Prediction of Local Failures with a Combination of Pretreatment Tumor Volume and Apparent Diffusion Coefficient in Patients Treated with Definitive Radiotherapy for Hypopharyngeal or Oropharyngeal Squamous Cell Carcinoma

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Diffusion-weighted magnetic resonance imaging/Apparent diffusion coefficient/Hypopharyngeal squamous cell carcinoma/Oropharyngeal squamous cell carcinoma.

Purpose: The purpose of this study was to investigate the clinical factors for predicting local failure after definitive radiotherapy in oropharyngeal or hypopharyngeal squamous cell carcinoma. Materials and Methods: Between July 2006 and December 2008, 64 consecutive patients with squamous cell carcinoma of the hypopharynx or the oropharynx treated with definitive radiotherapy were included in this study. Clinical factors, such as pretreatment hemoglobin (Hb) level, T-stage, gross tumor volume of primary tumors (pGTV), and maximum standardized uptake value (SUVmax) on FDG-PET, were evaluated for the correlation with local failure. A subset analysis of 32 patients with MR images including diffusion-weighted images (DWI) as a pretreatment evaluation was also performed. The Kaplan-Meier curves, the log-rank test, and the Cox proportional hazards model were used to evaluate these clinical factors.

Results: Eleven of 64 patients experienced local recurrence, with a median follow-up time of 15 months. In the univariate analysis, Hb level (p = 0.0261), T-stage (p = 0.012), pGTV (p = 0.0025), and SUVmax (p = 0.024) were significantly associated with local failure. In the multivariate analysis, pGTV (p = 0.0070) remained an adverse factor for local control. In the subset analysis of 32 patients with DWI, the median apparent diffusion coefficient (ADC) value of primary tumors on DWI was 0.79 × 10⁻³ mm²/s (range, 0.40–1.60 × 10⁻³ mm²/s). Patients with a high ADC value (> 0.79 × 10⁻³ mm²/s) had a significantly lower local control rate than patients with a low ADC value (100% vs. 44%, p = 0.0019). The rate of local failure among patients with a large pGTV and a high ADC value was 55% (6/11), whereas no local failures occurred (0%, 0/21) among patients with a small pGTV or a low ADC. Conclusions: These results suggest that a combination of a large tumor volume and a high ADC value could be predictive of local recurrence after definitive radiotherapy in hypopharyngeal or oropharyngeal squamous cell carcinoma.

INTRODUCTION

Primary radiotherapy, typically with concurrent chemotherapy, has recently been accepted as a standard manag-
Prediction of Local Failure with ADC Value

MATERIALS AND METHODS

Patient population and treatment

This retrospective study was approved by the Committee for Clinical Studies at our institution; the requirement for informed consent was waived. Between July 2006 and December 2008, 82 consecutive patients with newly diagnosed squamous cell carcinoma of the hypopharynx or the oropharynx were treated with definitive radiotherapy at our institution. Sixty-four of these patients were included in this study. The inclusion criteria were as follows: (a) histologically confirmed squamous cell carcinoma, (b) availability of pretreatment FDG-PET for the initial evaluation, (c) sufficient dose of radiotherapy (> 60 Gy), and (d) no combination therapy involving radiotherapy and surgery. We excluded 18 patients due to the unavailability of FDG-PET (n = 8) and preoperative radiotherapy (n = 10). Of the 64 patients included, 39 underwent MRI including DWI. To estimate the usefulness of DWI for predicting local failures, 32 of these 39 patients were identified for a subset analysis. Of the 39 patients who underwent MRI with DWI, 7 were excluded for the subset analysis due to the presence of a small and unevaluable primary lesion (n = 6) or a severe artifact (n = 1) on DWI.

