HEAD AND NECK

Redina Ljumanovic
Johannes A. Langendijk
Otto S. Hoekstra
Dirk L. Knol
C. René Leemans
Jonas A. Castelijns

Pre- and post-radiotherapy MRI results as a predictive model for response in laryngeal carcinoma

R. Ljumanovic (✉) · J. A. Castelijns
Department of Radiology, VU
University Medical Center,
De Boelelaan 1117, 1081 HV
Amsterdam,
P.O. Box 7057, 1007 MB
Amsterdam, The Netherlands
e-mail: Redina.Ljumanovic@vumc.nl
Tel.: +31-20-4440363
Fax: +31-20-4442831

J. A. Langendijk
Department of Radiation Oncology,
University Medical Center Groningen,
Groningen, The Netherlands

O. S. Hoekstra
Department of Nuclear Medicine and
PET research, VU University Medical
Center,
Amsterdam, The Netherlands

D. L. Knol
Department of Clinical Epidemiology
and Biostatistics, VU University
Medical Center,
Amsterdam, The Netherlands

C. R. Leemans
Department of Otolaryngology Head
and Neck Surgery, VU University
Medical Center,
Amsterdam, The Netherlands

Abstract The purpose was to determine if pre-radiotherapy (RT) and/or post-radiotherapy magnetic resonance (MR) imaging can predict response in patients with laryngeal carcinoma treated with RT. Pre- and post-RT MR examinations of 80 patients were retrospectively reviewed and associated with regard to local control. Pre-RT MR imaging parameters such as tumor involvement of specific laryngeal anatomic subsites including laryngeal cartilages and post-RT changes, i.e., complete resolution of the tumor or focal mass/asymmetric obliteration of laryngeal tissue and signal pattern on T2-weighted images, were evaluated. Local control was defined as absence of a recurrence at the primary site for 2 years. Local control rates based on pretreatment MR findings were 73% for low pre-RT risk-profile and 29% for high pre-RT risk-profile patients (p=0.0001). Based on posttreatment MR findings, local control rates were 100% score 1, 64% score 2, and 4% score 3 (p< 0.0001). Using post-RT T2-weighted images, significant association was found between differences in signal pattern and local control: 77% hypointense, 54% isointense and 15% hyperintense lesions (p<0.001). Differences between means of delay of post-MRI examination were significantly associated with regard to local control (p=0.003); recurrent tumors followed 5 months after RT were more easily detectable on MRI than recurrent tumors within 4 months after RT. Sensitivity, specificity, accuracy, negative and positive predictive values of post-RT score 3 were 96%, 76%, 83%, 98% and 66%. Pre- and post-RT MRI evaluation of the larynx can identify patients at high risk for developing local failure.

Keywords MR imaging · Laryngeal neoplasm · Radiation oncology · Response to treatment

Introduction

Imaging modalities like computed tomography (CT) and magnetic resonance (MR) imaging are increasingly used in follow-up of head and neck tumors. Promising results have also been achieved for differentiation between residual or recurrent head and neck tumors and postoperative or postradiation changes with diffusion-weighted echo-planar MR imaging [1]. However, the difference in pathology and type of treatment and postradiation changes would definitely affect the ADC value. The ability to provide an accurate pretreatment prediction of response may offer a possible opportunity to modify the initial treatment regimen to improve clinical outcome.

The preliminary studies suggest that with CT and MR imaging it is possible to identify patients treated with primary radiotherapy (RT) for squamous cell head and neck cancer that are at increased risk for local recurrence [2–11].

Residual or recurrent tumor after treatment can be difficult to detect by physical examination due to the radiation effects producing varying degrees of persistent mucositis, edema and fibrosis and cartilage necrosis. Approximately 50% of patients with severe edema or necrosis following radiotherapy will have a recurrence [12]. The need for biopsy itself can present a dilemma as this may exacerbate postradiotherapy changes. Familiarization with the expected imaging changes following radiotherapy allows accurate evaluation of imaging studies and may prevent misinterpretation of posttreatment changes as recurrent disease. Baseline imaging studies done specifically for follow-up of the primary site are usually obtained 3 to 4 months after completion of radiotherapy [13, 14]. Until now, most studies focused on posttreatment CT appearances of the irradiated larynx and indicated that post-RT CT evaluations can identify patients at increased risk for developing local recurrence and proved to be a better prognosticator than the pretreatment CT risk profiles [15–17]. The expected appearance of the irradiated larynx at MR imaging has received limited attention in the radiological literature [18]. Advantages of MR imaging include superior soft tissue contrast and exact delineation of tumor margins in arbitrary planes. Moreover, MR imaging may identify fibrosis showing low signal intensity (SI) in T1- and T2-weighted MR images, and consequently may allow differentiation between tumor and fibrosis [19, 20]. On T2-weighted MR images signal intensity of tumors is generally higher than signal intensity of fibrosis [19, 21, 22].

The purpose of this retrospective study is to determine if pre-RT and/or post-RT MR imaging can predict the risk for local failure in patients with laryngeal carcinoma treated with irradiation alone or combined with chemotherapy.

