Diagnostic value of dynamic contrast-enhanced MRI for unilocular cystic-type ameloblastomas with homogeneously bright high signal intensity on T2-weighted or STIR MR images

Miki Hisatomi\textsuperscript{a}, Yoshinobu Yanagi\textsuperscript{b}, Hironobu Konouchi\textsuperscript{b}, Hidenobu Matsuzaki\textsuperscript{b}, Toshihiko Takenobu\textsuperscript{a}, Teruhisa Unetsubo\textsuperscript{a}, Junichi Asaumi\textsuperscript{a,b}

\textsuperscript{a} Department of Oral and Maxillofacial Radiology, Field of Tumor Biology, Okayama University Graduate School of Medicine, Dentistry and Pharmaceutical Sciences, 5-1, Shikata-cho, 2-chome, Okayama 700-8525, Japan
\textsuperscript{b} Department of Oral Diagnosis and Dentomaxillofacial Radiology, Okayama University Hospital of Medicine and Dentistry, 5-1, Shikata-cho, 2-chome, Okayama 700-8525, Japan

Corresponding Author: Miki Hisatomi
E-mail address: tomi@md.okayama-u.ac.jp
Full postal address: Department of Oral and Maxillofacial Radiology, Field of Tumor Biology, Okayama University Graduate School of Medicine, Dentistry and Pharmaceutical Sciences, 5-1, Shikata-cho, 2-chome, Okayama 700-8525, Japan
Telephone number: +81-86-235-6705
FAX number: +81-86-235-6709
SUMMARY
Typical MR images of ameloblastomas on T2-weighted image (WI) or short inversion time inversion-recovery (STIR) show multiple bright high-signal-intensity loci on a high-signal-intensity background. Unilocular cystic-type ameloblastomas show homogeneously bright high signal intensity on T2WI or STIR as a water-like signal intensity. Therefore, it is difficult to distinguish unilocular cystic-type ameloblastoma from other cystic lesions such as keratocystic odontogenic tumors, radicular cysts (residual cysts) and dentigerous cysts only on the basis of MRI signal intensity. In the present study, we evaluated whether contrast-enhanced (CE)-T1WI and dynamic CE-MRI (DCE-MRI) could provide additional information for differential diagnosis in unilocular cystic-type ameloblastoma. Images from 12 cases of suspected unilocular cystic-type ameloblastoma were evaluated in the present study. Of them, 5 had areas suspected of indicating a solid component on T1WI and T2WI (or STIR). Ten had undergone additional CE-T1WI and DCE-MRI. On 5 of 10 cases of CE-T1WI, a tiny enhancement area was detected. On 6 of 10 DCE-images, a time-course enhanced area which was suspected to be a solid component was detected. CE-T1WI was helpful in the diagnosis of ameloblastoma because the tiny enhanced areas were taken to indicate possible solid components. Moreover, the rim-enhancement area on CE-T1WI could be divided into small regions of interest, and some of these showed slightly increased enhancement on DCE-MRI, which was taken to indicate a solid component and/or intramural nodule with focal invasion of ameloblastoma tissue. DCE-MRIs of the 4 remaining cases, which provided no clues to the diagnosis of ameloblastoma in the manner of the above descriptions, showed thicker rim enhancement than odontogenic cysts. Thus, CE-T1WI and DCE-MRI were helpful in the differential diagnosis of unilocular cystic-type ameloblastomas with homogeneously bright high signal intensity on T2WI or STIR.

Keywords: ameloblastoma, unicystic, solid/multicystic, MRI, DCE-MRI, odontogenic tumor, odontogenic cyst
Introduction

Ameloblastoma is the most common and the most clinically significant odontogenic tumor. Ameloblastomas show a remarkable tendency to undergo cystic change; most of them have combinations of cystic and solid features that vary over time. The cystic portion can be present as a large cyst which occupies a sizable portion of the ameloblastoma. Ameloblastomas are divided into solid/multicystic, extraosseous/peripheral, desmoplastic and unicystic types according to the 2005 WHO histological classification of odontogenic tumors. The most typical radiographic feature is multilocular radiolucency. The lesion is often described as having a “soap bubble” appearance. This feature is a direct clue to the diagnosis of ameloblastomas.