Radiation treatment was planned on a CT-based three-dimensional treatment planning system (Eclipse; Varian medical systems, Palo Alto, CA). Each patient was immobilized with a custom-made thermoplastic cast in the supine position, and 3-mm thick CT was performed. Target volumes and organs at risk were delineated on CT images. All patients were treated according to a conventional radiotherapy schedule, i.e., 5 days per week at 1.8 to 2.0 Gy per fraction. Typically, the total dose of 65.4–69.4 Gy in 35–37 fractions was prescribed to treat the primary tumor and involved nodes, whereas the prophylactic dose administered to the adjacent nodal regions was 41.4–45.0 Gy in 23–25 fractions. The median total dose targeted to the primary tumor and involved nodes was 65.4 Gy (range, 61.4 to 71.4 Gy). Chemotherapy was administered concurrently in 60 of 64 patients (94%). The regimen of concurrent chemotherapy was S-1 (Taiho Pharmaceutical Co., Ltd, Tokyo, Japan) in 50 patients (78%) and cisplatin-based in 10 patients (22%). Planned neck dissection was performed in 16 patients who had suspected persistent disease in the neck after radiotherapy, as assessed clinically or by imaging study.

Patients underwent routine post-treatment follow-up examination every 1 to 3 months. The follow-up evaluation included physical examination, fiberoptic pharyngolaryngoscopy, and radiographic imaging (CT and/or PET-CT), if needed. Persistent or recurrent primary disease was confirmed by histologic and/or physical examination, radiographic imaging, and by clinical course.
Diffusion-weighted MRI study and image interpretation

MRI studies were performed with a 1.5-T scanner (Intera Achieva; Philips Medical System, Best, the Netherlands) by using a neurovascular coil. Conventional MRI, including T2-weighted turbo spin-echo images, T1-weighted spin-echo images, and contrast-enhanced T1-weighted spin-echo images, were obtained in the transverse plane, a slice thickness of 4–5 mm, a slice gap of 1–1.5 mm, and a 20 × 20 cm – 23 × 23 cm field of view. A T2-weighted turbo spin-echo sequence was performed with the following parameters: matrix, 512 × 288; and repetition time/echo time (TR/TE) = 4467 ms/100 ms. A T1-weighted spin-echo sequence was performed with the following parameters: matrix size, 512 × 288; and TR/TE = 572 ms/10 ms. A contrast-enhanced T1-weighted sequence was obtained after the administration of 0.1 mmol/kg of gadopenatate dimeglumine (Magnevist; Schering, Berlin, Germany). Coronal or sagittal images were obtained when needed.

Diffusion-weighted images were acquired in the transverse plane using a single-shot spin-echo echo-planar imaging sequence with a spectral presaturation of inversion recovery for fat suppression, with diffusion gradient encoding in three orthogonal directions. The parameters used to obtain the diffusion-weighted images were as follows: matrix size, 112 × 79; TR/TE = 3000 ms/73 ms; and bandwidth, 1645.9 Hz/pixel. The following three different b-values were applied: 0, 300, and 1,000 sec/mm². Diffusion-weighted imaging was performed prior to the administration of the contrast media injection.

The ADC values were calculated according to the following formula: $ADC = \frac{\ln(S_1/S_2)}{b_2 - b_1}$, where $S_1$ and $S_2$ are the signal intensities measured on diffusion-weighted images obtained with a lower $b$ factor ($b_1$) and a higher $b$ factor ($b_2$). We used $b$ factors of 300 and 1,000 sec/mm² for calculation of ADC values. The ADC maps were calculated on a pixel-by-pixel basis using software integral to the MRI unit. For the ADC calculation, solid tumor components with $b$ values ranging from 2.9 to 28.2 (median, 12.0).

Statistical analysis

Local control was measured from the first day of radiotherapy to the time of local failure or last follow-up. We estimated the relationship between the clinical and radiographic data and local control. Adverse factors included pretreatment Hb level, T-stage according to the classification system of the American Joint Committee on Cancer (2002), gross tumor volume of the primary tumor (pGTV) calculated using the above mentioned radiation treatment-planning system, overall treatment time, maximum standardized uptake value (SUVmax) on FDG-PET, and mean ADC of the primary tumor on DWI. Due to the lack of an established cutoff level for these factors, we used the median of the SUVmax and the mean ADC value as the cutoff levels. Local control rates were calculated according to the Kaplan-Meier method, and the log-rank test was used to analyze differences between local control curves. The multivariate Cox proportional hazards model was used to adjust for the influence of local control factors. All statistical analyses were performed using computer software (JMP 7; SAS institute, Cary, NC). For all analyses, $p < 0.05$ was considered to be significant.

