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Myocardial relaxation times measured from postmortem magnetic resonance imaging in adult humans

Hajime Saitou[a,*], Tomoya Kobayashi[a], Seiji Shiotani[b], Kazuya Tashiro[a], Katsumi Miyamoto[a], Hideyuki Hayakawa[c], Kazuhiro Homma[d]

[a] Department of Radiological Technology, Tsukuba Medical Center Hospital, Japan
[b] Department of Radiology, Seirei Fuji Hospital, Japan
[c] Department of Forensic Medicine, Tsukuba Medical Examiner's Office, Japan
[d] Emeritus Researcher, National Institute of Advanced Industrial Science and Technology, Japan

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ABSTRACT

Purpose: To measure T_1, T_2, T_2^*, and ADC values of myocardium with postmortem magnetic resonance (PMMR) imaging in adult humans at 1.5 T and to investigate postmortem changes in the heart.

Materials and Methods: We performed myocardial PMMR imaging on 32 deceased adults (19 men, 13 women; mean age, 49.2 years) whose deaths were for reasons other than cardiac injury or disease. Before imaging, the bodies were kept in cold storage at 4 °C (mean rectal temperature, 17.3 °C), and PMMR imaging data were obtained at a mean of 31.1 h after the estimated time of death. We measured T_1, T_2, T_2^*, and ADC values in the short axis of the heart at four sites (the anterior, lateral, and inferior walls of the left ventricle, and interventricular septum at the middle level of the left ventricle). For 4 sites, homogeneity of variance was assessed by the Bartlett test. Parametric comparisons used analysis of variance (ANOVA). The association of rectal temperature, postmortem interval (time elapsed before MRI after the estimated time of death), and age in T_1, T_2, T_2*, and ADC values was measured by multiple regression analysis.

Results: We did not observe differences in the dispersion and central tendency in 4 parameters (T_1, T_2, T_2*, and ADC values) at the four measured sites. The average T_1, T_2, T_2^*, and ADC values were 934 ± 220 ms, 69 ± 12 ms, 34 ± 9 ms, and 0.198 ± 0.053 × 10^{-3} mm^2/s, respectively. T_1 values were influenced by age and rectal temperature, respectively (multivariable-adjusted partial Pearson correlations (r) = −0.363; p = 0.045 and r = 0.609; $p < 0.001$). T_2 values were influenced by age and postmortem interval, respectively (r = 0.457; p = 0.010 and r = −0.615; $p < 0.001$).

Conclusion: Reduction in rectal temperature, decomposition after death and age are conjointly related with myocardial relaxation times on PMMR imaging.

1. Introduction

Determination of correct cause of death is important, not only for writing appropriate medical records, but also for avoiding legal or insurance issues, and the improvement of public health. However, as the rate of autopsy is decreasing worldwide, the need for postmortem imaging has been increasing as a complementary, supplementary or alternative method to autopsy [1–6].

Among various causes of death, ischemic heart disease was the leading cause of death worldwide in 2004, and is projected to be the leading cause of death in 2030 [7]. Although postmortem magnetic resonance (PMMR) imaging of the heart can delineate ischemic heart disease [8–14], PMMR signals and image contrast change after death mainly due to lowered body temperature [15–21]. Therefore, analysis of quantified data is necessary to provide accurate information regarding interpretation of PMMR imaging findings and optimization for PMMR imaging parameters [21–23].

Zech et al. reported T_1 and T_2 values of the heart in 50 adult human cadavers, but used a 3.0 T scanner [24]. Results with a 3.0 T scanner would differ from those of a 1.5 T scanner, which is commonly used in clinical practice. Schwendener et al. also reported T_1 and T_2 values of the heart in 80 adult cadavers who died of either acute cardiac anamnesis or myocardial infarction and 10 normal controls using a 1.5 T scanner [25]. Crooijmans et al. investigated the feasibility of quantitative diffusion-weighed imaging (DWI) of the heart in two adult human cadavers using a 1.5 T scanner and reported the apparent

* Correspondence to: RT Department of Radiological Technology, Tsukuba Medical Center Hospital, 1-3-1 Amakubo, Tsukuba, Ibaraki 305-8558, Japan.
E-mail address: hajimo90@gmail.com (H. Saitou).

