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Original Article

Feasibility, safety, and potential demand of emergent brain magnetic resonance imaging of patients with cardiac implantable electronic devices

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ABSTRACT

Background: The feasibility, safety, and potential demand of emergent magnetic resonance imaging (MRI) of patients with a cardiac implantable electronic device (CIED) in emergency situations are unknown.

Methods: We retrospectively compared emergent and scheduled MRI orders for patients with CIEDs at Kameda General Hospital, a tertiary hospital in Japan, from October 2012 to September 2016.

Results: We identified 11 emergent MRI orders via the emergency room and 38 scheduled MRI orders. Although the baseline characteristics were similar between the two groups, brain scanning was predominant in emergent scanning ($p=0.002$). The reasons for MRI and physicians who ordered it were also significantly different between the two groups ($p < 0.001$, $p=0.03$, respectively). Among the emergent orders via the emergency room, 10 out of 11 were brain scans. Nine out of 10 patients underwent successful emergent brain MRI. The time from arrival at the emergency room to MRI was 144 ± 29 min, and the time from the MRI order made by the cardiologist to its actual performance was 60 ± 10 min. Four out of 9 patients had a diagnosis of acute stroke confirmed by emergent MRI, and two had emergent thrombolysis with a complete neurological recovery. All emergent scanning was conducted safely with no complications.

Conclusions: Our study found the potential demand of brain MRI of patients with CIEDs in emergency situations compared with scheduled scanning, which was shown to be feasible and safe for the diagnosis and treatment of an acute stroke.

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1. Introduction

Until recently, magnetic resonance imaging (MRI) was contraindicated for patients with cardiac implantable electronic devices (CIED) due to a potential safety concern [1–5]. Then, MRI-conditional CIEDs were introduced globally in 2008 and in Japan in 2012. Since then, the safety of MRI-conditional CIEDs has been reported [6–10].

It was estimated that up to 75% of patients with CIEDs require MRI during their lifetime [11,12]. Although MRI is useful for many diseases, an acute ischemic stroke is a disease whereby MRI is crucial for determining the stroke lesion and *penumbra*, which indicates the efficacy of treatment [13]. Thrombolysis within 4.5 h after the onset of a stroke [14] and thrombectomy within 8 h after

the onset have been shown to be effective for the treatment of an acute ischemic stroke [15,16]. Although the devices were not MRI-conditional CIEDs, 40% of MRI examinations of patients with CIEDs in a cohort study involved brain scanning [17]. Since an acute ischemic stroke requires rapid examination and treatment determination, MRI should not be a rate-determining step in its clinical course.

Japan has the most MRI systems per capita of the population, averaging 46.8 machines/million people compared to 14.0 machines/million people for Organization for Economic Cooperation and Development (OECD) countries [18]. Moreover, MRI is widely available in emergency departments. Since an MRI-conditional CIED is a relatively new technology and manipulation of its settings is necessary before MRI, there have been no studies focusing on the potential demand, feasibility, and safety of emergent MRI for patients with MRI-conditional CIEDs. Our hospital has implemented a 24-h MRI system for patients with MRI-conditional CIEDs since 2012.

Abbreviations: MRI, magnetic resonance imaging; CIED, cardiac implantable electronic device

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2. Materials and methods

2.1. Study design

We retrospectively compared emergent and scheduled MRI orders for patients with MRI-conditional CIEDs at Kameda Medical Center in Japan, from October 2012 to September 2016. This investigation was approved by the ethics committee of our hospital.

2.2. Statistical analysis

The Mann–Whitney *U* test, Chi-squared test, and Fisher's exact test were used for analysis. A *p* value less than 0.05 was considered significant.

2.3. MRI

All MRI examinations were conducted with a 1.5-T MR system (MAGNETOM Avanto, Siemens, Munich, Germany) in the presence of either a cardiologist or electrophysiologist and allied professionals with extensive experience in CIED programming. At every MRI examination, information of the patient and implanted device were screened and confirmed by either the cardiologist or electrophysiologist as compatible with MRI. The conditions of MRI, such as Slew Rate and Specific Absorption Rate, were confirmed by radiographers. A baseline interrogation to record the values, such as pacing threshold and lead impedance, and a change of settings to an MRI-compatible mode were conducted by clinical engineers. An appropriate monitoring system (oxygen saturation and electrocardiography) was used and equipment for advanced cardiac life support was always available during the scanning. Immediately after the scanning, all device settings were reprogrammed to the original state.