RESULTS

Patient characteristics

The patient characteristics are shown in Table 1. Fifty-eight (91%) of the patients were men, and the median age was 65 years (range, 37–87 years). The primary sites were the oropharynx in 30 patients (47%), and the hypopharynx in 34 patients (53%). The T-stage classifications were T1 in 12 patients (19%), T2 in 27 (35%), T3 in 17 (27%), and T4 in 12 (19%). The pretreatment Hb ranged from 8.6 to 16.3 g/dl (median, 13.4 g/dl). The pGTV ranged from 0.4 to 86.8 cm³ (median, 9.98 cm³). The SUVmax of the primary lesion ranged from 2.9 to 28.2 (median, 12.0).

Univariate and multivariate analysis of local failure

At the last follow-up, 52 patients were alive and 12 had died of the disease. The median follow-up time for all patients was 15 months (range, 3–42 months). Over the entire follow-up period, 11 of 64 patients (17%) experienced a local recurrence. Local failure occurred within 12 months after the completion of radiotherapy in all but one patient. The 2-year local control rate for all 64 patients was 80% (Fig. 1). Factors associated with poor local control were low pretreatment Hb level ($p = 0.0261$), advanced T-stage ($p = 0.012$), high pGTV ($p = 0.0025$), and high SUVmax ($p = 0.024$). The results of the univariate analysis are shown in Table 2.

Factors significantly influencing local control in the univariate analysis were included in the multivariate analysis using the Cox proportional hazards model. A high pGTV remained a significant adverse factor (hazard ratio, 6.12, $p = 0.0470$) for local control. Regarding pretreatment Hb level, the statistical significance was marginal (hazard ratio, 3.34, $p = 0.0530$). However, other two factors (T-stage and SUVmax) were not significantly associated with local failure in the multivariate analysis. The hazard ratios associated
with local control are listed in Table 3.

Local failure and pretreatment ADC value
We performed a subset analysis of 32 patients who underwent DWI during the pretreatment evaluation in order to assess the usefulness of the ADC value as a factor predictive of local control in addition to that of the pGTV, which is the most sensitive predictor among the conventionally considered factors. Local recurrence occurred in 6 of the 32 patients (19%), and the 2-year local control rate was 80%.

Table 1. Patient characteristics and treatment details.

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Total (n = 64)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (year), median (range)</td>
<td>65 (37–87)</td>
</tr>
<tr>
<td>Gender, n (%)</td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>58 (91)</td>
</tr>
<tr>
<td>Female</td>
<td>6 (9)</td>
</tr>
<tr>
<td>Hb value (g/dl), median (range)</td>
<td>13.4 (8.6–16.3)</td>
</tr>
<tr>
<td>Tumor site, n (%)</td>
<td></td>
</tr>
<tr>
<td>Oropharynx</td>
<td>30 (47)</td>
</tr>
<tr>
<td>Hypopharynx</td>
<td>34 (53)</td>
</tr>
<tr>
<td>Maximum SUV, median (range)</td>
<td>12.0 (2.9–28.2)</td>
</tr>
<tr>
<td>2002 AJCC T-stage, n (%)</td>
<td></td>
</tr>
<tr>
<td>T1</td>
<td>12 (19)</td>
</tr>
<tr>
<td>T2</td>
<td>23 (35)</td>
</tr>
<tr>
<td>T3</td>
<td>17 (27)</td>
</tr>
<tr>
<td>T4</td>
<td>12 (19)</td>
</tr>
<tr>
<td>2002 AJCC stage, n (%)</td>
<td></td>
</tr>
<tr>
<td>I</td>
<td>6 (9)</td>
</tr>
<tr>
<td>II</td>
<td>6 (9)</td>
</tr>
<tr>
<td>III</td>
<td>9 (14)</td>
</tr>
<tr>
<td>IV</td>
<td>43 (67)</td>
</tr>
<tr>
<td>Radiotherapy</td>
<td></td>
</tr>
<tr>
<td>pGTV (cm³), median (range)</td>
<td>9.98 (0.35–86.81)</td>
</tr>
<tr>
<td>Total dose (Gy), median (range)</td>
<td>65.4 (61.4–71.4)</td>
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<tr>
<td>OTT (day), median (range)</td>
<td>60 (48–110)</td>
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<tr>
<td>Chemotherapy</td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>4 (6)</td>
</tr>
<tr>
<td>Concurrent</td>
<td>43 (67)</td>
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<tr>
<td>Concurrent and adjuvant</td>
<td>17 (27)</td>
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<td>Concurrent chemotherapy regimen</td>
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<tr>
<td>S-1</td>
<td>50 (83)</td>
</tr>
<tr>
<td>Platinum-based</td>
<td>10 (17)</td>
</tr>
</tbody>
</table>

**Abbreviations:** SUV = Standardized uptake value; AJCC = American Joint Committee on Cancer; pGTV = Gross tumor volume of the primary tumor; OTT = Overall treatment time.

