ORIGINAL ARTICLE

Value of dynamic contrast enhanced magnetic resonance imaging in the differentiation between post-treatment changes and recurrent salivary gland tumors

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KEYWORDS
DCE-MRI; Recurrent salivary gland tumors; Post-treatment changes

Abstract Purpose: The purpose of this study was to investigate the diagnostic value of dynamic contrast enhanced magnetic resonance imaging (DCE-MRI) in the differentiation between post-treatment changes and recurrent salivary gland tumors. Patients and methods: A prospectively designed study was conducted on 37 patients having salivary gland malignant tumors treated by surgery or chemo/radiotherapy or both. All patients underwent conventional MRI and DCE-MRI. The obtained DCE-MRI data were interpreted semi quantitatively (using time intensity curves, TIC and time to peak TTP) and quantitatively (using wash in and washout rates). The obtained TICs were classified into four types (A, B, C, and D). Results: There was a significant statistical difference as regards TICs, wash in and washout rates of recurrent salivary gland tumors and that of post treatment changes, whereas there was no significant difference as regards TTP. Receiver Operating Characteristic (ROC) analysis revealed cutoff points of >10.25, and >6.25 for the wash in and washout rates used to differentiate recurrent tumors from post-treatment changes, respectively. Conclusion: We concluded that DCE MRI has a valuable diagnostic value in the differentiation of recurrent malignant salivary gland tumors from post-treatment changes, especially, for cases that remain unsolved by conventional MR imaging techniques.

1. Introduction

The management of head and neck cancer involves multidisciplinary evaluation and treatment. Often tumor recurrence may not be evident clinically until the recurrence is large enough to be clinically palpable, and hence imaging plays an important role in the post-treatment surveillance of head and neck cancers. Differentiating post-treatment changes from tumor recurrence with the use of imaging is challenging because of the presence of altered anatomy secondary to resection and postsurgical scarring. Furthermore, radiation therapy may induce tissue distortions such as edema, inflammation, and fibrosis,
which makes post-treatment images more difficult to interpret 

Conventional post-contrast MRI is currently used for differentiating recurrent tumor from fibrosis after treatment of head and neck cancer. Although the anatomical information derived from the conventional post-contrast MRI is valuable morphologically, it lacks functional information. Hence, the recent advances in head and neck imaging are shifting from the morphological to the functional techniques, which are used to assess the complex related processes in the cancer microenvironment such as hypoxia, and angiogenesis (2).

Dynamic contrast enhanced magnetic resonance imaging (DCE-MRI), is an emerging imaging method used to assess tumor angiogenesis. It relies on fast MRI sequences obtained before, during and after the rapid intravenous administration of a gadolinium based contrast agent (3) so that the variations of MR signal intensity with time can be recorded for each image voxel. As the agent enters into a tissue, it changes the MR signal intensity from the tissue to a degree that depends on its local concentration (4).

Dynamic contrast enhanced MRI (DCE-MRI) has been investigated for the differentiation of tumor recurrence and post-treatment fibrosis in regions, other than head and neck, such as the breast, pelvis, gastrointestinal and musculoskeletal system (5,6). In the head and neck region, DCE-MRI is an adjuvant clinical tool used in the evaluation of soft tissue neoplasms and lymph nodes, and is thought to be a useful predictor of response to radiotherapy. It is also used to monitor the treatment and distinguish post-therapeutic changes from recurrent mass with greater confidence (7–10).

The aim of this study was to investigate the role of dynamic contrast enhanced magnetic resonance imaging (DCE-MRI) in the differentiation between recurrent salivary gland tumors and post-treatment changes.

2. Patients and methods

2.1. Patients

Dynamic contrast enhanced imaging (DCE-MRI) and conventional post-contrast MRI of salivary glands were performed prospectively in 37 consecutive patients (22 males and 15 females) with treated malignant salivary gland tumors obtained between January 2014 and July 2015. Their age ranged 38–79 years. All patients were referred to our department from the follow-up clinics of the radiation therapy and oncology departments of Mansoura University Hospitals. Patients were evaluated because of recurrence of symptoms (n = 20) or abnormal physical examination findings during routine follow-up (n = 17). Three patients were excluded from the study due to bad MR images caused by motion artifact in two patients and because of claustrophobia in one patient. We obtained the approval of the institutional review board of our hospital and an informed consent from the patients before the study.