On the other hand, it is difficult to diagnose ameloblastomas radiographically when they show unilocular features. Ameloblastomas that show unilocular radiolucency have two possible MR feature types. One is a mixed type with multicystic and solid components. On MRIs of this ameloblastoma type, the solid portions show a predilection for intermediate signal intensity on T1 weighted image (WI) and high signal intensity on T2WI or short inversion time inversion-recovery (STIR) images, and the cystic portions show a predilection for homogeneous intermediate signal intensity on T1WI and homogeneously bright high signal intensity on T2WI or STIR. At that time we can easily diagnose these lesions as ameloblastomas because this type of T2-weighted MR image shows a multiple-locus bright high signal intensity corresponding to cystic fluids intermixed with areas of relatively high signal intensity corresponding to the solid portion. Another is the unilocular cystic type, which shows homogeneously bright high signal intensity on T2WI or STIR reflecting the inner part
of the water-like content. Therefore, the latter type is difficult to distinguish from cystic lesions such as keratocystic odontogenic tumors, radicular cysts (residual cysts) and dentigerous cysts, which present as unicystic lesions, on the basis of MR signals only.

In contrast-enhanced MRI (CE-MRI) the margins are more clearly defined, and secondary mass effects are more clearly shown. In addition, dynamic contrast enhanced MRI (DCE-MRI), which produces functional images, can illustrate the time course of contrast enhancement. DCE-MRI not only aids diagnosis but also provides measures that relate to the histological assessment of vascular density.\textsuperscript{10, 11} Some studies have shown the rapid uptake patterns of invasive cancers on DEC-MRI reflect high intratumor angiogenesis.\textsuperscript{12, 13} It has been reported that DCE-MRI is useful for the differential diagnosis of some tumors, and many investigators have attempted to identify the differences between benign and malignant tumors by analyzing curve patterns such as rapid uptake or gradual increase from the time course of dynamic contrast enhancement.\textsuperscript{14, 15} Therefore, we may be able to differentiate unilocular cystic lesions including ameloblastomas by detecting nodular regions on CE-MRI and/or DEC-MRI, or by detecting areas of high intratumor angiogenesis on DEC-MRI.

In the present study, we retrospectively evaluated the DCE-MRI of unilocular cystic-type ameloblastomas suspected of being cystic lesions due to homogeneously bright high signal intensity on T2WI (or STIR) MRI in order to assess whether the DCE-MRI could provide additional information in the differential diagnosis between cystic-type ameloblastomas and other cysts.
Materials and methods

Patient population

Thirty-five patients who were histopathologically diagnosed with ameloblastoma and underwent MR examinations in our university hospital between April, 1998 and December, 2009 were enrolled in this retrospective study. Of 35 cases, 12 that had been suspected of being cystic lesions including unilocular cystic-type ameloblastomas due to homogeneously bright high signal intensity on T2WI (or STIR) MRI were selectively examined. Of these 12 patients, 5 were men and 7 were women (age range: 16-67 years; mean: 37.1 years) (Table 1).

This study was approved by our institutional review board (No. 232).

MR imaging

The MR examination was performed on a 1.5-T unit (Magnetom Vision; Siemens, Erlangen, Federal Republic of Germany) with a CP head coil or a head-neck coil. Routine T1-weighted axial images were acquired with a spin-echo sequence using a repetition time (TR) of 500 to 660 ms and echo time (TE) of 15 ms. T2-weighted axial images in 5 cases or STIR axial images in 7 cases were acquired with a turbo-spin-echo sequence using 3000/90 ms (TR/TE) for T2WI and 4500/60/140 ms (TR/TE/TI) for STIR.