Materials and methods

Patient selection

The hospital charts of 160 patients who underwent radiation therapy with curative intent for squamous cell carcinoma of the larynx between June 1995 and May 2003 were retrospectively reviewed. At least 24 months of follow-up after completion of RT was required. Out of these 160 patients, 80 (50%) were eligible for this study, including 63 men (79%; mean age, 63 years; range, 39–82 years) and 17 women (21%; mean age, 60 years; range, 45–71 years). The major reasons for exclusion were less than 24 months' follow-up after RT, patients with a previous history of laryngeal cancer or other malignant diseases in the head and neck region, and lack of suitable

MR imaging studies. Stage of disease in all patients was appraised clinically according to the UICC recommendations [23]. The institutional review board waived patient informed consent since all images were acquired for clinical purposes and were considered as existing data documents. The pretreatment tumor characteristics are listed in Table 1.

All patients were treated with primary radiation therapy with a mean total dose of 67 Gy (median, 70 Gy; range, 60–70 Gy) using 2.0 to 2.5 Gy per fraction. Twelve patients (15%) received neoadjuvant chemotherapy prior to radiation therapy. Follow-up included indirect laryngoscopy at 2-month intervals in the first 2 years after finishing radiation therapy and every 4–6 months thereafter, supplemented in case of suspicion by direct laryngoscopy under anesthesia with biopsies if indicated. No patient was 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, 23.7 months; range, 4.5–107.7 months).

MR imaging

MR imaging was performed with a 1.0-T or 1.5-T MR machine (Siemens-Impact or Vision, Erlangen, Germany). A neck surface coil (Medical Advances, Milwaukee, WI) was

Table 1 Pretreatment tumor characteristics (n=80)

| Variable	Number of patients		
	Supraglottic site	Glottic site	% of total
T classification			
T1		6	7
T2	12	32	55
T3	12	3	19
T4	8	7	19
N classification			
N0	23	47	88
N1	8	1	11
N2	1		1
Vocal cord mobility (both sides)			
Normal	23	19	53
Impaired	6	23	36
Fixed	3	6	11
Histopathology			
Well differentiated	3	15	23
Moderately differentiated	22	26	60
Poorly differentiated	7	6	16
Undifferentiated		1	1
Primary treatment			
Radiotherapy	22	46	85
Radiochemotherapy	10	2	15

used for higher spatial resolution. Pre-RT MR images with standard spin-echo T1-weighted (repetition time ms/echo time ms, 310–800/15), fast T2-weighted (2,200–4,550/90–98), and contrast-enhanced T1-weighted images (310–800/15) were available. Post-RT MR images were obtained in a similar plane to that of the pre-RT non-contrast and contrast-enhanced images. Other technical factors included a slice thickness of 3–7 mm with a 1-mm intersection gap, and each acquisition lasted approximately 2–5 min.

Two authors (JAC, RLJ) working in consensus, with respectively 13 and 4 years of experience of head and neck MR imaging, who were unaware of the patients' clinical findings retrospectively performed the imaging assessment of all MRI studies. On pre-RT MRI examinations, each tumor was assigned a low- or high-risk profile for local failure after RT, based on previously determined specific CT and MR imaging parameters [2, 11]. Patients with supraglottic carcinoma were considered to be at high risk if tumor invasion in the pre-epiglottic space in combination with abnormal signal intensity of thyroid adjacent to the anterior commissure and/or cricoid cartilage was present [2]. A high-risk profile was attributed to a glottic carcinoma if the tumor extended to the hypopharynx or if a tumor mass demonstrated an intermediate T2 signal in cartilage similar to tumor intensity [11]. In 14 patients the pretreatment MRI study was not available. Determination of the pretreatment risk profile in the patients who received RT

combined with neoadjuvant chemotherapy was based on a MR imaging before initiation of chemotherapy.

The post-RT MRI examinations were evaluated for changes using a three-point score [15, 16]: 1 = expected post-RT changes, i.e., complete resolution of the tumor at the primary site and symmetrically appearing laryngeal and hypopharyngeal tissues (Fig. 1); 2 = focal mass with a maximal diameter of less than 1 cm and/or asymmetric obliteration of laryngeal tissue planes (Fig. 2); 3 = focal mass with a maximal diameter of more than 1 cm, or less than 50% estimated tumor volume reduction (Fig. 3). According to preliminary experience with CT as imaging method [14–16], this post-RT MRI scoring system can be similarly interpreted as: 1 = likely to achieve permanent local control, no evidence of disease; 2 = indeterminate, suspicious for local failure or treatment complication; 3 = indicated high likelihood of local failure. The MRI examinations used for analysis were performed as part of routine follow-up (n=51) or because of certain symptomatology, potentially indicating local recurrence (n=29).

