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MR imaging predictors of local control of glottic squamous cell carcinoma treated with radiation alone

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ABSTRACT

Purpose: To retrospectively evaluate the prognostic significance of magnetic resonance (MR) imaging-determined tumor parameters, especially the presence of cartilage invasion, regarding local control of glottic squamous cell carcinoma treated with radiation therapy (RT) alone.

Materials and methods: The study was performed with the approval of our institutional review board; direct patient consent was waived. Pretreatment MR images of 118 patients aged 41-86 years (110 men, eight women) with glottic carcinoma treated with RT alone were reviewed for tumor involvement of specific laryngeal anatomic subsites (including laryngeal cartilages), tumor volume, and extralaryngeal tumor spread; these findings were compared with local control**.** Local control was defined as absence of a recurrence at the primary site for 2 years. Statistical significance of differences between curves for local control estimated with the Kaplan-Meier was tested with log-rank test.

*Results***:** Results of univariate analysis showed all MR imaging-determined parameters to be significant predictors of local control rate, compared with clinical parameters where T classification and vocal cord mobility were the only significant parameters associated with local control. Multivariate analysis (Cox regression model) of clinical and radiologic parameters revealed that hypopharyngeal extension ($p=0.04$) and intermediate T2 signal intensity (SI) in cartilage similar to tumor SI ($p<0.001$) were independent prognostic factors with regard to local control.

Conclusion: Intermediate T2 SI in cartilage, which may suggest cartilage invasion, and hypopharyngeal extension of tumor, predict greater likelihood of local failure, whereas high T2 SI, which may suggest inflammatory tissue in cartilage, predicts lower likelihood of local failure.

INTRODUCTION

Clinical tumor extension, and to some degree imaging findings, according to the TNM system, provide important information about the probability of local control of laryngeal carcinoma after radiation therapy (RT) with curative intent. Patients with advanced disease (e.g., in the case of extensive cartilage invasion and/or extralaryngeal extension), comprise an unfavorable group for RT and are often advised to undergo laryngectomy [1]. Combined chemo- and radiation therapy for advanced stages of laryngeal carcinoma with salvage surgery constitute a good alternative for primary surgery followed by postoperative RT [2-4].

Computed tomography (CT) findings of the primary tumor have been described as potential effective predictors of local control of glottic carcinoma treated with RT alone [5-9]. In several studies, a large CT-derived tumor volume was found to be a predictor of local failure [6,7,9]. Pameijer et al. [6] proposed that T3 glottic cancer with a CT-based tumor profile smaller than 3.5 cm^3 and single or no laryngeal cartilage sclerosis may potentially be treated by RT with a curative intent. In other studies, the risk of tumor recurrence has been reported to increase with invasion of the pre-epiglottic and paraglottic spaces and subglottic extension, where primary tumor volume is an important predictor, but covariates reflecting deep tissue invasion seem to be even stronger predictors of local control in glottic cancer [5,8]. The presence of extralaryngeal spread has also been recognized as an important prognostic factor regarding local control in the head and neck and was associated with higher rates of failure [10].

It is often suggested that cartilage involvement depicted at imaging precludes voice-sparing partial laryngectomy and is also a contraindication to radiation treatment, thus leaving total laryngectomy as the only alternative [11-13]. Previous reports have shown that CT evidence of subtle cartilage invasion may not be a valid predictor of poor results with RT [5]. CT is more specific, but less sensitive, than magnetic resonance (MR) imaging [12]. As reviewed by Castelijns et al. [14-16], pretreatment MR findings of tumor volume, especially in combination with the so-called *abnormal signal intensity in cartilage* seen on T1-weighted images, indicate an adverse prognosis with regard to tumor recurrence. To our knowledge, MR findings have not been studied regarding differences in T2 signal intensity (SI) in cartilage and its correlation with local outcome for glottic cancer after radiation therapy. Thus, the objective of our study was to retrospectively evaluate the prognostic importance of MR imaging-determined tumor parameters, especially the presence of cartilage invasion, regarding local control of glottic squamous cell carcinoma treated by RT alone.

MATERIALS AND METHODS

Patient population

Patients eligible for this retrospective study were those with pathologically proven glottic squamous cell carcinoma, treated with RT alone between 1984 and 1999. All patients underwent pretreatment MR imaging. Patients with a previous history of laryngeal cancer or other malignant diseases in the head and neck region were excluded. The study was performed with the approval of our institutional review board; direct patient consent was waived.