For DCE-images, 14 consecutive data sets were acquired for 210 s (14 s/1 scan) with three-dimensional fast imaging with steady-state precession (repetition time/echo time/flip angle 5/2/25 degrees, 16 slices over 48 mm of slab thickness, resulting in an effective slice thickness of 3 mm). Frequency-selective fat-suppressed T1WI was
immediately acquired as CE-T1WI. Intravenous injection of a contrast medium (Omniscan syringe; Daiichi Pharmaceutical Co., Tokyo, Japan or Magnevist syringe; Nihon Schering, Osaka, Japan) was archived manually at a rate of approximately 2 ml/s through a 21-gauge butterfly needle inserted into a vein in the cubital fossa. The injection of contrast medium started 6 s before the initiation of a second scan of 14 DCE-image data sets.

**Image analysis**

The MR images in 12 cases were retrospectively examined as shown in Table 1. For the criteria of the signal intensity, the musculature was defined as intermediate signal on T1WI, and the cerebrospinal fluid as a bright high signal on T2WI or STIR. The signal intensity between intermediate and high signal intensities on T1WI was described as slightly high signal intensity. CE-T1WI and DCE-images were obtained in 10 cases.

The T1WI, T2WI (or STIR), CE-T1WI and DCE-images were studied for signal intensity, cystic and solid features and marginal features. MR images of ameloblastomas suspected of being cystic lesions with homogeneously bright high signal intensity on T2WI or STIR were evaluated to assess whether T1WI, T2WI (or STIR), CE-T1WI and DCE-images could provide additional diagnostic information.

**Data analysis**

Regions of interest (ROI) were drawn in the suspected solid area and rim-enhancement area on DCE-images. The ROI of each lesion was calculated using the Volume Analyzer SYNAPSE VINCENT 3D image analysis system (FUJIFILM Medical, Tokyo, Japan). Time-to-intensity curves were obtained by plotting the signal intensity
on a time course.
Results

Table 1 shows the clinical features and the results of the signal intensity on T1WI, T2WI (or STIR), CE-T1WI and DCE-images in 12 cases. In terms of histopathological diagnosis, 9 of the 12 cases were solid/multicystic type and the remaining 3 unicystic (Table 1). On the basis of histological classification of unicystic ameloblastoma subtypes according to Ackermann et al., the 3 unicystic ameloblastomas were further classified into 1 mural type (invading cyst wall) (Case 1) and 2 intraluminal type (protruding into cyst cavity) (Case 5, 6).

Of the 12 cases, five were diagnosed as ameloblastomas because they had an area of suspected solid component on T1WI and T2WI (or STIR) (Case 2-4, 7, 8).

CE-MRI was performed on all but 2 cases (Case 7, 8). Of the 10 cases with CE-MRI, 5 revealed tiny nodular enhanced areas and were therefore diagnosed as ameloblastomas (Case 2-6) (Fig. 1; Case 2). Of these, cases 5 and 6 had not been diagnosed as ameloblastoma on the basis of T1 and/or T2WI (or STIR) alone.

DCE-MRI was also performed on all but 2 cases (Case 7, 8). Of the 10 cases with DCE-MRI, 6 revealed a time-course enhancement area, which was suspected of indicating a solid component; hence, they were diagnosed as ameloblastomas (Case 1-6). Case 1 had not been previously diagnosed as ameloblastoma because its T1 and STIR showed homogeneous signal intensity like a liquid component of an inner part. However, DCE-MRI allowed a diagnosis of ameloblastoma because it showed a gradual increase of enhancement (Fig. 2). Therefore, DCE-MRI of Case 1 was useful in detecting the region of high intratumor angiogenesis indicative of a solid portion.

