RESEARCH

MR T_1 and T_2 relaxations in cysts and abscesses measured by 1.5 T MRI

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Objectives: The main objective of this study was to make a comparison between the relaxation rates in jaw cysts and abscesses. Such a comparison should provide quantitative information for MR image analysis.

Methods: A phantom containing 20 odontogenic jaw cysts and 11 jaw abscesses was imaged with 1.5 T MR. T_1 measurements were performed by using a mixed sequence of inversion recovery and spin echo, while T_2 measurements were carried out by the Carr–Purcell Meiboom–Gill (CPMG) sequence. Cystic fluids and abscesses were compared statistically.

Results: In cysts and abscesses, respectively, the mean $1/T_1$ was 0.9355 s^{-1} and 0.8245 s^{-1} and the mean $1/T_2$ was 2.4575 s^{-1} and 4.7073 s^{-1} . The $1/T_2$ in cysts was very highly significantly different from that in abscesses ($p = 0.0001$). Both T_1 and T_2 were linearly proportional to material contents. T_2 relaxivities [$26.458\text{ ml(g s)}^{-1}$ for abscesses and $21.455\text{ ml(g s)}^{-1}$ for cysts] were higher than T_1 relaxivities [$5.4766\text{ ml(g s)}^{-1}$ for abscesses and $10.075\text{ ml(g s)}^{-1}$ for cysts].

Discussion: Present T_2 measurements differentiate cysts from abscesses with a confidence interval of 95%. Because *in vivo* and *in vitro* image contrasts are changed by the same parameters, the T_2 findings should present valuable information for *in vivo* MRI. Hence the significant difference and the relaxivities may provide quantitative information for clinicians and researchers making image analyses.

Conclusion: T_2 may differentiate cysts from abscesses. The difference in T_2 is related to the material content of samples.

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Introduction

MRI is known to be a conventional diagnostic tool in medicine. MR films compare contrasts obtained for different fluids, organs or masses for diagnostic purposes. The comparison differentiates healthy and pathological situations through the appearance of images which are caused by different signal intensities.^{1–3} In such cases, the detailed information is qualitatively produced only by hypo and hyper-signal intensities. In parallel with the use of MRI in medicine, some *in vitro* T_1 and T_2 measurements in fluids (or solutions) were carried out by nuclear magnetic resonance (NMR) spectroscopy in order to get the relevant information for obtaining the

best MR images.^{4–7} Besides this, the phantom imaging of body fluids (or solutions), organs and other complementary measurements using MRI have been used together to acquire detailed information for image analysis or image interpretation.^{8–15} In the latter case, the cause of contrast is quantitatively determined. The number of such complementary studies is not limited to the references given here. One might find numerous papers published for these purposes.

MR images of maxillary cysts and abscesses have been reported in a large number of studies.^{1–3,8,9,14–26} Qualitative MR information was mostly obtained through hypo (low) and hyper (high) signal intensities of those images.^{1–3,19,23–26} In two studies, differentiation of hepatic malignancies from cysts was made using a T_2 or T_1/T_2 ratio, while distinction of the odontogenic keratocysts from other cysts and ameloblastoma was

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made by T_2 in another study.^{15,16,22} However, a comparison between MR relaxation times of jaw cysts and abscesses has not yet been made. Also, the cause of MR contrast is not quantitatively determined for such cases. A phantom study comparing the relaxation times of cysts and abscesses, and also determining reasons for MR contrast, should be a complementary work and it should be useful for MR image interpretation.

One aim of this study was to find out the comparison of the relaxation times in cysts and abscesses, while the other was to obtain dependencies of the relaxation rates ($1/T_1$ and $1/T_2$) on water-free material contents of samples. For these purposes, the relaxation times in cystic fluids and abscesses were measured by MR. The water free-material content of each sample was determined by dehydration. The data of groups were compared statistically.

Materials and methods

Cysts and abscesses

20 odontogenic cystic fluids and 11 abscesses were collected from patients with jaw cysts and abscesses before surgical operation. Each fluid was carefully aspirated from the lesion of the jaw region and immediately transferred into a covered tube. Particular attention was paid to the sample transfer in order to leave minimal contamination in the injectors. Each tube was then sealed using Parafilm“M” (Pechiney Plastic Packing, Chicago, IL) to prevent water loss and placed in a capped plastic container and stored in a refrigerator at -2°C . During phantom preparation, each sample was shaken gently to make the samples homogeneous. 3 ml of samples were then carefully transferred into tubes in the phantom. The inlet of each tube in the phantom and the whole phantom were sealed using parafilm. The phantom was then brought to the MRI facility in a Dewar Flask (KGW-Isotherm, Karlsruhe, Germany) containing dry ice in closed plastics. Even if the sedimentation rate for the material in the fluids was very low, the phantom was shaken gently before replacing it in the MR machine. The fluids were diagnosed on the basis of radiological and histopathological findings and they were treated as two groups: cysts and abscesses.