One hundred eighteen patients, aged 41-86 years (median, 64 years) met the inclusion criteria: 110 men (93%) and eight women (7%). Seventy-seven patients (65.3%) had normal vocal cord mobility, 30 patients (25.4%) had impaired cord mobility and 11 (9.3%) had no cord mobility. Stage of disease in all patients was clinically assessed according to International Union Against Cancer staging system 2002 [17]. Finally, the classification was T1a in 10 patients (8.5%), T1b in 29 patients (24.5%), T2 in 59 patients (50.0%), T3 in 10 patients (8.5%), and T4 in 10 patients (8.5%). Five patients with positive lymph nodes were clinically and according to MR imaging findings classified: T2N1 (n=3), T3N1 (n=1), and T4N1 (n=1). Histopathologic examination of biopsy specimens showed well-differentiated squamous cell carcinoma in 28 patients (23.7%), moderately differentiated carcinoma in 69 patients (58.5%) and poorly differentiated carcinoma in 21 patients (17.8%).

MR imaging

Before 1994, MR images were obtained by using a 0.6-T MR system (Teslacon I; Technicare, Solon, Ohio). From 1994 on, MR images were obtained with 1.0-T MR system (Impact; Siemens Medical Solutions, Erlangen, Germany). MR examinations were performed with an anterior surface neck coil. A multisection two-dimensional Fourier-transform spin-echo pulse sequence was used in all cases. In sagittal and transverse planes, a T1-weighted spin-echo technique (repetition time msec/echo time msec, 200-700/15) was applied. We also generated intermediate-weighted (1500/38) and T2-weighted (1500-4000/76-98) spin-echo MR images in the transverse plane at each corresponding level. Transverse planes were obtained parallel to the vocal cords. The acquisition of T1-weighted MR images was repeated four times for signal averaging, while intermediate-weighted and T2-weighted MR images were acquired twice. Gadolinium-based (contrast material) was not routinely used in these patients. A 4-mm section thickness was used, with a 1-mm intersection gap. The field of view was kept as small as possible (200 X 200 mm). Acquisition times varied from 3 to 6 minutes per sequence.

Radiation therapy and follow-up

The mean period between MR imaging examination and start of RT was 28 days (range, 2-86 days). All patients were treated with a linear accelerator using 6-MeV photons. In T1- and small T2-stage lesions, the clinical target volume consisted of the thyroid cartilage and no field reductions were used. In the case of T3- and T4-stage tumors or T2-stage lesions with impaired mobility and/or tumor extension at the level of the false vocal cords, the primary clinical target volume included the gross tumor volume (GTV) with a margin of at least 1.5 cm, the thyroid cartilage, and the lymph nodes in levels II-IV on both sides of the neck. In the case of pathologic lymph nodes, the elective nodal area was extended to level Ib to V on both sides. The clinical target volume of the boost included the GTV with a 1-cm margin. Total RT dose for patients ranged from 58 to 74 Gy (mean, 64.5 Gy), by using 2.0 to 2.5 Gy per fraction. The fractionation schedule for the early stages of RT (i.e., T1-T2N0) was 2.5 Gy per fraction, five times a week, to a total dose of 60.0-62.5 Gy. This policy was not changed during the inclusion period. Before 1998, different fractionation schedules were used for more advanced laryngeal carcinoma cases. After 1998, planning CT was implemented routinely in these cases and the fractionation schedule was standardized to 70 Gy, 2 Gy per fraction, and six fractions per week, including a second fraction on Friday afternoon with a concomitant boost technique. The interval between the first and second fraction on Friday was at least 6 ours.

Follow-up included indirect laryngoscopy at regular intervals every 2 months during the first 2 years after finishing RT and every 4 to 6 months thereafter, supplemented by direct laryngoscopy with biopsies as necessary. Imaging was not routinely performed. No patients were lost to follow-up. The follow-up period was designated as the total time of follow-up ending either at local recurrence, or at last patient contact without local recurrence with a minimum of 2 years (mean follow-up time, 33 months; range, 4–97 months).