The signal patterns of posttreatment changes were observed on the T2-weighted images of post-RT MRI examinations, but enhancement on post-contrast T1-weighted images was evaluated if interpretation of T2 images was not optimal (Figs. 4, 5 and 6). The MR imaging criteria for recurrent or residual tumor are an enlarging enhancing infiltrating mass that is of intermediate to high signal intensity on T2-weighted MR images [18, 24]. Areas
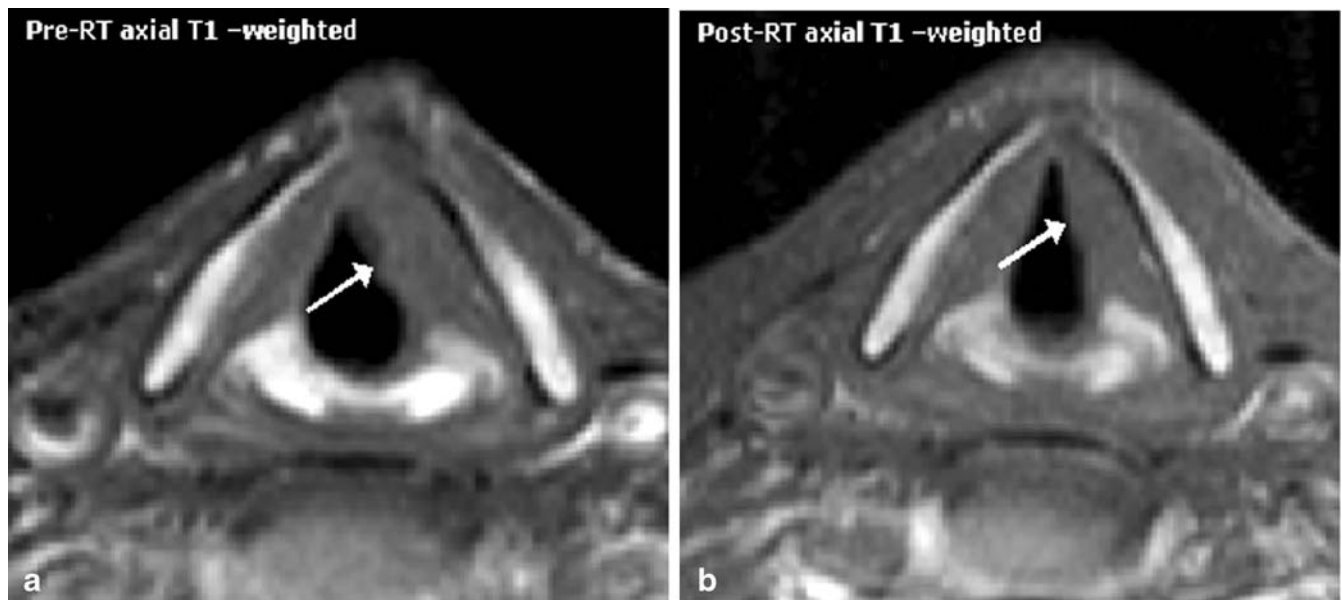
Fig. 1 Clinical stage T2 glottic carcinoma in a 63-year-old patient with low pre-treatment MR risk profile. (A) Pre-treatment axial T1-weighted MR image at the level of the true vocal cord shows a mass (arrow) with intermediate signal intensity in the left cord. (B) Image obtained 4 months post-RT (after radiation therapy) at the same level. There is complete resolution of the tumor (arrowheads). The laryngeal tissue appears symmetric and post-RT MR score is 1. Local recurrence was not documented within 24 months after RT

with very high signal intensity (equivalent to water) in T2-weighted images were regarded as necrosis and not included in this study. The hypointense areas were considered as fibrotic changes [18].

All 80 patients in this study had undergone at least one follow-up examination after radiation therapy. The 80 follow-up MR scans were obtained between 1 and 16 months after completion of radiotherapy (in 7 patients more than 9 months). The mean time between completion of radiotherapy and MRI was 5 months (median, 4 months).

Statistical analyses

The endpoint used in the statistical analyses was local control at 2 years. Intervals were measured from the first day of radiation therapy to the date of failure or the date of last follow-up. The Kaplan-Meier method was used to estimate curves and differences between curves we tested by means of the log-rank test. Calculation of risk ratios and simultaneous testing of pre-RT and post-RT MRI scores were performed by Cox proportional hazards analysis. In the analysis, post-RT MRI score was considered linearly related with the log (hazard).

Tumor lesions on T2-weighted MR images after primary treatment were classified into three groups, hypointense, isointense/mixed and hyperintense, and were associated using Cox regression model with regard to local control. Differences in the means of delay of post-RT MRI examination were tested with a one-way analysis of variance.

The sensitivity, specificity, accuracy, and negative and positive predictive values of follow-up MR imaging for detection of local failure (score of 3) were calculated.

A p-value<0.05 was designated for determining significant differences. The SPSS version 11.0 (SPSS, Chicago, IL) software package was used for analysis.

Results

The mean age at the time of radiotherapy was 63 years (range, 39–82 years). There were no statistically significant age-related differences between the male and female patients (Mann-Whitney test, p=0.3), which matched the sex ratio for laryngeal carcinoma.

A total number of 38 out 80 patients (48%) developed local recurrence, which was confirmed by histopathological examination. Six patients (6/12; 50%) were treated with chemoradiation and 32 patients (32/68; 47%) with irradiation alone. No significant difference was found between these two groups. Thirty-four out of these 38 patients (89%) underwent salvage (partial) laryngectomy, 3 patients refused salvage treatment, and 1 patient died suddenly after recurrent tumor was diagnosed.