Water free-material contents of cysts and abscesses per 1 ml of samples

1 ml of each sample was replaced in a weighted glass tube. The water free-material content of each sample was determined by weighing the tube containing the sample before and after drying at 120°C for 24 h.^{27,28}

Relaxation measurements

Cysts and abscesses were transferred into cylindrical glass tubes (1.2 cm diameter and 10 cm height), which

were placed in a plastic phantom. The sample volume was 3 ml.

The phantom was imaged by 1.5 T MR scanners (Philips Medical Systems, Intera, Netherlands) at a room temperature of $20\text{--}22^{\circ}\text{C}$ using a head coil. The field of view (FOV) was 160×160 mm and the acquisition matrix was 256×256 . Images with a slice thickness of 15 mm were reconstructed using a two-dimensional fourier transform (2D-FT) technique. T_1 measurements were then performed by using a mixed sequence where an inversion recovery (IR) and a spin-echo (SE) were consecutively combined in one cycle.^{29–31} SE and IR pulse repetition times (TR_{SE} and TR_{IR}) were chosen as 7000 ms and 8000 ms, respectively, to allow a full recovery of magnetization, whereas the delay time (T_1) between the 180° and 90° pulses of the IR part of the mixed sequence was 1000 ms. T_2 measurements were carried out by the Carr–Purcell Meiboom–Gill (CPMG) pulse sequence with eight-echoes. In this case, the pulse repetition time (TR) was set at 7000 ms and echo delays (TEs) were increased stepwise from 30 ms to 240 ms in increments of 30 ms. The T_1 and T_2 maps of the phantoms are shown in Figures 1 and 2, respectively.

Statistical evaluations

The groups were compared statistically by using the statistical package Medcalc version 10.3.0.0 for Windows (Medcalc Software bvba, Ghent, Belgium). The data were expressed as a category mean $\pm$ standard deviation (SD). The differences among the mean values of all categories were tested first by one-way analysis of variance (ANOVA), followed by the Student–Newman–Keuls test for multiple comparisons.^{32–34} The significance level for the difference between the groups was ascertained at $p < 0.05$.

Figure 1 T_1 map of cysts and abscesses. Top to bottom: second and third rows show abscesses and other rows show cysts

Figure 2 T_2 map of cysts and abscesses. Top to bottom: second and third rows show abscesses and other rows show cysts

Results

The mean values of the $1/T_1$ and $1/T_2$ in different groups are given in Table 1 together with SD. The mean $1/T_1$ in cysts and abscesses are 0.9355 s^{-1} and 0.8245 s^{-1} , respectively. The mean $1/T_2$ was 2.4575 s^{-1} for cysts and 4.7073 s^{-1} for abscesses.

The statistical evaluation reveals that the $1/T_1$ in cysts is not significantly different compared with that in abscesses ($p = 0.4683$). However, the $1/T_2$ in cysts is very highly significantly different from that in abscesses ($p = 0.0001$). The comparisons are also given in Figure 3 for T_1 and in Figure 4 for T_2 . A confidence interval (CI) of 95% for T_2 of cysts does not overlap that of abscesses but both CI regarding T_1 overlap each other.

The $1/T_1$ and $1/T_2$ vs the water-free content of cysts and abscesses are shown in Figures 5 and 6, respectively. Both cysts and abscesses give a moderate correlation with material contents. Correlation coefficients for cysts (0.6668 for T_1 and 0.6972 for T_2) are higher than those for abscesses (0.6103 for T_1 and 0.6186 for T_2). This is consistent with previous data expressing the relaxation rates in jaw cysts as the product of total relaxivity and total material content.¹⁸ Each linearity, indicated in Figures 5 and 6, is also consistent with those given for cysts and other similar works.^{4,17,18,27,28}

The slope of each line in Figures 5 and 6 denotes the incremental increase in the relaxation rate per unit concentration of dry material which is termed as relaxivity.⁴ T_2 relaxivities [$26.458\text{ ml}(\text{g s})^{-1}$ for abscesses and $21.455\text{ ml}(\text{g s})^{-1}$ for cysts] are higher than T_1 relaxivities [$5.4766\text{ ml}(\text{g s})^{-1}$ for abscesses and $10.075\text{ ml}(\text{g s})^{-1}$ for cysts]. Higher T_2 relaxivities are consistent with the literature.^{4,18,20,21} The relatively higher T_2 relaxivity of cysts is also consistent with the significant difference between the T_2 of cysts and abscesses.

Discussion

Medical examinations by MRI require a separate image for each patient. Gathering such images for one or two groups of patients takes months. During this period, choices for operator dependent parameters, artefacts caused by patient motions and the use of different machines affect the image quality.^{35–38} Therefore, MR images obtained at different times or by different machines are not suitable for a reliable scientific estimation. Also, such clinical studies do not provide quantitative information. However, in the phantom study, the several samples were replaced in a phantom for each type of disease. The procedures used for sample collection, storage and phantom preparation is assumed not to have a significant effect on the experiment if they were applied carefully.^{39,40} Operator dependent parameters were the same for all samples since all of them are imaged simultaneously. Therefore, phantom studies should be more convenient for a comparison of a large number of MR images.