Our MR diagnoses were correlated with histopathological findings in twenty-six patients (n = 26) or with, clinical follow-up in 8 patients (n = 8). Histopathological diagnoses were done by surgical biopsy in thirteen patients (n = 13), core biopsy in seven patients (n = 7), and fine needle aspiration biopsy in six patients (n = 6). The selection of the site of biopsy was guided by the imaging findings on conventional and DCE-MRI. The surgeons selected the biopsy site after discussing the MR findings with the radiologists. When there was suspicion of more than one pathological condition, multiple biopsies were taken from the suspicious sites. The time delay between the biopsy and MR studies varied between 7 and 15 days.

Clinical follow-up for one year was considered as post-treatment changes if there is no change or decrease in the size of the lesion under question and no new lesions appeared and are considered as a tumor recurrence if the lesion increased in size or new lesions appeared.

2.2. MRI protocol & image interpretation

MR images were obtained with a superconducting 1.5 T MR imaging unit (Philips Ingenia) using neck array coil for all cases. Precontrast reference scan was first performed through the region of interest (ROI) and was followed by intravenous injection of gadolinium dimeglumine (Meglumine Gadopentate, Magnevist). The standard MR acquisition parameters were as follows: Multiplanar (axial, coronal, and sagittal) T2-weighted images, axial T2 fat-suppressed fast spin-echo images (TR, 5000 ms; TE, 102 ms; averages, 2; matrix, 256 × 256; section thickness, 4.0 mm; and gap, 1.0 mm) and axial T1-weighted images (TR, 675 ms; TE, 20 ms; averages, 2; section thickness, 4.0 mm; gap, 1.0 mm; matrix, 256 × 192). Conventional T1- and T2-weighted images were followed by DCE-MRI. Then, post-contrast axial, sagittal and coronal T1-weighted images were finally obtained.

Characterization of the lesions on the conventional MRI was based upon morphological criteria regarding tumor volume, signal intensity (SI) in different sequences and enhancement after Gd-DTPA. Areas with very high SI (equivalent to water) on T2-weighted images were interpreted as necrosis or cystic degeneration and the very low SI areas on T1- and T2-weighted images were interpreted as fibrosis. Lesions with iso to hypointense areas on T1 and T2WI that showed enhancement after contrast injection and positive mass effect to its surroundings, were regarded as recurrent tumors.

2.3. DCE-MRI protocol

Using automatic injector, a single bolus dose of gadolinium dimeglumine was injected intravenously, at a dose of 0.3 ml/kg body weight and at an injection rate of 2.5 ml/s, followed by a 20 ml saline flush.

A dynamic two dimensional, spoiled gradient recalled echo (2D-SPGR) axial T1WI fat suppressed sequence was done with total acquisition time of 240 s during bolus injection of the contrast agent. The imaging parameters are as follows: 10.4 ms repetition time (TR), 2.3 ms echo time (TE), 30° flip angle; 4 mm section thickness, section gap 1 mm, 180–240 mm field of view (FOV), and 256 × 128 mm matrix size.

2.4. Image post-processing

The sequential dynamic MR images were transferred into Philips extended work space (EWS) 2.6 workstation using its specific software. The ROI was manually placed in the solid most enhancing portion of the lesion avoiding the necrotic areas.
The same ROI was automatically placed onto the subsequent dynamic MR images by automatically copying and pasting the initial ROI. Then, time intensity curves (TIC) including their analyses were generated automatically using the machine software. Wash-in rate (K trans) was derived from the first pass phase of signal intensity enhancement. It is defined as the rate of enhancement between 10% and 90% of the signal intensity difference between maximum signal post-enhancement (SI max) and signal intensity prior to enhancement (SI base). Wash-out rate (K ep) was derived from the enhancement signal decay phase. It is defined as the rate of mono exponential decay of the enhancement signal in the tissue (11).

2.5. Image interpretation

The obtained DCE-MRI data were interpreted semi quantitatively and quantitatively. The semi quantitative interpretation was done using time intensity curve (TIC) and time to peak (TTP), while the quantitative interpretation was done by measuring the K trans and K ep values. Each of the obtained TIC was classified into four types (Fig. 1): type-A (gradual enhancement curve), type-B (rapid enhancement with low washout curve) and type-C (rapid enhancement with high washout curve) and type-D (flat curve) (12).