Pre-RT MRI risk profile

In 66 out of 80 patients (83%) the pretreatment MR scans were available for review. The pretreatment MR imaging
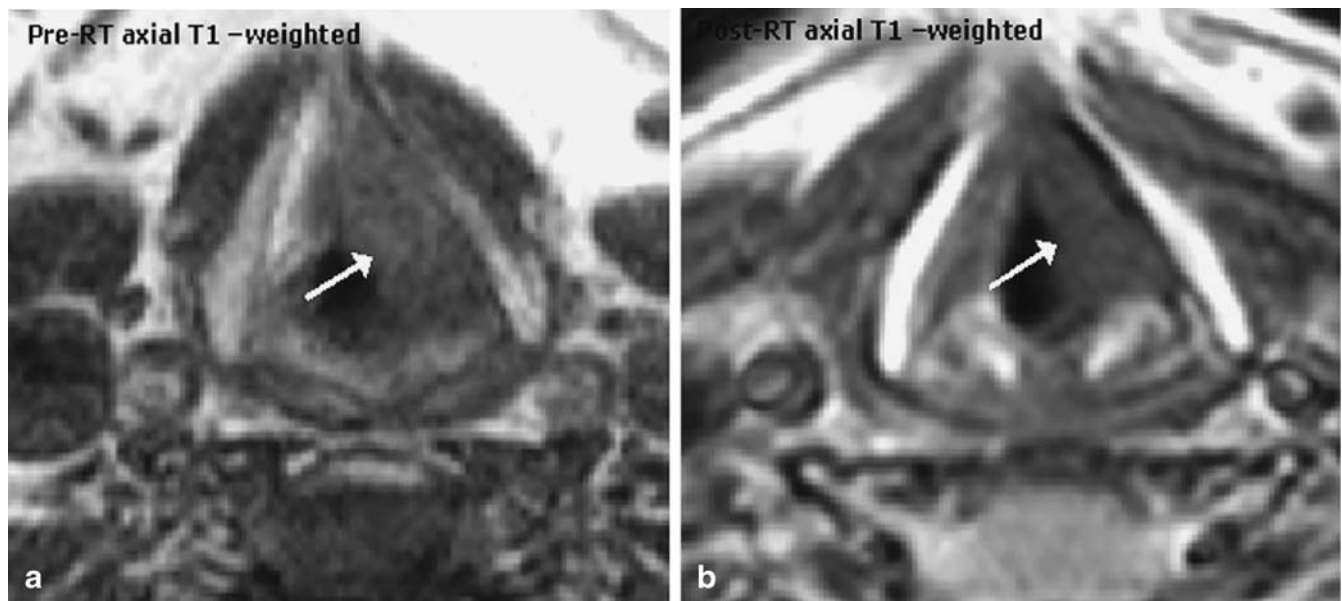
Fig. 2 Clinical stage T1b glottic carcinoma in a 62-year-old patient with high pre-treatment MR risk profile. (A) Pre-treatment axial T1-weighted MR image at the level of the true vocal cord shows a mass (arrow) with intermediate signal intensity in the left cord. (B) MR image at the same level, obtained at 7 months post-RT, shows that the tumor has regressed, but there is asymmetric obliteration of the fatty tissue at the left side without obvious focal mass. Post-RT MR score is 2. There was no clinical evidence of disease
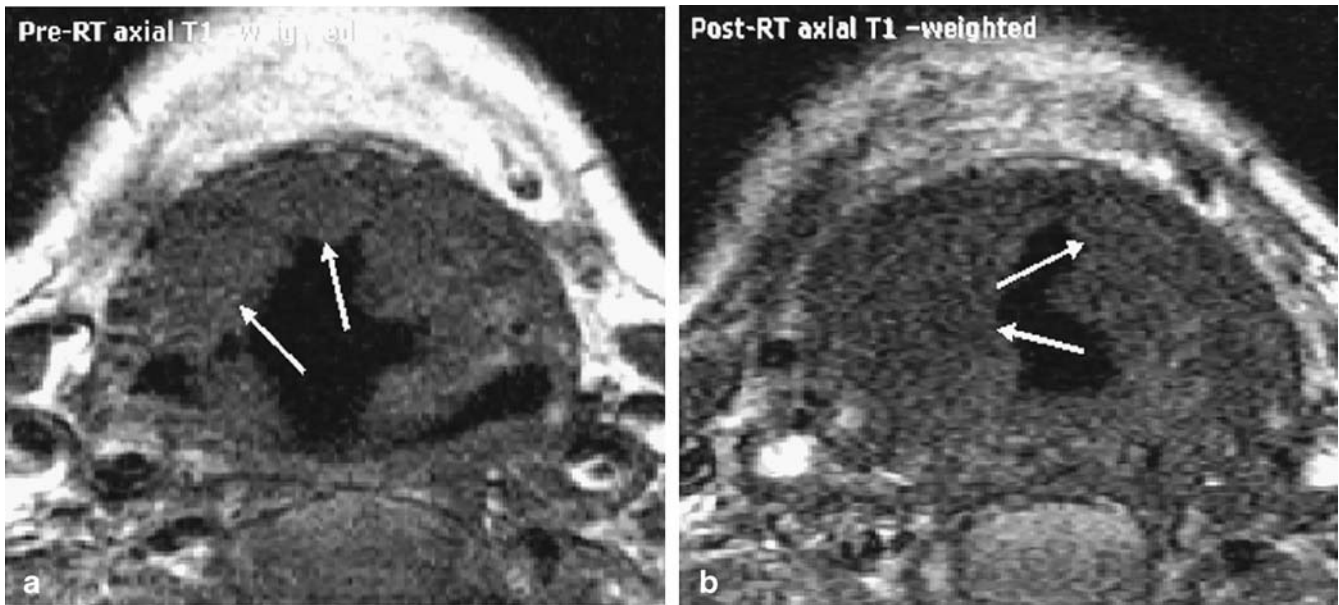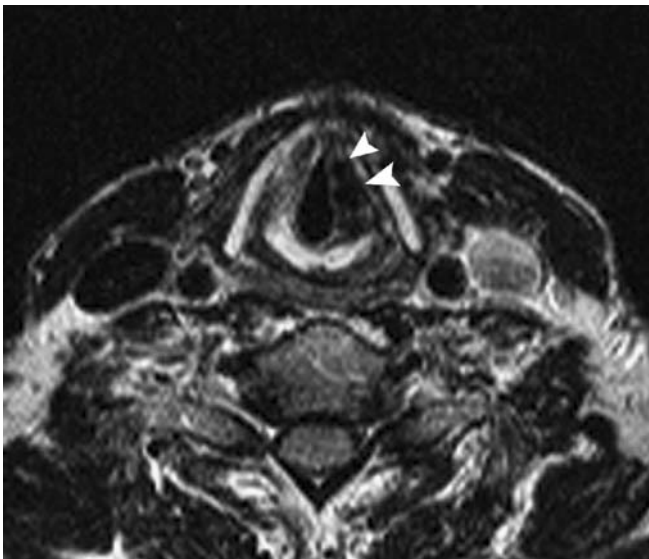
Fig. 3 Clinical stage T3 supraglottic carcinoma in a 64-year-old patient with high pre-treatment MR risk profile. (A) Pre-treatment axial T1-weighted MR image demonstrates a tumor mass (arrows) with intermediate signal intensi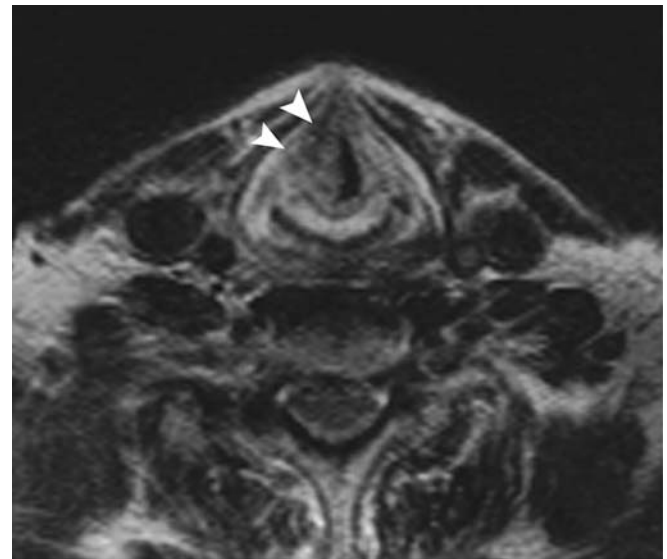ty on the left and right sides. (B) MR image obtained 6 months after RT shows a focal mass (arrows) a maximal diameter greater than 1 cm in the original tumor bed. This image had MR score of 3. The patient developed a local failure at 9 months post-RT