**Fig. 1.** Kaplan-Meier estimate of local control probabilities in all 64 patients.

Table 2. Univariate analysis of local control (n = 64)

<table>
<thead>
<tr>
<th>Factors</th>
<th>Patients (n)</th>
<th>2-year Local control</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hb value (g/dl; ≥ 12.5 vs. &lt; 12.5)</td>
<td>44</td>
<td>88%</td>
<td>0.0261</td>
</tr>
<tr>
<td>T-stage (T1-2 vs. T3-4)</td>
<td>35</td>
<td>94%</td>
<td>0.0120</td>
</tr>
<tr>
<td>pGTV (cm³; &lt; 10.0 vs. ≥ 10.0)</td>
<td>33</td>
<td>97%</td>
<td>0.0025</td>
</tr>
<tr>
<td>OTT (days; &lt; 60 vs. ≥ 60)</td>
<td>32</td>
<td>80%</td>
<td>0.7848</td>
</tr>
<tr>
<td>Maximum SUV</td>
<td>32</td>
<td>93%</td>
<td>0.0240</td>
</tr>
</tbody>
</table>

**Abbreviations:** pGTV = Gross tumor volume of the primary tumor; OTT = Overall treatment time; SUV = Standardized uptake value.

Table 3. Multivariate analysis of local control (n = 64)

<table>
<thead>
<tr>
<th>Factors</th>
<th>HR (95% CI)</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hb value (g/dl; ≥ 12.5 vs. &lt; 12.5)</td>
<td>3.34 (0.98, 11.80)</td>
<td>0.0530</td>
</tr>
<tr>
<td>T-stage (T1-2 vs. T3-4)</td>
<td>2.39 (0.57, 16.37)</td>
<td>0.2501</td>
</tr>
<tr>
<td>pGTV (cm³; &lt; 10.0 vs. ≥ 10.0)</td>
<td>6.12 (1.02, 118.21)</td>
<td>0.0470</td>
</tr>
<tr>
<td>Maximum SUV</td>
<td>2.32 (0.54, 16.26)</td>
<td>0.2790</td>
</tr>
</tbody>
</table>

**Abbreviations:** HR = hazard ratio; CI = confidence interval.
These subset analysis results were similar to those of the large-group analysis, suggesting that the 32 patients included in the ADC value analysis were representative of the entire group. Also in the univariate analysis of the 32 patients, patients with a high pGTV ($\geq 10$ cm$^3$) had significantly lower rates of local control compared to those with a low pGTV ($< 10$ cm$^3$) (66% vs. 100%, $p = 0.0358$) (Fig. 2).

The mean ADC of the primary tumors in the 32 patients ranged from $0.401 \times 10^{-3}$ mm$^2$/s to $1.636 \times 10^{-3}$ mm$^2$/s (mean $\pm$ S.D. $0.798 \pm 0.207 \times 10^{-3}$ mm$^2$/s; median, $0.794 \times 10^{-3}$ mm$^2$/s). The median ADC values of the primary tumors in the 6 patients with local failure was significantly higher than that of the 26 patients without local failure (0.9288 vs. 0.7628, $p = 0.0013$, two-tailed Mann-Whitney U test) (Fig. 3). Due to the lack of an established ADC cutoff value, the median value was used to establish two groups, i.e., one with a high ADC ($\geq 0.79 \times 10^{-3}$ mm$^2$/s) and the other with a low ADC ($< 0.79 \times 10^{-3}$ mm$^2$/s). In the univariate analysis, patients with a high ADC value had a significantly lower local control rate than patients with a low ADC value (100% vs. 44%, $p = 0.0019$) (Fig. 4).