Evaluation of MR imaging parameters

All pretreatment MR images were retrospectively reviewed and evaluated by two observers in consensus with 13 and 4 years experience of head and neck MR imaging. They were blinded to the identity of patients and their clinical records. The following MR imaging parameters were assessed: primary tumor volume; presence of supraglottic and subglottic extension, and involvement to pre-epiglottic space; abnormal signal intensity in or destruction of cartilage adjacent to tumor tissue (i.e., abnormal SI in cartilage at the anterior commissure, thyroid cartilage, and/or cricoarytenoid cartilage; and extralaryngeal extension beyond these cartilages-see below); and hypopharyngeal extension.

Abnormal signal intensity in thyroid cartilage with tumor extent into the anterior commissure was separately assessed from abnormal SI in the remaining part of thyroid cartilage without tumor extent to the anterior commissure.
Abnormal signal intensity in the cricoarytenoid region was defined as abnormal SI in the cricoid or arytenoid cartilage around the cricoarytenoid joint.
Extralaryngeal extension beyond cartilage adjacent to the anterior commissure was considered to have spread beyond the cartilaginous framework into contiguous soft tissues. Tumor involvement into the hypopharynx was described as invasion of the lateral wall of the piriform sinus and postcricoid area.

Tumor extension was assessed on T1-weighted MR images as an area of intermediate signal intensity, in high contrast to high-signal fat and with somewhat lower SI than that of muscular tissue [18]. Abnormal SI in cartilage was diagnosed on the basis of combined use of T1- and T2-weighted MR images at corresponding levels. On T1-weighted MR images, the tumor showed intermediate SI with high contrast to high-signal bone marrow of ossified cartilage. Different degrees of T2 SI in the cartilage were evaluated (low vs. intermediate vs. high): low T2 SI, as nonossified cartilage; intermediate T2 SI in cartilage, as similar to tumor SI; and high T2 SI in cartilage, as higher than T2 SI of intralaryngeal tumor tissue. Glottic cancers showing abnormal signal intensity in one of the cartilages (thyroid, cricoarytenoid, and thyroid at anterior commissure) on T1-weighted MR images and with intermediate SI on T2-weighted MR images in at least one of the involved cartilages were classified as tumors with intermediate T2 SI in cartilage similar to tumor SI.
From 1985 to 1994, MR examinations were redigitized by using a film scanner. After 1993, digital MR images were obtained directly. The tumor outlines were traced manually on T1-weighted MR images by one observer (R.Lj.) with use of a computerized image analysis tool that is available as part of our hospital's (VU University Medical Center) picture archiving and communication system (Centricity Radiology RA 600, version 6.1; GE Healthcare, Milwaukee, Wis). The volume of the tumor was calculated in cubic centimeters by multiplying the tumor areas by section thickness and intersection gap and was then summarized over all sections in which the tumor was present. In 16 of 118 patients, no soft-tissue abnormality could be detected on MR images because the tumor was too small. In the analyses, tumors in these patients were considered to have a volume of 0 cm^3.

Statistical analysis

To evaluate the effectiveness of RT in local control, histologically proved local recurrences during follow-up were considered local failures. Local control was calculated from the first day of radiotherapy. In the univariate analysis, the

curves for local control were estimated by using the Kaplan-Meier method. To test the statistical significance of differences between curves, the log-rank test was used. A multivariate analysis using the Cox proportional hazards model was performed stepwise to identify clinical and radiologic covariates that were significantly associated with local control.

In the uni- and multivariate analyses, the following variables were entered stepwise into the model: sex (male vs. female), age (≤64 yr vs. >64 yr), T classification (T1a vs. T1b vs. T2 vs. T3 vs. T4), N classification (N0 vs. N1), vocal cord mobility (normal vs. impaired vs. fixed), primary tumor volume (0.1-1.1 cm^3 vs. 1.1-3.0 cm^3 vs. >3.0 cm^3), supraglottic extension (no vs. yes), subglottic extension (no vs. yes), involvement in pre-epiglottic space (no vs. yes), abnormal SI in the thyroid at the anterior commissure (no vs. yes), abnormal SI in thyroid and/or cricoarytenoid cartilage (no vs. yes), extralaryngeal extension beyond cartilage at the anterior commissure (no vs. yes), hypopharyngeal extension (no vs. yes), and T2 SI in cartilage (low vs. intermediate vs. high). In the first step of the multivariate analysis, only the clinical parameters were entered. In the second step, the MRI parameters were entered as well.