high-risk parameters, as defined in the previous section, are illustrated in Table 2. There were 26 patients with supraglottic carcinoma (low-risk group, n=14; high-risk group, n=12) and 40 patients with glottic carcinoma (low-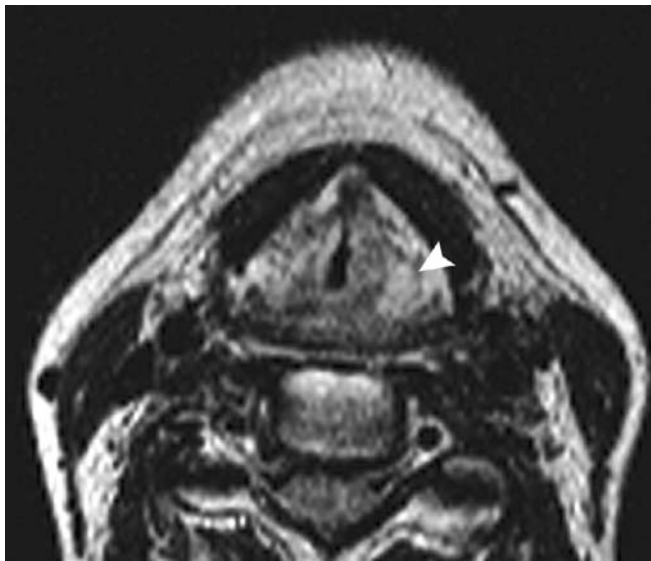risk group, n=24; high-risk group, n=16). Figure 7 illustrates local control stratified by pre-RT MRI risk profiles. At 2 years, the local control rate was approximately 73% in the low-risk group and 29% in the high-risk group, which was statistically significant (95% CI: 1.9–8.5; p=0.0001).

Fig. 4 Clinical stage T2 glottic carcinoma in an 80-year-old patient. Posttreatment axial T2-weighted MR image, obtained 11 months after RT, at the level of the true vocal cord demonstrates a tumor mass (arrowheads) with low signal intensity. The tumor was considered as a hypointense tumor, which did not locally recur within 24 months after RT

Fig. 5 Clinical stage T2 glottic carcinoma in a 78-year-old patient. Posttreatment axial T2-weighted MR image, obtained 5 months after RT, at the level of the true vocal cord demonstrates a tumor mass (arrowheads) with low to intermediate to high signal intensity. The tumor was considered as an isointense/mixed tumor, which locally recurred within 9 months after RT

score 3) were 96% (25/26), 76% (41/54), 83% (66/80), 98% (41/42), and 66% (25/38), respectively.

Combination of pre-RT MRI risk profile and post-RT MRI score

In the group of patients classified as a low pretreatment risk profile (n=38), 13 patients had posttreatment score 1 and showed no local recurrence, whereas 8 patients with posttreatment score 3 all failed locally. In the group with posttreatment score 2 (n=17), 4 local recurrences occurred (24%). Local control rates at 2 years were 100% for score 1, 60% for score 2, and 0% for score 3 (HR 7.3; 95% CI: 3.9–6330.9; p<0.001).