Between patients with a large pGTV ($\geq 10$ cm$^3$) and those with a small pGTV ($< 10$ cm$^3$), there was no significant difference of the pretreatment ADC (0.8162 vs. 0.8229, $p = 0.1345$, two-tailed Mann-Whitney U test). A scatter plot for

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**Fig. 2.** Kaplan-Meier estimate of local control probabilities in 32 patients by gross tumor volume of primary tumor (pGTV) with respect to time after radiotherapy.

**Fig. 3.** Comparison of mean ADC values of primary tumors between patients with local failure and those with local control.

**Fig. 4.** Kaplan-Meier estimate of local control probabilities by ADC value with respect to time after radiotherapy.

**Fig. 5.** A scatter plot of the incidence of local failure with respect to the relationship between the apparent diffusion coefficient (ADC) and the gross tumor volume of primary tumors (pGTV). The entire area of interest is divided into subsections (lines) at a pGTV of 10 cm$^3$ and at an ADC of $0.79 \times 10^{-3}$ mm$^2$/s. Closed diamonds indicate local failure and open diamonds indicate local control.
prediction of local failure with respect to the relationship between pGTV and ADC values is shown in Fig. 5. All local failures occurred in patients with a high pGTV and a high ADC value (pGTV \( \geq 10 \text{ cm}^3 \) and ADC \( \geq 0.79 \times 10^{-3} \text{ mm}^2/\text{s} \)). The rate of local failures among patients with a high pGTV and a high ADC value was 55% (6/11), whereas no local failures occurred (0%, 0/21) among patients with a low pGTV or a low ADC value. Representative images of MRI before the treatment in two patients with a high pGTV of hypopharyngeal squamous cell carcinoma treated with definitive radiotherapy were shown in Fig. 6. One patient had a T3 primary tumor (pGTV = 21.7 cm\(^3\)) with a high ADC value \((0.86 \times 10^{-3} \text{ mm}^2/\text{s})\). The patient experienced local failure 7 months after the treatment. (A) A 50-year-old man with T3N0M0 disease. The gross tumor volume of the primary tumor (pGTV) was 21.7 cm\(^3\). The ADC value was \(0.86 \times 10^{-3} \text{ mm}^2/\text{s}\). The patient experienced local failure 7 months after the treatment. (B) A 80-year-old man with T3N2bM0 disease. The pGTV was 21.6 cm\(^3\). The ADC value was \(0.75 \times 10^{-3} \text{ mm}^2/\text{s}\). The patient has local control 13 months after the treatment.

DISCUSSION

In this study, we investigated the usefulness of ADC as a possible factor to be considered together with other clinical factors in the prediction of local control with radiation therapy for hypopharyngeal or oropharyngeal squamous cell carcinoma. Primary tumor volume was found to be the most sensitive predictive factor of local control among the traditionally considered clinical factors. In addition, a high ADC was significantly associated with less local control in a group of patients with large primary tumors. These results suggest that a combination of large tumor volume and high ADC value is predictive of local recurrence after definitive radiotherapy.

Various factors for predicting outcome in HNSCC have been described in previous clinical studies. Pretreatment Hb level,6–10) T-stage,11) primary tumor volume,12–19) and overall treatment time20–43) have been widely reported to be factors related to local control. Recently, the potential value of FDG-PET has been demonstrated in several studies.20–23) In the present study, only primary tumor volume was a significant factor associated with local failure in both univariate and multivariate analyses, whereas pretreatment Hb level, T-stage, and SUV\(_{\text{max}}\) were significantly associated with local failure in the univariate analysis. The 2-year local control rates for tumor volumes < 10 cm\(^3\) compared with those \(\geq 10 \text{ cm}^3\) were 97% and 64%, respectively. It remains difficult to directly compare our results with those of the preceding studies, because other studies of various tumor sub-sites have been reported in which each factor was evaluated separately. However, we collectively analyzed such predictive factors in a relatively homogenous group of patients with primary tumors in the hypopharynx and the oropharynx treated with definitive radiotherapy. The result of multivariate analysis in the present study shows that primary tumor volume is more predictive for local control than pretreatment Hb level, T-stage and SUV\(_{\text{max}}\) on FDG-PET in our patient group. Therefore, primary tumor volume is considered to be one of the most useful predictors for local control after definitive radiotherapy in patients with hypopharyngeal or oropharyngeal squamous cell carcinoma. Primary tumor volume measured by CT for HNSCC has been shown to be variable within T-stage in several studies.45–47) In addition, it has been reported that primary tumor volume is more important to predict local control after radiotherapy compared to T-stage in the studies of nasopharyngeal carcinoma, and hypopharyngeal carcinoma.15,48) Regarding to the FDG-PET, maximum SUV was reported to be not independent prognostic factor after radiotherapy for HNSCC by several authors.49–51) Instead of maximum SUV, metabolic tumor volume was reported to be an adverse prognostic factor in patients with HNSCC.51) Primary tumor volume combined with metabolic activity may be useful to predict local control after definitive radiotherapy. In the present study, pretreatment Hb level was associated with local failure with a marginal significance in the multivariate analysis. This result of an influence of pretreatment Hb level on local failure is
thought to be not contradicted to those of the previous reports.\textsuperscript{5–10} Pretreatment Hb level should be considered to have an important role in local control of hypopharyngeal or oropharyngeal squamous cell carcinoma with definitive radiotherapy as a factor in the host.