Of 12 cases, 4 could not be diagnosed as ameloblastoma because no solid component was detected even using CE-T1WI and/or DCE-MRI (Case 9-12) (Case 9,
Fig. 3). Although in Case 9, a tiny enhanced area was detected on DCE-imaging (Fig. 3d), the area was not confirmed as a solid component in the time-to-intensity curve (Fig. 3e, f). DCE-MRIs of these 4 cases showed thicker rim enhancement than odontogenic cysts without any of the above clues leading to the diagnosis of ameloblastoma (Fig. 3d). This feature was considered to be an important point for differential diagnosis of cystic-type ameloblastoma from other cystic lesions.
Discussion

Unilocular radiolucent lesions in the jawbone include dentigerous cysts, radicular cysts, keratocystic odontogenic tumors and ameloblastomas. In the present study, we evaluated whether MRI was useful for the differentiation of unilocular cystic-type ameloblastoma from other cystic lesions. Odontogenic cysts such as dentigerous cysts and radicular cysts have the same predilections in terms of signal intensity: homogeneously intermediate signal intensity on T1WI and homogeneously bright high signal intensity on T2WI (or STIR), reflecting the fluid content of the inner part of the lesion.17 Keratocystic odontogenic tumors are classified as benign tumors of odontogenic origin according to the 2005 WHO histological classification; specifically, cystic lesions including fluid with a characteristically parakeratinized stratified squamous epithelium. Keratocystic odontogenic tumors have heterogeneous intermediate-to-high signal intensity on T1WI and heterogeneous low-to-high signal intensity on T2WI (or STIR), findings which distinguish them from other cystic lesions.17 The cystic lumen of keratocystic odontogenic tumors may be filled with a cheesy material that consists of keratinaceous debris on microscopic examination.1 MR findings of heterogeneous intermediate-to-high signal intensity on T1WI and heterogeneous low-to-high signal intensity on T2WI or STIR would reflect the protein content in the cyst fluid. Therefore, the higher signal intensity on T1WI and the heterogeneous signal intensity on MRI are useful findings for diagnosing keratocystic odontogenic tumor as opposed to other odontogenic cysts.

Ameloblastomas are divided into solid/multicystic, extraosseous/peripheral, desmoplastic, and unicystic types according to the 2005 WHO histological classification of odontogenic tumors.5 Any of these types can show a unilocular radiolucency. In the
present study, of 35 cases, 32 were solid/multicystic types, and 3 were unicystic types. Of the 32 solid/multicystic type cases, 9 showed unilocular and 23 multilocular radiolucency. All three unicystic type cases showed unilocular radiolucency. Extraosseous/peripheral types and desmoplastic types were not present.