P values <0.05 were designated for determining significant differences. All statistical calculations were performed by using software (SPSS, version 11.0; SPSS, Chicago, III).

RESULTS

MR imaging parameters

The mean tumor volume was 2.3 cm^3 (median, 1.5 cm^3; range, 0.0-11.0 cm^3), and a significant correlation was found between T classification and tumor volume ($p<0.001$).

In our population, extralaryngeal extension beyond thyroid and cricoid cartilage was not found. In 52 (44%) of 118 patients abnormal signal intensity of cartilages adjacent to tumor tissue was found. Abnormal SI of cartilages in 17 (14%) of 118 patients was seen as higher than tumor T2 SI and was considered to be high T2 SI in cartilage. In 35 (30%) of 118 patients, the abnormal SI of at least one of the involved cartilages was similar to tumor SI on T2-weighted MR images and was considered to be intermediate T2 SI in cartilage (Table 1, Figs. 1 and 2).

Local control

Thirty-nine (33%) of 118 patients developed a local failure within 2 years and thirty-six of these underwent salvage laryngectomy. Of the clinical parameters, only T classification and vocal cord mobility were significantly associated with

Table 1: Tumor extension and abnormal SI in adjacent laryngeal cartilages

Site	No. Of patients
Supraglottic extension	
No	78 (66)
Yes	40 (34)
Subglottic extension	
No	63 (53)
Yes	55 (47)
Extension to the pre-epiglottic space	
No	108 (92)
Yes	10 (8)
Abnormal SI of cartilage at anterior commissure	
No	72 (61)
High T2 SI in cartilage	16 (14)
Intermediate T2 SI in cartilage	30 (25)
Abnormal extralaryngeal tissue at anterior commissure	
No	109 (92)
High T2 SI in cartilage	2 (2)
Intermediate T2 SI in cartilage	7 (6)
Abnormal SI of thyroid cartilage	
No	113 (96)
Yes	5 (4)
Abnormal SI of cricoarytenoid cartilage	
No	111 (94)
Yes	7 (6)
Abnormal SI of thyroid and/or cricoarytenoid cartilage	
No	106 (90)
High T2 SI in cartilage	2 (2)
Intermediate T2 SI in cartilage	10 (8)
T2 SI in all cartilages	
Low	66 (56)
High	17 (14)
Intermediate	35 (30)
Hypopharyngeal extension	
No	111 (94)
Yes	7 (6)

Note.--No patients had abnormal extralaryngeal tissue at thyroid and/or cricoid cartilage. Numbers in parentheses are precentages of the total.

local control (Table 2). For all MR imaging parameters, a significant association was found with local control (Table 3). Owing to the limited number of patients (n=12), abnormal SI in thyroid and cricoarytenoid cartilage was considered in the statistical analyses as one covariate of both cartilages ("at least one" or "both no").

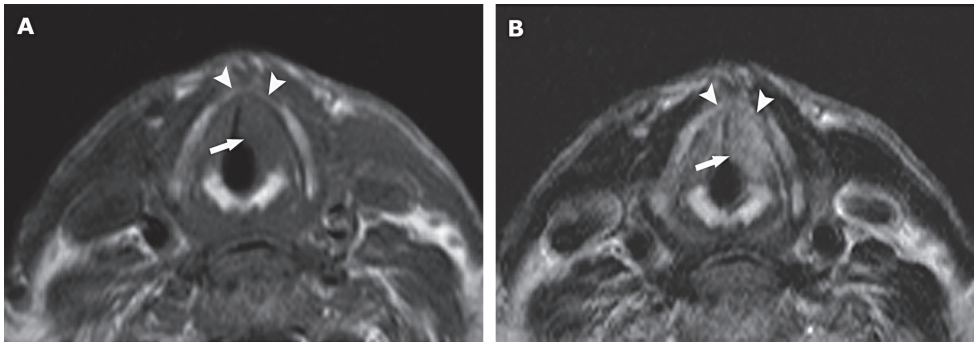

Figure 1: Clinical stage T2 glottic carcinoma in 70-year-old patient. (A) Transverse T1-weighted MR image (600/15) at level of true vocal cord shows mass (arrow) with intermediate SI in left cord. Abnormal SI of the thyroid cartilage at anterior commissure is shown (arrowheads) as intermediate T1 SI. No tumor was noted in right vocal cord. (B) Transverse T2-weighted MR image (3000/98) at corresponding level demonstrates tumor tissue (arrow) with intermediate SI of tumor mass and of tumor extension compared with A, confirming abnormality in cartilage (arrowheads).