In patients with a high pretreatment risk profile (n=28), 3 patients had posttreatment score 1 and none of these cases developed a local recurrence, whereas for 15 patients with posttreatment score 3, 14 failed locally. In the group with posttreatment score 2 (n=10), six local recurrences occurred (60%). Local control rates at 2 years were 100% for score 1, 40% for score 2, and 7% for score 3 (HR 6.3; 95% CI: 1.2–6.8; p=0.01).

Post-RT MR imaging and local failure

Table 3 demonstrates the post-RT MRI examinations and disease status (failure vs. not failure). In 25 out of the 38 patients with local failure, the findings of the first follow-up MRI examination were classified as having a posttreatment score of 3. One patient without local failure had posttreatment score of 3 due to chondronecrosis and very pronounced edema at clinical examination treated with hyperbaric oxygen therapy. This patient remained free of local recurrence.

In 13 out of 38 patients with local failure, findings of first post-RT MRI examination were classified as a posttreatment score of 2. In four of these patients, an increase of the posttreatment MRI score from 2 to 3 occurred over time. In the other 4 of 13 patients, the follow-up MRI was only

Fig. 6 Clinical stage T4 supraglottic carcinoma in a 65-year-old patient. Posttreatment axial T2-weighted MR image, obtained 3 months after RT, at the level of the false vocal cord shows a tumor mass (arrowheads) with high signal intensity. The tumor was considered as a hyperintense tumor, which locally recurred within 10 months after RT

Post-RT MRI score

The follow-up MR images of 80 patients were recorded by using a three-point, post-radiation therapy changes scale, and results were as follows: (1) score =1, i.e., 21 patients with the complete remission after radiotherapy, 33 patients with score 2, and 26 patients with MR imaging indicating definite local failure (score=3).

Figure 8 illustrates the local control stratified for post-RT MRI risk profiles. The local control rates at 2 years were 100% for score 1, 64% for score 2, and 4% for score 3, which was statistically significant (95% CI: 4.2–15.5; p< 0.0001). The sensitivity, specificity, accuracy, and negative and positive predictive values of use of follow-up MRI examination for detection of local failure (post-RT MRI

Table 2 Pretreatment low-risk versus high-risk profile based MR imaging parameters

Site	Number of patients	% of total
Supraglottis		
Low-risk	14	17.5
High-risk PES + abnormal SI of thyroid at ant.comissure	6	7.5
PES + abnormal SI of cricoid	6	7.5
No data avalaible	6	7.5
Glottis		
Low-risk	24	30
High-risk Intermediate T2 signal in cartilage	15	19
Hypopharyngeal extension	1	1
No data avalaible	8	10

PES = pre-epiglottic space involvement; SI = signal intensity
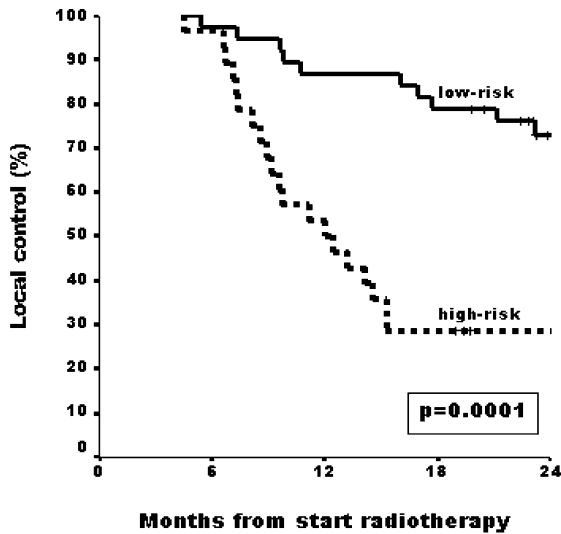
Straight line=Low-risk group (38 patients); Dotted line=High-risk group (28

patients). In 14 patients the pre-treatment risk profile was not available.

Fig. 7 Patients with a high pre-treatment MR risk profile showed poor prognosis (2-year local control rate: 29%) compared to patients with a low pre-treatment MR risk profile (2-year local control rate: 73%)

performed 3–7 months after RT, and diagnosis of tumor recurrence was confirmed 1 to 5 months later.

None of the patients with a post-RT MRI score of 1 had a tumor recurrence at the time of follow-up MR imaging.
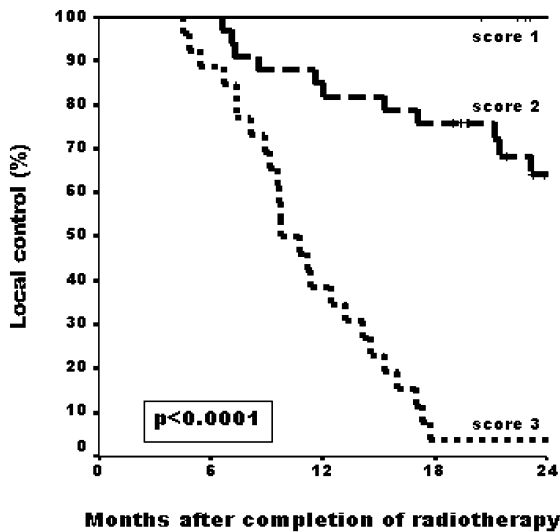
Straight line=Score1: likely achieved permanent local control (21 patients); Interrupted line=Score 2: indeterminate (33 patients); Dotted line=Score 3: suspicious for local failure (26 patients). Score 1 vs. Score 2: p=0.9; Score 1 vs. Score 3: p<0.001.