MR images of ameloblastomas can be divided into solid and cystic portions on the basis of signal intensity. Most ameloblastomas have multiple cystic portions of various sizes that show intermediate signal intensity on T1WI, bright high signal intensity on T2WI or STIR, and no enhancement on CE-T1WI. Ameloblastomas show a predilection for intermediate signal intensity on T1WI, high signal intensity on T2WI or STIR, and good enhancement on CE-T1WI in the solid portion. These types of ameloblastoma can be easily differentiated from other odontogenic cystic lesions. However, ameloblastomas sometimes show unilocular cystic lesions that show cyst-like signal intensity on T1WI and T2WI (or STIR). The unilocular cystic type ameloblastoma is difficult to distinguish from other cystic lesions using MRI signal intensity alone. Of the 35 cases of ameloblastomas on which MRI was performed, 12 (34.3%) were suspected of being cystic lesions and 23 (65.7%) were diagnosed as ameloblastomas according to the findings described above. Enhancement solid portions on CE-T1WI and multiple cystic portions on T2WI or STIR are useful in diagnosing ameloblastoma. However, unilocular cystic-type ameloblastomas show homogeneous bright high signal intensity on T2WI or STIR as a water-like signal intensity. Unilocular cystic-type ameloblastoma are difficult to distinguish from odontogenic cysts such as dentigerous cysts and radicular cysts on the basis of MR signals alone. An area of rim enhancement on DCE-MRI was verified in the present study as differentiating unilocular cystic-type ameloblastomas from other cystic lesions.
Histopathological variants of unicystic-type ameloblastoma are luminal (ameloblastomatous cyst epithelium), intraluminal (protruding into the cyst cavity) and mural (invading the cyst wall). In the present study, case 5 and 6 were the intraluminal type, i.e., protruding into the cyst cavity, and case 1 was a mural type, invading the cyst wall. In the intraluminal type, the area which showed an enhancement on CE-T1WI and gradual increased enhancement on DCE-MRI corresponded to the solid component. An enhancement area on MRI appearing to protrude into the cyst cavity defined the intraluminal type. In the mural type, an area which showing a thick rim enhancement on CE-T1WI and gradually increasing enhancement on DCE-MRI corresponded to an intramural nodule with focal invasion of the ameloblastoma tissue (Case 1, Fig. 2). Areas suspected of being intramural nodules with focal invasion of ameloblastoma tissue could be retrospectively detected on CE-T1WI and DCE-MRI. However, it was difficult to prospectively diagnose the mural type of unicystic ameloblastoma even using DCE-MRI. Therefore, clinicians should not overlook the signs of mural-type unicystic ameloblastoma in cases with thick rim enhancement. The luminal type (ameloblastomatous cyst epithelium) of unicystic ameloblastoma would have limitations in being diagnosed as cystic lesion even using CE-T1WI and DCE-MRI, although no luminal cases were observed in the present study. DCE-MRIs of the remaining 4 cases, on which no clues leading to the diagnosis of ameloblastoma could be observed, showed thicker rim enhancement than odontogenic cysts (Fig. 3d). This feature of thicker rim enhancement than odontogenic cysts was considered to be an important point for differentiating cystic-type ameloblastomas from other cystic lesions. Minami et al. have also suggested that 7 out of 19 keratocystic odontogenic tumors (odontogenic keratoceysts) had thick walls and unilocular in 10/19; but for
ameloblastoma 11/11 had irregular thick walls based on standard MR imaging. In the present study, we gave additional information that small ROIs set on the irregular thick wall of unicystic ameloblastomas on DCE-MRI would show gradually increasing enhancement that proved a proliferative ability of ameloblastoma as we have already shown in our previous report.6 Thus, DCE-MRI could give useful information to distinct unilocular keratocystic odontogenic tuomors from ameloblastomas.

In conclusion, CE-MRI and DCE-MRI could provide additional information in the differential diagnosis of unilocular cystic-type ameloblastoma according to findings as follows. 1) CE-T1WI showed tiny enhanced areas indicating the exact location of the solid component. 2) Some small ROIs set on the rim-enhanced area of CE-T1WI showed gradually increasing enhancement on DCE-MRI; these areas were suspected of being a solid component and/or intramural nodules with focal invasion of ameloblastoma tissue. 3) DCE-MRI of cystic-type ameloblastomas shows thicker rim enhancement than odontogenic cysts.

**Conflict of interest statement**

None declared.
References

Usefulness of contrast enhanced-MRI in the diagnosis of unicystic ameloblastoma.


Figure legend

Figure 1 Case 2
MRI showed homogeneously intermediate signal intensity on T1WI (a), and
homogeneously bright high signal intensity on short inversion time inversion-recovery
(b). A small area of intermediate signal intensity on short inversion time
inversion-recovery showed enhancement on CE-T1WI (b, c). A small area, region of
interest (ROI) 1, showed more increased enhancement than ROI 2 and 3 on dynamic CE
images (d-f).

Figure 2 Case 1
MRI showed homogeneously intermediate signal intensity on T1WI (a), homogeneously
bright high signal intensity on short inversion time inversion-recovery (b), and thick rim
enhancement on contrast-enhanced (CE)-T1WI (c). Some small ROIs were drawn on
the rim-enhancement area on dynamic CE image (d, e). The area of ROI 1 was
recognized as a solid component by showing a gradual increase of enhancement on
dynamic CE images (f).

Figure 3 Case 9
T1WI (a), short inversion time inversion-recovery (b) and contrast-enhanced
(CE)-T1WI (c) showed no area indicating a solid component. Although a tiny enhanced
area (arrowhead) which was suspected to solid component was detected on dynamic CE
image (d), the area was not confirmed as a solid component due to its time-to-intensity
curve (e, f).
Figure 1
Figure 3