2.6. Statistical analysis

The statistical analysis of data was done using SPSS program (Statistical Package of Social Science) version 17. Quantitative data were presented as mean and standard deviation. To compare between two groups, student t-test was used. To compare between more than two groups, one way ANOVA test was used. The Receiver Operating Characteristic (ROC) curves were drawn to detect cutoff point for K trans and K ep values used to differentiate recurrent tumors from post-treatment changes. P value of ≤0.05 was considered to be statistically significant and P value < 0.001 was considered highly significant in all analyses.

3. Results

Dynamic contrast enhanced imaging (DCE-MRI) and conventional post-contrast MRI of salivary glands were performed prospectively in 37 consecutive patients (22 males and 15 females) with treated salivary gland tumors. Their age ranged 38–79 years, mean 59 years. Patients were evaluated because of recurrence of symptoms (n = 20) or abnormal physical examination findings during routine follow-up (n = 17). Three patients were excluded from the study due to bad MR images caused by motion artifact in two patients and because of claustrophobia in one patient.

All the patients included in our study were treated from salivary gland malignant tumors. These tumors were treated with surgery alone in four patients (n = 4), radiation therapy alone in thirteen patients (n = 13), or both surgery and radiation therapies in the remaining seventeen patients (n = 17). The tumors were located in: parotid gland (n = 24), submandibular gland (n = 4), and oral cavity (n = 6) Table 1. Pathology of primary tumors was mucoepidermoid carcinoma (n = 12), adenoid cystic carcinoma (n = 10), carcinoma in ex pleomorphic adenoma (n = 8), and sarcoma (n = 4) Table 2.

The analysis of conventional post-contrast MR images of the lesions was based on the morphological MR criteria illustrated in Table 3, where 16 lesions were diagnosed as tumor recurrence, and 18 lesions as post-treatment changes with sensitivity of 60% and specificity of 71% Table 4.

The semi quantitative assessment of dynamic post-contrast enhanced MR data included analysis of time intensity curves (TIC) and time to peak (TTP). There was a significant statistical difference (P < 0.05) as regards TIC of salivary gland tumor recurrence and that of post-treatment changes. TIC of recurrent tumors showed Type C curves in eight patients (n = 8, 40%), Type B curves in eight patients (n = 8, 40%) and type A curves in four patients (n = 4, 20%). TIC of post-treatment changes showed type B curves in ten patients (n = 10, 71.4%) and type A curves in four patients (n = 4, 28.6%) Table 5. There was no significant difference (P = 0.007) as regards TTP between recurrent malignant sali-
vary gland tumors and post-treatment changes. The ranges of TTP of recurrent tumors were 78.30–145.00, median 80.15 and the ranges of TTP of post-treatment changes were 119.30–189.50, median 126.10 Table 6.

The quantitative assessment of dynamic post-contrast enhanced MR data included analysis of wash in rates (K trans), and washout rates (K ep). There was significant difference (P = 0.01) as regards wash in rates between recurrent malignant salivary gland tumors and post-treatment changes, and also there was a significant difference (P = 0.03) as regards washout rates between recurrent tumors and post-treatment changes. ROC analysis revealed cutoff point of >10.25 for K trans values used to differentiate recurrent tumors from post-treatment changes, with 85.7% sensitivity, 70% specificity and 76.5% accuracy. ROC analysis of K ep values revealed cutoff point of >6.35 for differentiation of recurrent tumors from post-treatment changes with 71.4% sensitivity, 75% specificity and 73.3% accuracy Table 7 (Fig. 2).

4. Discussion

Imaging surveillance after treatment of head and neck tumors is useful to detect residual or recurrent tumor, even when clinical recurrence is not suspected (13). Also, the interpretation of post-treatment follow-up imaging studies is complicated because surgery can alter anatomy, and radiation/chemotherapy can result in edema and fibrosis. These post-treatment changes can mimic tumor recurrence, and sometimes it is difficult to distinguish these from residual or recurrent tumor using conventional imaging (14).