Fig. 8 Patients with a posttreatment MR risk profile of 3 showed clearly poor prognosis (2-year local control rate: 4%) compared to patients with posttreatment MR risk profiles of 1 and 2 (2-year local control rate: 100% and 64%, respectively)

Table 3 Detection of local recurrence and post-RT MRI examinations (n=80)

Post-RT	No local recurrence	Local recurrence	% of total
Score 1	21	0	26
Score 2	20	13	41
Score 3	1	25	33

Score 1 = likely achieved permanent local control; score 2 = indeterminate; score 3 = suspicious for local failure

In addition, in 10 out of 38 (26%) patients the local failure was first suspected on routine MR imaging (post-RT MRI score of 2 or 3). In six of these ten patients, these MRI findings were confirmed within 2 months by histopathologic examination. In the remaining four patients, no immediate action was undertaken (not within 4 months after radiologic diagnosis) because of the paucity of clinical symptoms or lack of suspicious findings on direct laryngoscopy.

From the entire patient population, 42 out of 80 patients were examined after irradiation with MRI between 1 and 10 months (mean, 3.8 months; median, 3.6 months), and these had no evidence of disease; in 25 out of 80 patients, the post-RT MR imaging showed clearly the residual disease suspected clinically with a mean delay of 7 months (median, 5.2 months). In the remaining 13 out of 80 patients, post-RT MR imaging did not indicate recurrent tumor, but these patients did develop a local failure with a mean delay for post-RT MRI examination of 5 months (median, 3.9 months). There was significant association between means of delay of post-MRI examination (test of variance, p=0.003).

Observed lesions on posttreatment T2-weighted MR images

In T2-weighted MR images after radiation therapy, 35 tumors were hypointense (44%), 25 isointense/mixed (31%), and 20 were hyperintense (25%) compared with the signal intensity of the contralateral side of the larynx. From the 38 patients that recurred locally, 9 patients had hypointense tumor lesions (24%), 12 patients had isointense (32%), and finally 17 patients had hyperintense lesions (45%). Figure 9 illustrates local control stratified by intensity on T2-weighted images after RT. At 2 years the local control rates were 77% for hypointense, 54% for isointense/mixed, and 15% for hyperintense lesions (95% CI: 1.7–4.1; p<0.001).

Discussion

Monitoring the response to non-surgical treatment is one of the challenges in head and neck oncology today. Accurate
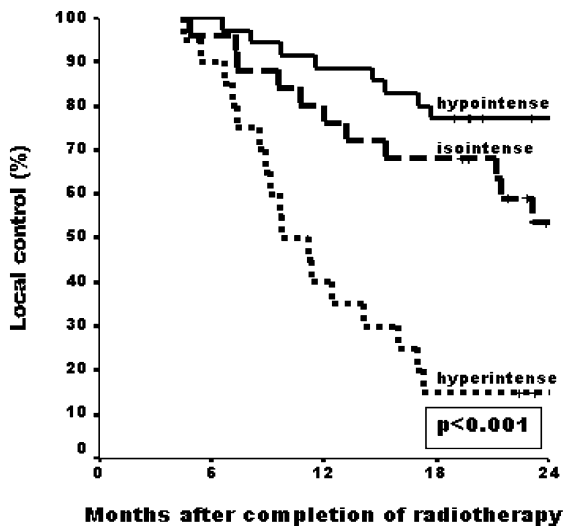
Fig. 9 Patients with a hyperintense tumor mass on posttreatment T2-weighted MR image showed very bad prognosis (2-year local control rate: 15% compared to patients with a hypointense and isointense/mixed tumor mass on posttreatment T2-weighted MR image; 2-year local control rate: 77% and 54%, respectively)

evaluation of the response to RT by clinical examination may be hampered by posttreatment fibrosis, edema, inflammation, or scarring. According our study, combined MR imaging before and after primary treatment may be helpful in evaluating response in laryngeal carcinoma treated by radiotherapy.

First, accurate pretreatment staging is essential for planning of optimal therapy for patients with laryngeal carcinoma, and data in this study provided valuable information for identifying patients at high risk for local recurrence. Around 42% of patients were retrospectively identified as the high-risk pretreatment MRI group, which means that the primary treatment chosen in these patients may not have been optimal.

In this study, recurrence after radiotherapy may be detected in an early stage on MR imaging. Especially the identification of patients who are at high risk (post-RT MRI score 3) for local failure was highly significant with regard to local control. Only 1 out of 26 patients in the posttreatment score 3 group remained free of disease at the primary site and showed osteoradionecrosis, which mimicked tumor recurrence. Our results are consistent with CT studies that report 10% local control rate at 2 years for patients in the score 3 group [15] and based on posttreatment CT findings a high significance of predicting the likelihood of local control in laryngeal carcinoma [15–17]. Application of the post-RT MRI scoring system within the two pretreatment risk groups resulted in an additional separation within both groups into three risk groups for local recurrence. In patients with both a low and high pretreatment MRI risk profile, classification into the post-RT MRI score 1 group was an infallible sign and proved to be strongly predictive for local control. Three patients classified as high risk on pre-RT MRI risk profile with a favorable response to RT were identified on post-RT MRI as a score 1 group and had no evidence of residual disease. Moreover, eight patients with initially low pretreatment MRI risk profile were identified as poor responders by follow-up MRI examination, and these patients recurred locally. Consequently, the post-RT MRI scoring system was demonstrated to be a better prognosticator than pretreatment MRI risk profile. Lell et al. [18] have reported that the main criteria for recurrent/residual tumor in MR imaging was infiltrative mass with intermediate signal intensity on T1-weighted, high signal intensity in T2-weighted and enhancement after Gd-DTPA in T1-weighted MR images. They concluded that because of differences in aspect, MR imaging proved to be better than CT in characterizing recurrent lesions and in differentiation between scar tissue and local tumor failure. According to Engelbrecht et al. [20], the specificity of CT to detect recurrence was 76% and of MRI was 86%. MRI is reported to be more sensitive (92%) than CT (81%).