During day-time hours, either the cardiologist or electrophysiologist in charge that day and all the related allied professionals were called for either the emergent or scheduled scanning. During night-time hours, the cardiologist and radiographers on call and staying in the hospital were called and clinical engineers in charge that night were re-called from their homes for the emergent scanning.

3. Results

3.1. Baseline characteristics

We identified a total of 57 MRI orders for patients with MRI-conditional CIEDs, of which 11 were emergent orders via the emergency room, 8 were unscheduled or urgent orders within the same day via an outpatient clinic or inpatient service, and 38 were scheduled orders. The 11 emergent orders and 38 scheduled orders were compared in this study.

Table 1 shows the baseline characteristics of the two groups. There were no significant differences in the age, sex, implanted device, device manufacturer, reason for device implantation, implantation hospital, or days after implantation between the emergent and scheduled scanning. The products of five companies are currently available in Japan, and devices from all five manufacturers were used in this study (Medtronic Inc., Minneapolis, MN, USA; St. Jude Medical, St. Paul, MN, USA; Boston Scientific, Natick MA, USA; Biotronik, Berlin, Germany; and Sorin, Milan, Italy).

3.2. Emergent vs. scheduled MRI

Table 2 shows a comparison of MRI between the emergent and scheduled MRI groups. Brain scanning was predominant in emergent

Table 1

Baseline characteristics of patients with CIEDs who had MRI orders.

	Emergent MRI	Scheduled MRI	<i>p</i> Value
Age	81.1 ± 10.4	76.1 ± 6.1	0.07
Sex	Men Women	8 23 3 15	0.72
Implanted device	Pacemaker ICD	11 35 0 3	1.00
Device manufacturer	Medtronic St. Jude Medical Boston Scientific Biotronik Sorin	6 26 1 8 1 1 2 3 1 0	0.93
Reason for implantation	SSS AVB VT/Vf	6 15 5 20 0 3	0.89
Implantation hospital	our hospital other hospital	10 32 1 6	1.00
Days after implantation	379 ± 205	376 ± 280 (mean ± SD)	0.50

CIED: cardiac implantable electronic device; MRI: magnetic resonance imaging; ICD: implantable cardiac defibrillator; SSS: sick sinus syndrome; AVB: atrioventricular block; VT/Vf: ventricular tachycardia/ventricular fibrillation; SD: standard deviation.

Table 2

Comparison of emergent MRI scanning and scheduled MRI scanning for patients with CIEDs.

	Emergent MRI	Scheduled MRI	<i>p</i> Value
Site of scanning	Brain Others	10 14 1 24	0.002
Physicians who ordered MRI	Emergency physician Neurologist Cardiologist Others	7 0 4 6 0 11 0 21	< 0.001
Reason for order	Stroke evaluation Orthopedic Cancer Preoperative evaluation Cardiac sarcoidosis Others	10 8 1 12 0 8 0 5 0 3 0 1	0.03
Time of scanning	9:00–17:00 17:00–9:00	8 36 3 1	0.03
Success	Yes No	10 37 0 1 (high pacing threshold)	1.00
Complication	0	0	1.00

MRI: magnetic resonance imaging; CIED: cardiac implantable electronic device.

scanning ($p=0.002$). This dominance of brain scanning for emergent MRI differed from the variety of scanning positions for the scheduled examination: 14 brain cases, 11 lumbar cases, seven abdomen cases, four chest or cardiac cases, and two neck cases (not shown in Table 2 in detail). Based on this significance for emergent scanning compared to scheduled scanning, the potential demand of brain MRI in patients with CIEDs in emergency situations was revealed.

The types of physicians who ordered MRI were also significantly different between the two groups ($p < 0.001$). Emergency physicians

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