In this univariate analysis, local control among patients with abnormalities of the cartilage classified as a high T2 SI was similar to that obtained from patients with normal cartilage seen as a low T2 SI on MR images (87% vs. 84%). In patients with intermediate T2 SI in cartilage, local control was significantly worse (27%) (Table 3, Fig. 3).

In the first step of the multivariate analysis, when the clinical parameters were entered, T classification ($p=0.05$) and vocal cord mobility ($p=0.04$) were independent prognostic factors with regard to local control. When the MR parameters were entered, hypopharyngeal extension ($p=0.04$) and intermediate T2 SI in cartilage ($p<0.001$) were found to be significantly associated with local control, while clinical parameters were no longer significantly associated with local control (Table 4).

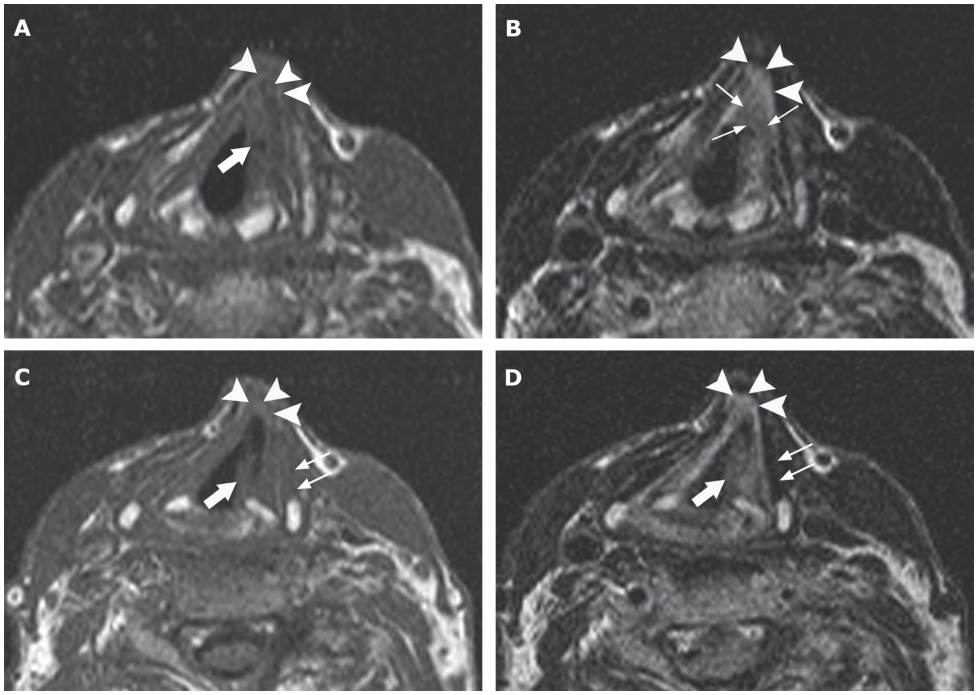

Figure 2: Clinical stage T1b glottic carcinoma in 76-year-old patient. (A) Transverse T1-weighted MR image (400/15) at level of true cord shows mass (arrow) with intermediate SI in left cord. Abnormal intermediate SI of the thyroid cartilage at anterior commissure (arrowheads) is also seen. (B) Transverse T2-weighted MR image (2700/98) at corresponding level demonstrates tumor tissue (arrows) with intermediate T2 SI of tumor mass in high contrast to non-ossified cartilage. Thyroid cartilage at anterior commissure shows higher T2 SI than does tumor tissue, which may suggest inflammatory tissue (arrowheads). (C) Transverse T1-weighted MR image (400/15) of same patient, one section lower, again shows tumor mass (large arrow) with intermediate SI in left cord with abnormal SI of thyroid cartilage at anterior commissure (arrowheads). The remaining part of thyroid cartilage on left side (small arrows) is also seen with intermediate SI. (D) Transverse T2-weighted MR image (2700/98) at corresponding level clearly demonstrates low SI in remaining part of thyroid cartilage on left side, suggesting non-ossified cartilage. Consequently, the anterior two-thirds of thyroid lamina cartilage is non-ossified. (Keys are as in C.)