We evaluated thirty-four patients with malignant salivary gland tumors, after different treatment modalities, using conventional and dynamic contrast enhanced MRI. The conventional post-contrast MR diagnoses in our study were based only on the morphological MR criteria. According to these morphological criteria, sixteen (n = 16) lesions were diagnosed as recurrences of malignant salivary gland tumors, and eighteen (n = 18) lesions as post-treatment changes, with sensitivity of 60% and specificity of 71%. These relatively low percentages could be explained by at least three reasons. Firstly, the presence of gadolinium enhancement was found in all recurrent tumors and in some of fibrotic tissues, so this single morphological character is not specific. Secondly fibrosis was

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Location and methods of treatment in 34 patients with treated malignant salivary gland tumors.</th>
</tr>
</thead>
</table>
| Location of lesions | Parotid gland 24  
Oral cavity 6  
Submandibular gland 4  
Total 34 |
| Method of treatment | Surgery 4  
Radiotherapy 13  
Combined surgery & radiotherapy 17  
Total 34 |

<table>
<thead>
<tr>
<th>Table 2</th>
<th>Pathological types of the studied salivary gland tumors.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pathological type</td>
<td>Number</td>
</tr>
<tr>
<td>Mucoepidermoid carcinoma</td>
<td>12</td>
</tr>
<tr>
<td>Adenoid cystic carcinoma</td>
<td>10</td>
</tr>
<tr>
<td>Carcinoma in ex-pleomorphic adenoma</td>
<td>8</td>
</tr>
<tr>
<td>Sarcoma</td>
<td>4</td>
</tr>
<tr>
<td>Total</td>
<td>34</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table 3</th>
<th>Conventional post-contrast MRI morphological criteria used in our study for differentiation between tumor recurrence and post-treatment changes.</th>
</tr>
</thead>
<tbody>
<tr>
<td>MRI tumor character</td>
<td>Number of lesions</td>
</tr>
</tbody>
</table>
| Margin | Well defined (n = 6)  
Ill defined (n = 28)  
T2 SI | Low (n = 10)  
High (n = 24)  
Post-contrast | Faint (n = 8)  
Intense (n = 26)  
Other findings (e.g.: bony invasion, nodal mets., mass effect) | Present (n = 12)  
Absent (n = 22) |

<table>
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<tr>
<th>Table 4</th>
<th>Sensitivity and specificity of conventional MRI in differentiation between post-treatment changes and recurrent salivary gland tumors.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recurrent tumors</td>
<td>Post-treatment changes</td>
</tr>
<tr>
<td>Pathology</td>
<td>MRI</td>
</tr>
<tr>
<td>20</td>
<td>16</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table 5</th>
<th>The TICs obtained in our study for the recurrent salivary gland tumors and for the post-treatment changes.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of TIC</td>
<td>Recurrent tumors</td>
</tr>
<tr>
<td>No.</td>
<td>%</td>
</tr>
<tr>
<td>A</td>
<td>4</td>
</tr>
<tr>
<td>B</td>
<td>8</td>
</tr>
<tr>
<td>C</td>
<td>8</td>
</tr>
<tr>
<td>D</td>
<td>0</td>
</tr>
</tbody>
</table>

True (+) = 12, True (−) = 10, False (+) = 4, False (−) = 8.
found to display several signal intensity characters, and most of fibrotic tissue displays low SI on T2WIS, which reflects its low water content and decreased vascularity; however, fibrosis may show mixed SI and may appear as a mass lesion, so it can be difficult to recognize it only by signal intensity characters. Lastly, the high T2 SI found in persistent inflammation in a fibrotic tissue can mimic high signal intensity pattern of recurrent tumor on conventional T2WIS.

Dynamic contrast enhanced imaging (DCE-MRI) produces information about the vascularity of cancers and has the potential to be used to detect and characterize tumors, and evaluate treatment response (15,16). Different studies demonstrated that dynamic contrast enhanced MRI is valuable for the differentiation of tumor recurrence and post-treatment fibrosis in different regions such as breast, pelvis, musculoskeletal system and in the head and neck regions (2,17).

Table 6  Ranges and median values of TTP obtained in recurrent salivary gland tumors and in post-treatment changes.

<table>
<thead>
<tr>
<th>Time to peak (TTP)</th>
<th>Recurrence</th>
<th>Post-treatment changes</th>
<th>(P) value</th>
</tr>
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<tbody>
<tr>
<td>Range</td>
<td>Median</td>
<td>Range</td>
<td>Median</td>
</tr>
<tr>
<td>78.30–145.00</td>
<td>80.15</td>
<td>119.30–189.50</td>
<td>126.10</td>
</tr>
</tbody>
</table>

Table 7  Ranges and median values of wash in (K trans) and wash out (K ep) in recurrent tumors and post-treatment changes.