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diffusion coefficient (ADC) values on PMMR imaging [11], although the number of subjects was small. Herein, we report the T_1, T_2, T_2^*, and ADC values of myocardial PMMR imaging of 32 adult human hearts using a 1.5 T scanner.

2. Materials and methods

2.1. Subjects

We examined PMMR imaging data of 32 adults (19 men, 13 women; aged 26–80 years, mean: 49.2 years) who died suddenly and unexpectedly, and for whom cardiopathological examination results showed no abnormality. Neither pericardial effusion nor gas formation from putrefaction were observed by whole-body PMCT scans immediately before PMMR imaging in all subjects. Their bodies were kept in cold storage at 4 ℃ and subjected to PMMR imaging 6–72 h after the estimated time of death based on death scene investigation by police officers and surface inspection by forensic pathologists (mean 31.1 h), though the time span from the estimated time of death to transfer to the cold storage was unclear. Their rectal temperatures, measured immediately after PMMR imaging with an industrial thermometer (7–257-01, AS ONE Corp., Osaka, Japan), ranged from 7 to 30 ˚C (mean: 17.3 ˚C).

Autopsy was performed on each subject after PMMR imaging. Causes of death were 5 cases of trauma not involving the thorax (2 cases of acute subdural hematoma and 3 cases of spinal cord injury due to traffic accidents), 5 cases of suffocation, 5 cases of near-drowning, 4 cases of acute drug overdose, 3 cases of malnutrition, 2 cases of acute alcohol intoxication, 2 cases of ileus, 2 cases of respiratory failure and 1 case of sleep apnea syndrome, 1 case of cerebral infarction, 1 case of subarachnoid hemorrhage, and 1 case of cerebral hemorrhage.

2.2. Scan conditions

With the permission of the ethics committee of our institution, PMMR imaging was performed using a 1.5 T clinical MRI system (Avanto, Siemens, Erlangen, Germany) with a dedicated 6-channel body matrix coil and a spine matrix coil. We measured T_1, T_2, and T_2^* values with a relaxation time map creation tool (syngo MapIt, Siemens, Erlangen, Germany) [26], and ADC value. The scan parameters for the heart are shown in Table 1.

2.3. Analyses

A radiological technologist (H.S.) with 12 years of experience defined 7-mm-circular regions of interest (ROI) at 4 sites of the heart: the anterior wall, the lateral wall, the inferior wall, and the interventricular septum on cardiac short-axis images at the mid portion level of the left ventricle (Fig. 1). The location and size of the ROIs in each subject were identically set on T_1, T_2, T_2*-weighted images, and the ADC map using the copy and paste function of a Windows personal computer. The measured data at the 4 sites were shown by parametric statistics (arithmetic mean value ± standard deviation (SD)), and the Bartlett test was used to verify the homogeneity of variances. When no significant differences were seen in the variance of the 4 sites, one-way analysis of variance (ANOVA) was used to verify the significant differences between the average values of the 4 sites, with the significance level defined as $p < 0.05$ for group differences. When significant differences between the average values of the 4 sites were not found by ANOVA, the mean value of the 4 sites was employed for further analysis.

Pearson's correlation coefficient was used to study the relationships between T_1, T_2, T_2^*, and ADC values, with the ages, rectal temperatures, and postmortem intervals (= the time between the estimated time of death based on death scene investigation by police officers or surface inspection by forensic pathologists and the measurement with MRI). We measured the impact of rectal temperatures and postmortem intervals on T_1, T_2, T_2^*, and ADC values by stepwise multiple regression analysis. We constructed two multiple regression models (one for T_1, and the other for T_2). We adjusted for the age of subjects that may have influenced postmortem myocardial relaxation times. Data were analyzed with SPSS (version 11, SPSS Inc., Chicago, IL, USA).

