that it is a mo-
dality limited to single-session treatment. Our prelimi-
inary observations demonstrate that RFA may achieve local
tumor control and improve QOL.

One clear advantage provided by RFA is that individ-
uals who are experiencing the terrible symptoms of
locally recurrent HNC can undergo a short, minimally
invasive procedure resulting in an immediate improve-
ment in their QOL. Our study suggests that RFA is fea-
sible and may provide a meaningful interval of pallia-
tion in patients with recurrent advanced head and neck
cancer who have no other treatment alternatives. Regres-
sion of a tumor, such as is seen with chemotherapy or
radiation, was not observed. However, nonprogression
of disease was documented in most evaluable patients af-
after intervention. Clinically significant adverse sequelae
were noted in 2 patients, which mandates that the cur-
rent technique is not to be used for tumors on or near the
carotid artery. Further study of this novel therapy is
warranted.

Submitted for Publication: September 1, 2010; final re-
vision received February 14, 2011; accepted February 23,
2011.

Author Affiliations: Department of Surgery, Mount Si-
nai Medical Center, Mount Sinai School of Medicine, New
York, New York (Dr Owen); Department of Surgery, Uni-
versity of Chicago Medical Center, Chicago, Illinois (Dr
Khan); Division of Biostatistics, Department of Epide-
miology and Population Health (Dr Negassa), Depart-
ment of Radiation Oncology (Dr Beiter), Department of
Otorhinolaryngology—Head and Neck Surgery (Drs
Beiter, Garg, and Smith), Department of Surgery (Dr Sil-
ver), Division of Neuroradiology, Department of Radi-
ology (Drs Bello, Brook, Farinhas, Miller, and Shifteh),
and Division of Medical Oncology, Department of Medi-
cine (Dr Haigentz), Montefiore Medical Center and Al-
bert Einstein College of Medicine, Bronx, New York; De-
partment of Pediatrics, Kaiser Permanente, Los Angeles,
California (Dr Hsu); and Departments of Oncology and
Innovations, Geisinger Health System, Wilkes-Barre, Pennsyl-
Vania (Dr Ravikumar).

Correspondence: Randall P. Owen, MD, MS, Depart-
ment of Surgery, Mount Sinai Medical Center, Mount Si-
nai School of Medicine, 5 E 98th St, Box 1259, New York,
NY 10029 (randall.owen@mountsinai.org).

Author Contributions: Dr Owen had full access to all the
data in the study and takes responsibility for the integ-
rety of the data and the accuracy of the data analysis. Study
concept and design: Owen, Khan, Negassa, Beiter, Brook,
Ravikumar, and Smith. Acquisition of data: Owen, Khan,
Farinhas, Garg, Haigentz, Miller, Hsu, Shifteh, and Sil-
ver. Analysis and interpretation of data: Owen, Khan, Ne-
gassa, Bello, Brook, and Miller. Drafting of the manu-
script: Owen, Khan, Negassa, Brook, and Shifteh. Critical
revision of the manuscript for important intellectual con-
tent: Owen, Khan, Negassa, Beiter, Bello, Brook, Farinhas,
Garg, Haigentz, Miller, Hsu, Ravikumar, Smith, and Sil-
ver. Statistical analysis: Negassa. Administrative, tech-
nical, and material support: Owen, Khan, Negassa, Beiter,
Bello, Brook, Garg, Haigentz, Miller, Hsu, Ravikumar,
Shifteh, Smith, and Silver. Study supervision: Owen, Bello,
Brook, Farinhas, and Smith.

Financial Disclosure: None reported.

REFERENCES


2. Gleich LL, Ryenman J, Gluckman JL, Wilson KM, Barrett WL, Redmond KP. Recurrent advanced (T3 or T4) head and neck squamous cell carcinoma: is sal-

3. Goldstein DP, Karnell LH, Yao M, Chamberlin GP, Nguyen TX, Funk GF. Out-
comes following reirradiation of patients with head and neck cancer. Head Neck.

73(2):399-409.

5. Cohn AB, Lang PO, Agarwal JP, et al. Free-flap reconstruction in the doubly ir-

6. Organ LW. Electrophysiologic principles of radiofrequency lesion making. Appl


8. Ravikumar TS, Kaleya RM, Kishinesvy A. Surgical ablation therapy of liver tumors.

ablation of head and neck tumors: dramatic results from application of a new

10. Owen RP, Silver CE, Ravikumar TS, Brook A, Bello J. Breining D. Techniques for
radiofrequency ablation of head and neck tumors. Arch Otolaryngol Head Neck

11. Brook AL, Gold MM, Miller TS, et al. CT-guided radiofrequency ablation in the
palliative treatment of recurrent advanced head and neck malignancies. J Vasc

12. Therasse P, Arbuck SG, Eisenhauer EA, et al. New guidelines to evaluate the re-
response to treatment in solid tumors: European Organization for Research and
Treatment of Cancer, National Cancer Institute of the United States, National Can-

sectable head and neck carcinoma: experience at the Gustave-Roussy Institute


15. Hassane SJ, Weymuller EA Jr. Assessment of quality of life in head and neck can-


17. Kuehl H, Staatsaa J. Hertel S, et al. Mid-term outcome of poston emission to-
mography/computed tomography-assisted radiofrequency ablation in primary

©2011 American Medical Association. All rights reserved.