<table>
<thead>
<tr>
<th></th>
<th>Recurrence</th>
<th>Post-treatment changes</th>
<th>(P) value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wash in (K trans) (1/s)</td>
<td>8.70–16.30</td>
<td>5.50–11.10</td>
<td>12.05</td>
</tr>
<tr>
<td>Wash out rate (K ep) (1/s)</td>
<td>2.40–14.60</td>
<td>3.20–6.50</td>
<td>9.80</td>
</tr>
</tbody>
</table>

Table 8  Statistical analysis of wash in (K trans) and wash out (K ep) rates in differentiation of recurrent tumors and post-treatment changes.

<table>
<thead>
<tr>
<th>Area under the curve</th>
<th>Cut off value</th>
<th>Sensitivity (%)</th>
<th>Specificity (%)</th>
<th>PPV (%)</th>
<th>NPV (%)</th>
<th>Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wash in rate (K trans) (1/s)</td>
<td>0.87 (0.55–1.0)</td>
<td>&gt;10.25</td>
<td>85.7</td>
<td>70.0</td>
<td>66.7</td>
<td>87.5</td>
</tr>
<tr>
<td>Wash out rate (K ep) (1/s)</td>
<td>0.83 (1.00–1.00)</td>
<td>&gt;6.35</td>
<td>71.4</td>
<td>75.0</td>
<td>71.4</td>
<td>75.0</td>
</tr>
</tbody>
</table>

PPV: positive predictive value, NPV: Negative predictive value.

Fig. 2  (a and b): ROC curves of wash in (a) and washout rates (b) in differentiation of recurrent salivary gland tumors and post-treatment changes.

In this study we investigated the utility of DCE-MRI for the differentiation of recurrent malignant salivary gland tumors from post-treatment changes using two different analytical methods (the semiquantitative and the quantitative methods). We firstly applied the semiquantitative approach by plotting the signal intensity against time, to obtain the time intensity curves (TIC). Then we proceeded to the quantitative approach, using the contrast wash in (K trans) and washout rates (K ep).

Many investigators used different approaches in the evaluation of TIC curves. Sasaki et al. (18) used visual analysis and classification of TIC to differentiate between benign and malignant tumors. Takashima et al. (19) depended on the time at which the curves displayed peak enhancement, and classified TIC curves into five groups: type A, the curve peaked at 0–30 s after the administration of contrast.
medium; type B, the curve peaked at 30–60 s after the administration of contrast medium; type C, the curve peaked at 60–210 s after the administration of contrast medium; type D, the curve displayed a gradual upward slope; and type E, the curve was flat. Kuhl et al. (20) presented another approach, in which the shape of the entire time signal intensity curve is visually assessed, yielding three different curves: steady, plateau, and washout.

In agreement with our study, Eida et al. (11) classified TIC curves into four types: type A (gradual enhancement), type B (rapid enhancement and low washout), type C (rapid enhancement and high washout), and type D (flat). There was a significant difference ($P < 0.5$) as regards TIC between benign post-treatment changes and recurrent tumors. Benign post-treatment changes revealed type B curves in ten patients (71.4%) and type A curves in four patients (28.6%) (Figs. 3 and 4), while 80% of malignant recurrent salivary gland tumors revealed type B and C curves (Figs. 5 and 6).

Yabuuchi et al. (21) in a study of parotid gland tumors agreed with our results, they regarded type A, B and D TIC tumors as benign neoplasms and type C TIC tumors as malignant neoplasms, and the sensitivity, specificity, accuracy, and positive and negative predictive values were 71%, 86%, 82%, and 67% and 89% respectively.

Fig. 3  Post-treatment changes after left total parotidectomy. (a and b) Axial T1WI, and T2WI show an ill-defined hypointense and hyperintense area in the region of left parotid gland (in a and b respectively). (c) Axial post-contrast T1WI with fat suppression shows mild heterogeneous enhancement of the lesion. (d) Axial delayed phase dynamic post-contrast T1WI with fat suppression shows progressive lesional enhancement. (e) Time signal intensity curve shows progressive pattern of enhancement (type-A curve). (f) Measurements of wash in and washout rates.
In a study done by Sasaki et al. (18) on 44 patients with head and neck tumors, they found that benign lesions presented curves type D, A and C in disagreement with our study, while malignant tumors showed type C and B curves which is in agreement with the present study. The differences in types of curves happened between our study and the study by Sasaki et al. could be explained by the large number of Warthin tumors contained in their study which gave type C curve.