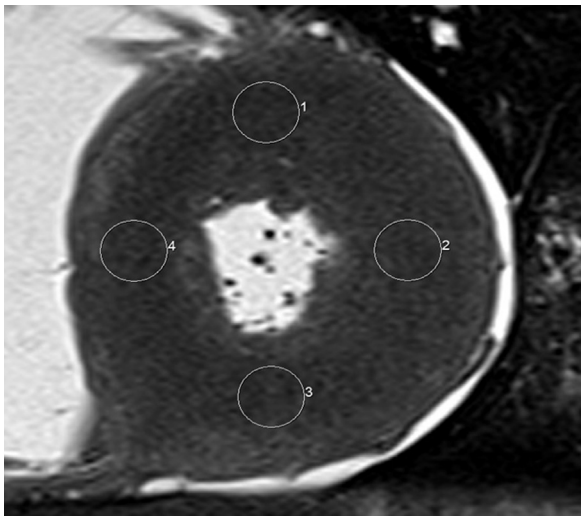

Fig. 1. Four myocardial sites measured on a T_2-weighted image. Regions of interest (ROIs) were placed at the mid portion level of the short axis in the left ventricle: 1) anterior wall, 2) lateral wall, 3) inferior wall, and 4) interventricular septum.

Table 1
Scan parameters of postmortem magnetic resonance (PMMR) imaging.

Scan parameters	T_1 map (GE)	T_2 map (SE)	T_2^* map (SE)	DWI (EPI)
TR/TE (ms)	15/1.62	2000/30, 60, 90, 120, 150	1000/4, 14, 23, 30, 80	5000/117
Flip angle	3˚, 19˚	180˚	60˚	–
Slice Tickness/gap (mm)	4/0	4/0.8	4/0.8	4/0.8
Matrix size (mm)	0.9 × 0.9	0.9 × 0.9	0.9 × 0.9	1.7 × 1.7
Field of view (FOV)	220	220	220	220
Scan time (min)	2	3.3	3.6	3.8
Number of slices	22(3D)	11	11	30

GE,gradient echo; SE,spin echo; EPI,echo planar imaging; TR,reptition time; TE,echo time; 3D,3-dimensional.

3. Results

A diagnostic radiologist (S.S.) with 25 years of experience observed no specific cardiac abnormalities on PMMR images of all subjects, although signal intensity and image contrast were different from those of living bodies (Fig. 2).

Table 2 shows mean T_1, T_2, T_2^*, and ADC values of the heart measured with PMMR imaging of our subjects. The T_1, T_2, T_2^*, and ADC values showed no significant differences between the four measured sites (the Bartlett test, $p = 0.50$, $p = 0.96$, $p = 0.22$, and $p = 0.72$; one-way ANOVA, $p = 0.51$, $p = 0.95$, $p = 0.56$, and $p = 0.60$). Therefore, the mean values of the 4 measurement sites were employed, which were T_1 (934 ± 220 ms), T_2 (69 ± 12 ms), T_2^* (34 ± 9 ms), and ADC ($0.198 \pm 0.053 \times 10^{-3}$ mm^2/sec).

The unadjusted pairwise correlations between T_1, T_2, T_2^*, and ADC values, with the ages, rectal temperatures, and postmortem intervals are shown in Table 3. With myocardial PMMR imaging, rectal temperature correlated inversely with the postmortem interval (correlation coefficient (r) = −0.62; $p < 0.001$). T_1 values of the heart correlated significantly with the age ($r = -0.41$; $p = 0.021$), the rectal temperature ($r = 0.63$; $p < 0.001$), and the postmortem interval (r =