The highly significant difference ($p = 0.001$) between the T_2 values of cysts and abscesses (Table 1) indicates that *in vitro* T_2 measurements may differentiate cysts from abscesses for a confidence interval (CI) of 95%. This differentiation is also demonstrated in Figure 4. In this figure, the upper borders of boxes show the mean values of $1/T_2$, whereas the vertical lines represent the CI for the mean values. The relevant $1/T_2$ values of cysts distribute along the left vertical line, whereas those of abscesses distribute along the right vertical line. The discreteness between vertical lines is about 0.756 s^{-1} and it displays the differentiation. This means that $1/T_2$ values for 95% of the cystic fluids are different from those for 95% of the abscesses. Knowledge of such a difference is a very valuable for diagnosis. In MRI, the image contrast is only dependent on three intrinsic independent parameters: (i) the spin density, (ii) the spin-lattice relaxation time T_1 and (iii) the spin-spin

Table 1 Comparison of the mean relaxation rates ($1/T_1$ and $1/T_2$) in cysts and abscesses. $p < 0.05$ denotes a significant difference between the two groups

Groups	$1/T_1\text{ (s}^{-1}\text{)}$	p-value	$1/T_2\text{ (s}^{-1}\text{)}$	p-value
Cysts	0.9355 ± 0.5893	0.4863	2.4575 ± 1.2291	0.0001
Abscesses	0.8245 ± 0.2851	0.4863	4.7073 ± 1.3679	0.0001

Figure 3 Comparison of the $1/T_1$ in cysts and abscesses for a confidence interval (CI) of 95%. The upper borders of the left and right boxes show the mean values of $1/T_1$ for cysts and abscesses, respectively. The vertical lines represent the relevant CI. A large part of the CI for cysts overlaps that of abscesses. It means that $1/T_1$ values of a significant amount of cysts overlap those of abscesses

relaxation time T_2 .^{29,35} Because *in vivo* and *in vitro* image contrasts of fluids and masses are changed by the same parameters, the T_2 findings obtained by the phantom imaging should be valid for *in vivo* MRI. Accordingly, *in*

vivo T_2 -weighted images of jaw cysts should be different from those of abscesses. Hence the differences given in Table 1 may provide statistical information for clinicians and researchers making MRI analysis.

Figure 4 Comparison of the $1/T_2$ in cysts and abscesses for a confidence interval (CI) of 95%. The upper borders of the left and right boxes show the mean values of $1/T_2$ for cysts and abscesses, respectively. The vertical lines represent the relevant CI. The CI for cysts is completely discrete from that of abscesses. This means that $1/T_2$ values for 95% of cysts are different to that for 95% of abscesses

Figure 5 The least square fits of the $1/T_1$ in cysts and abscesses vs dry solid content. Squares and triangles denote cysts and abscesses, respectively

The relaxation of a fluid associated with material content is written as $N_b 1/T_{ib} C$ (i:1, 2). N_b , $1/T_{ib}$ and C denote the number of bound water, the relaxation rates of bound water and concentration of dry solid material, respectively.³⁵ The relaxation in a natural sample is proportional to its dry material content. This means

that C is a significant source of contrast. In fact, the darkest three images in Figure 2 belong to the samples with the highest material content ($>0.15 \text{ g ml}^{-1}$) while the brightest three images belong to the samples with the lowest material content ($<0.05 \text{ g ml}^{-1}$). Other images can also be related to the content of fluids.

Figure 6 The least square fits of the $1/T_2$ in cysts and abscesses vs dry solid content. Squares and triangles denote cysts and abscesses, respectively

The cause of contrasts seen in Figure 2 is given in Figure 6. Accordingly, the relationship between dry material content and the relaxation rates, indicated in Figures 5 and 6, provide quantitative information for the image contrast. According to Figure 6, this information is about 70% for cysts and 62% for abscesses. Since such information is related to MR contrast and since *in vitro* findings are most likely valid for *in vivo* studies, the relationships in Figure 6 should provide quantitative information for the source of MR contrast, which is useful for the image interpretation and further investigations.

The relaxivity is known to express the efficiency of a material to alter the relaxation times.^{4,18} According to Figures 5 and 6, T_2 is more efficiently altered by dry solids than the T_1 . Also, the dry solids in abscesses are much more effective than those in cysts in altering the T_2 relaxation times. This is consistent with findings given in

Table 1, revealing the discrimination of cysts from abscesses by T_2 . Given that relaxivities are used for diagnostic purposes, the current figures should supply complementary information for MR image analysis and further research.^{20,21}

In conclusion, current data implies that T_2 measurements may differentiate jaw cysts from jaw abscesses. Also, the data show that the relaxation rates are correlated to dry material content. Both findings may provide quantitative information for clinicians making image analysis.

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