Table 2: Univariate analysis of local control for clinical and histopathological variables estimated with the Kaplan-Meier method

Variable	No. of patients	2-year local control (%)	P value (log rank)*
Sex			ns
Male	110	65	
Female	8	62	
Age			ns
≤64 years	57	65	
>64 years	61	68	
T classification			0.03
T1a	10	83	
T1b	29	79	
T2	59	63	
T3	10	55	
T4	10	30	
N classification			ns
N0	113	67	
N+	5	53	
Vocal cord mobility			0.047
Normal	77	76	
Impaired	30	53	
Fixed	11	50	
Grade of differentiation			ns
Well differentiated	28	70	
Moderately differentiated	69	61	
Poorly differentiated	21	80	

* ns = not significant.

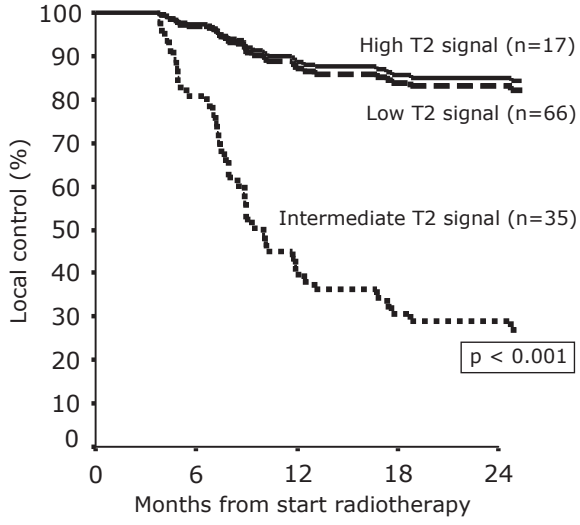

Figure 3: Graph shows that patients with glottic cancer with intermediate T2 SI in cartilage similar to tumor SI had a poor prognosis (n=35, 2-year local control rate, 27%; 95% confidence interval: 20-34%) compared with patients with high T2 SI in cartilage (n=17, 2-year local control rate, 84%; 95% confidence interval: 76-98%) and patients with low T2 SI in cartilage (n=66, 2-year local control rate, 87%; 95% confidence interval: 75-93%).

Table 3: Univariate analysis of local control for MRI imaging variables estimated with the Kaplan-Meier method

Variable	No. of patients	2-year local control (%)	*P* value (log rank)
Primary tumor volume			0.001
0-1.1 cm^3	40	90	
1.1-3.0 cm^3	45	64	
>3.0 cm^3	33	44	
Supraglottic extension			0.009
No	78	76	
Yes	40	50	
Subglottic extension			0.001
No	63	81	
Yes	55	52	
Extension to the pre-epiglottic space			0.05
No	108	70	
Yes	10	40	
Abnormal SI in cartilage at anterior commisure			0.001
No	72	79	
Yes	46	48	
Abnormal SI in thyroid and/or cricoarythenoid cartilage			<0.001
No	106	72	
Yes	12	24	
Extralaryngeal extension beyond cartilage at anterior commisure			0.008
No	109	72	
Yes	9	22	
Hypopharyngeal extension			<0.001
No	111	70	
Yes	7	21	
T2 SI in cartilage			<0.0001
Low	66	84	
High	17	87	
Intermediate	35	27	

Table 4: Final results of the multivariate analysis regarding local control

Variable	Score	Regression coëfficent	Hazard ratio*	*P* value
T2 signal in cartilage				<0.001
High	Compared to low	-0.41	0.6 (0.1, 3.0)	0.593
Intermediate	Compared to low	1.86	6.4 (3.1, 13.3)	<0.001
Hypopharyngeal extension	0 = no, 1 = yes	1.03	2.7 (1.0, 7.4)	0.039

Note.-- The model included all clinical and imaging parameters from Table 2 and 3. * Numbers in parentheses are 95% confidence intervals.

DISCUSSION

In our study, the most important independent prognostic factor turned out to be intermediate T2 signal in cartilage as assessed on MR images. With T2-weighted MR images, it may be possible to accurately assess extension of the tumor into adjacent cartilages, showing tumor tissue in cartilage with an intermediate signal intensity similar to that of intralaryngeal tumor tissue. Consequently, T2-weighted MR images may be useful for assessing tumor invasion into cartilage. In initial reports by Becker et al. [11,19] and Zbaren et al. [20], it was thought that apparent inability to differentiate between non-tumorous inflammatory changes and tumor by using MR imaging may lead to overestimation of neoplastic invasion.