To date, ADC values have been studied as a potential marker for predicting treatment outcome; some studies have demonstrated that a high ADC value is an adverse factor in patients who undergo chemotherapy or chemoradiotherapy. In a rectal cancer study, Dzik-Juraz \textit{et al.} found strong negative correlations between mean pretreatment tumor ADC and changes in tumor size after chemotherapy and chemoradiation.\textsuperscript{50} Koh \textit{et al.} reported that a high pretreatment mean ADC of colorectal hepatic metastatic lesions was predictive of a poor response to chemotherapy.\textsuperscript{52} Moreover, in the case of cervical squamous cell carcinomas, McVeigh \textit{et al.} reported that the 90th percentile of ADC values was lower in responders than in non-responders to chemoradiation.\textsuperscript{53} Although the biophysical basis for an association between a high ADC and poor outcome is not yet fully understood, there is some accounting for this relationship. A negative correlation between ADC and cell density has been observed in certain primary and secondary malignancies.\textsuperscript{54–57} Therefore, it appears that tumors with a lower ADC are more likely to have viable proliferative cells, which exhibit a better response to chemoradiotherapy. On the other hand, the presence of necrosis, inflammatory changes, and/or submucosal fibrosis was associated with high ADC values, which correlates with an increased interstitial water content and low cell density on histologic samples.\textsuperscript{58} This observation indicates that tumors with a high ADC exhibit a poor response to chemoradiotherapy.

In a study of HNSCC, Kim \textit{et al.} reported that the pretreatment ADC value in the metastatic lymphnodes of complete responders was significantly lower than in those of partial responders.\textsuperscript{59} Kato \textit{et al.} also reported that tumors responded to neo-adjuvant therapy tended to have lower ADC values.\textsuperscript{71} Our observation of an association between high local control and low primary-tumor ADC values is consistent with the findings of these previous studies. Moreover, in patients with large-volume primary tumors, a significant difference in local control rate was observed between those with low and high primary-tumor ADC values. Since sample size of the present study was too small to arrive at definitive conclusions, further study will be needed in order to define the associated mechanisms of action and the potential role for the ADC value in predicting local failure. However, it appears likely that a high primary-tumor ADC value is an adverse factor related to local control of large-volume tumor.

New biomarkers (e.g., human papilloma virus (HPV) infection,\textsuperscript{59–61} epidermal growth factor receptor expression (EGFR),\textsuperscript{62} and p53 overexpression\textsuperscript{63}) potentially predictive of or able to detect treatment outcomes in HNSCC patients have been recently reported. In the present study, no analysis was performed to investigate the biological basis of this disease. Nevertheless, our results demonstrated a significant correlation between ADC value and local failure, which suggests the great predictive potential of the ADC value.

In conclusion, our results indicate that a combination of the tumor volume and the ADC value, calculated using diffusion-weighted MRI, can predict local failure in patients with squamous cell carcinoma of the hypopharynx or oropharynx. The inclusion of diffusion-weighted MRI during pretreatment evaluation will provide useful information for the selection of patients appropriate for definitive radiotherapy. In particular, function may be preserved with definitive radiotherapy in cases involving primary tumors with a low ADC value.

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