TIC shape analysis does not provide absolute measures. It is dependent, and is affected by the length of the scan, and the scan parameters (TR/flip angle), and all these factors can influence the final shape of the curve, resulting in the same tissue possibly being classified differently when using different parameters (22).

Semiquantitative analysis in our study showed that time to peak (TTP), is not statistically significant in differentiating benign post-treatment changes from salivary gland tumor recurrence. However the quantitative assessment of dynamic post-contrast enhanced MR data including the analysis of wash in rates (K trans), and washout rates (K ep) was proved to be significant in differentiating both entities. We found a significant difference \( P = 0.01 \) as regards wash in rates between recurrent malignant salivary gland tumors and post-treatment changes, and also there was a significant difference \( P = 0.03 \) as regards washout rates between recurrent tumors and post-treatment changes. Receiver Operating Characteristic (ROC) analysis revealed cutoff point of \( >10.25 \) for K trans values used to differentiate recurrent salivary gland tumors from post-treatment changes, with 85.7% sensitivity, 70% specificity and 76.5% accuracy. ROC analysis of K ep values revealed cutoff point of \( >6.35 \) for differentiation of recurrent salivary gland tumors from post-treatment changes with 71.4% sensitivity, 75% specificity and 73.3% accuracy.

These results are in agreement with those of Rouviere et al. (23); they stated that there was no difference in time to peak (TTP) in differentiating benign from malignant prostatic tissue and the contrast washout was significantly more rapid in tumor than in normal peripheral zone. In another study of the role of DCE-MRI in head and neck tumors, Tomura et al. (24), concluded that maximum slope of increase (which corresponded to contrast washout rates in our study) is lower in non-tumor involved lesions, than in the involved ones, which is also in agreement with our results.
Our study had some limitations, we included salivary gland cancers with various locations, treatment modalities, and intervals between last treatment and imaging, and this heterogeneity could limit the standardization of our results. Another limitation of our present study was that the selection of optimal sites for data sampling and localization of ROIs would affect the consistent acquisition of reliable DCE data. The reproducibility of the quantitative cutoff levels of Ktrans and Kep in our results might not be transferable to other institutions, as the analysis of data generated by DCE-MRI is not fully standardized yet (22). And however the semiquantitative data have the advantage of being simple to obtain, but are not readily transferable between different MRI scanners and radiofrequency coils because the baseline signal from the tissue will vary between systems. In addition, they do not take into account the underlying T1 value of the tissue being studied, and do not accurately indicate the tissue concentrations of gadolinium present (25).

5. Conclusion

We concluded that DCE-MRI has a valuable diagnostic value in the differentiation of recurrent malignant salivary gland tumors from post-treatment changes, especially, for cases that remain unsolved by conventional MR imaging techniques.

Fig. 5  Recurrent left parotid adenoid cystic carcinoma. (a and b) Axial T1WI and T2WI showing lobulated mass lesion of intermediate SI (a) and of heterogeneous high SI (b) in the left parotid region. (c) Axial post-contrast T1WI with fat suppression shows mild heterogeneous enhancement. (d) Axial delayed phase dynamic post-contrast T1WI with fat suppression shows progressive lesional enhancement. (e) Time signal intensity curve shows progressive pattern of enhancement with rapid wash out (type-C curve). (f) Measurements of wash in and wash out rates.
The authors declare that there are no conflicts of interest.

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Fig. 6  Recurrent Right parotid mucoepidermoid carcinoma. (a) Axial T1WI shows a large mass of intermediate SI and a focus of high SI of hemorrhage in the RT parotid region. (b) Axial T2WI shows heterogeneous high SI of the lesion. (c and d) Axial post-contrast T1WI with fat suppression (c) and axial delayed phase dynamic post-contrast T1WI with fat suppression (d) showing progressive lesional enhancement. (e) Time signal intensity curve shows progressive pattern of enhancement with rapid wash out (type-C curve). (f) Measurements of wash in and wash out rates.
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