According to our study, abnormal MR imaging SI patterns in cartilage (thyroid, cricoarytenoid, and thyroid at anterior commissure), without distinguishing different SIs as seen on T2-weighted images, were correlated with the risk of tumor recurrence. Univariate analyses demonstrated that SI abnormalities of cartilages were significantly associated with local control, but in multivariate analysis these findings did not reach significance when compared with more specific T2-weighted MR SI. These findings are in agreement with a preliminary report that stated that abnormal cartilage as shown on MR imaging increases the risk on local tumor recurrence [14]. In other MR studies, tumor lesions have an increased risk of local failure after RT, especially when invasion of the thyroid cartilage is suggested [21].

In a previous CT study by Hermans et al. [5], invasion of cartilage was not found to be an important predictor of local recurrence. While CT may enable detection of cartilage invasion, it may also fail because of the large variability of ossification patterns in the laryngeal cartilages. However, on the basis of results from a well-performed MRI-histopathologic correlative study, Becker et al. recently showed that SIs may enable differentiation between a tumor and inflammatory tissue in cartilage as found on T2-weighted spin-echo MR images (personal communication, Minerva Becker, MD, October 7, 2004). These findings are in agreement with those of the present study in which MRI abnormalities classified as an intermediate T2 SI in cartilage similar to tumor SI were significantly associated with decreased local control.

The second most important prognostic factor in the present study was extension into the hypopharynx as assessed on MR imaging, which might be explained by a combination of large tumor volume and deep tissue extension. Hamilton et al. [9] reported that hypopharyngeal involvement of a tumor would be useful as a potential indicator of local control. However, Hamilton et al. also demonstrated a correlation between the tumor volume of T2- and T3-stage laryngeal glottic carcinoma and local control, however [9]. In our

study, MR imaging-determined tumor volume was significantly associated with local control in the univariate analysis, but in the multivariate analysis tumor volume was no longer an independent prognosticator. Both, intermediate T2 SI in cartilage and hypopharyngeal tumor extension were potential confounders for the association between tumor volume and local control.

Another question arises regarding accurate volume measurement by using CT and/or MRI. In a study by Daisne et al. [22], tumor delineation at CT, MRI, and fluorine 18-fluorodeoxyglucose positron emission tomography was compared and validated with the macroscopic surgical specimen when available. In that study, the results showed that in hypopharyngeal and laryngeal cancer, tumor volume on CT and MR images were substantially overestimated when compared with the volume assessed by using the surgical specimens, owing to the presence of peritumoral infiltration.

Consequently, MR findings (i.e., hypopharyngeal extension and intermediate T2 SI in cartilage, which may suggest cartilage invasion) may be effective predictors for outcome of glottic carcinomas after definitive RT. In most patients with glottic carcinoma, non-surgical organ preservation strategies are considered as best initial management approach. However, some selected subgroups of patients may have a higher risk to local failure than other patient groups. The results of our study showed that in patients with tumors with an intermediate SI pattern (suggesting cartilage invasion) in cartilages on T2-weighted MR images have a poor outcome with respect to local control, which was only 27% after 2 years. On the other hand, the results also showed that inflammatory changes possibly defined as high T2 SI in cartilage indicate that the patients with these SI abormalities in cartilage should not automatically imply laryngectomy and could successfully be treated with non-surgical treatment modalities.

One of the limitations of our study was that MR examinations were performed using different techniques (0.6- vs. 1.0-T MR machines, digitization of older films). However, in our opinion, this did not influence contrast between tumor tissue and surrounding tissue and therefore did not interfere with adequate diagnosis of the extent of tumor tissue. Furthermore, we could not perform a pathologic analysis because our whole patient population was treated with definitive radiation therapy.

The results of our study confirmed that T2-weighted MR images may be helpful for determining outcome of primary RT in glottic carcinoma. Intermediate T2 SI in cartilage, which may suggest cartilage invasion, and hypopharyngeal extension of tumor predict a greater likelihood of local failure, whereas high T2 SI, which may suggest inflammatory tissue in cartilage, predicts a lower likelihood of local failure. A pathologic study would then determine whether this intermediate SI indeed represents a tumor.

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