The potential role of MR imaging in distinguishing tumor recurrence from radiation fibrosis on the basis of signal intensity on long repetition time (TR)/echo time (TE) (T2-weighted) pulse sequences for several head and neck carcinomas treated with radiotherapy has been described [21, 25, 26]. These studies conclude that tumors, that appeared hyperintense on T2-weighted MR images after radiation therapy were significantly correlated with pathologic findings [25, 26]. In accordance with previous studies, our results suggest that recurrent tumors may appear as a hyperintense mass after contrast administration in comparison with fibrotic changes after RT, which can be seen as hypointense masses. However, the prolonged T2 value is not specific for tumor and may be seen in radiation edema or infection. Three patients with a hyperintense mass in our study proved to be false positive. Ebner et al. [21] found that MR imaging was useful in distinguishing recurrent tumors in the female pelvis from posttreatment fibrosis in six patients. They emphasized that signal intensities from radiation changes vary with time; fatty replacement changes are seen, and abnormal soft tissue that has decreased T2-weighted signal intensity is suggestive of posttreatment scarring rather than recurrent tumor [18, 19, 27]. Arakawa et al. [28] also correlated MR imaging with pathology in nine patients with tongue cancer who underwent radiation or chemotherapy or both before surgery, and suggested that dynamic and T2-weighted MR imagings were considerably superior to contrast-enhanced T1-weighted MR imaging in revealing tumor mass. Hyperintensity on T2-weighted MR imaging in

recurrent tumors may be caused by increased intracellular water content of tumor cells and tumor edema.

CT findings of the laryngeal carcinoma within 3 to 6 months post-RT are reported to be often nonspecific [13, 14]. In our study the first MR study is performed 3–4 months after RT to evaluate the primary site, assuming no strong clinical suspicion of failure is present. MRI examination less than 4 months after the end of RT may be very helpful as a baseline, which may be useful to distinguish mass with complete remission. These findings suggest that in the posttreatment score 1 group, additional MRI follow-up is actually not necessary, unless there is clinical suspicion of recurrence. Moreover, the results of our study showed that recurrence followed later than 5 months (median value) after RT were detectable more easily on MR imaging than tumor recurrence earlier than 4 months after RT. In accordance with our results, Lell et al. [18] reported that in the first 3–4 months, edema, tumor necrosis, and acute or chronic inflammation lead to signal changes equivalent to tumor, but with long intervals, these changes are minimized and diagnosis is becoming more sufficient. Therefore, the use of MR imaging for assessment of tumor recurrence within 4 months after the end of radiation therapy may not be indicated. First post-RT MRI examination should be performed at 4 months after the end of RT. Progression of pathologic findings is strongly predictive of recurrence, such that an early MR imaging might lead to earlier detection of recurrence than those of clinical examination (26% of local failure in this study). Patients with "suspicious" post-RT MR study should be followed by imaging at regular intervals later than 4 months, and therefore this might help any urge to biopsy prematurely. This approach is supported by data from FDG-positron emission tomography (PET) studies, showing that baseline exams before 4 months post-RT may not accurately reflect outcome, and that studies done at 4 months and later result in a more accurate prediction of outcome [29, 30]. Keane et al. [31] supported routine reassessment with biopsy 8–12 weeks after completion of radiation therapy to detect recurrence as early as possible. Results of this study suggest that use of post-RT MRI examination could reduce substantially the number of patients needing biopsy.

The follow-up imaging of laryngeal carcinoma patients treated with chemoradiotherapy generally shows no obvious difference from those treated with radiation therapy alone. It is important to note that, in this retrospective setting, no strict follow-up protocol with repeat MR studies was followed.

Traditionally, the measurement of tumor volume has been widely used for evaluating response after oncologic therapy, and correlation with tumor control has been documented [32–34]. We did not include MR volumetric tumor evaluation after RT in our study due to factors contributing to apparent tumor radioresistance; it was very difficult to outline real tumor margins. Within the limitations of this retrospective study, it can be concluded that the manual drawing of the ROI area may result in some errors related to the operator's experiences and obscure the tumor margin. Although our study is limited by no standard time for follow-up of patients after primary treatment and subjective criteria for the diagnosis of radiation change versus recurrent tumor (observed lesions on T2 images), there was good intraobserver and interobserver agreement.

Conclusion

In the evaluation of laryngeal carcinoma on post-RT MRI examinations, symmetric post-RT changes without detectable mass are strongly indicative of ultimate control at the primary site. When post-RT MRI shows a discrete mass or asymmetric post-RT changes at the primary site, the pre-RT MRI high-risk profile and hyperintense mass on T2-weighted images after radiation therapy should be suggestive for further workup in patients. Follow-up MR study performed 4 months or later after RT appears to be a reliable tool to refer a residual mass to scar tissue and is recommended in addition to careful clinical follow-up.

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