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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.

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 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

Table 1
Baseline characteristics of patients with CIEDs who had MRI orders.

	Emergent MRI		Scheduled MRI	*p* Value
Age	81.1 ± 10.4		76.1 ± 6.1	0.07
Sex	Men	8	23	0.72
	Women	3	15	
Implanted device	Pacemaker	11	35	1.00
	ICD	0	3	
Device manufacturer	Medtronic	6	26	0.93
	St. Jude Medical	1	8	
	Boston Scientific	1	1	
	Biotronik	2	3	
	Sorin	1	0	
Reason for implantation	SSS	6	15	0.89
	AVB	5	20	
	VT/Vf	0	3	
Implantation hospital	our hospital	10	32	1.00
	other hospital	1	6	
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	*p* Value
Site of scanning	Brain	10	14	0.002
	Others	1	24	
Physicians who ordered MRI	Emergency physician	7	0	< 0.001
	Neurologist	4	6	
	Cardiologist	0	11	
	Others	0	21	
Reason for order	Stroke evaluation	10	8	0.03
	Orthopedic	1	12	
	Cancer	0	8	
	Preoperative evaluation	0	5	
	Cardiac sarcoidosis	0	3	
	Others	0	1	
Time of scanning	9:00–17:00	8	36	0.03
	17:00–9:00	3	1	
Success	Yes	10	37	1.00
	No	0	1 (high pacing threshold)	
Complication	0		0	1.00

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

Table 3
Details of emergent MRI scanning for patients with CIEDs.

Age	Sex	Location	Success	Scanning time	Finding	Management
85	F	Brain	Yes	19:40	Acute stroke confirmed	Admission and tPA
79	M	Brain	Yes	14:10	Acute stroke confirmed	Admission and tPA
76	M	Brain	Yes	12:24	Acute stroke confirmed	Admitted
76	M	Brain	Yes	11:58	Acute stroke confirmed	Not admitted
72	M	Brain	Yes	14:50	Stroke ruled out	Admitted for other reason
92	M	Brain	Yes	11:43	Stroke ruled out	Admitted for other reason
59	F	Brain	Yes	16:37	Stroke ruled out	Not admitted
93	F	Brain	Yes	20:14	Stroke ruled out	Not admitted
82	M	Brain	Yes	1:30	Stroke ruled out	Not admitted
84	M	Brain	No	14:48 (Delayed until later on the same day)	Acute stroke confirmed	Admitted
94	M	Neck	Yes	16:40	Spinal cord damage ruled out	Not admitted

CIED: caridac implantable electronic devices; MRI: magnetic resonance imaging; tPA: tissue plasminogen activator; F: female, M: male.

and neurologists dominated in emergent scanning, whereas cardiologists and various other doctors (nine orthopedists, four gastroenterologists, one neurosurgeon, one general surgeon, one urologist, one gynecologist, one otolaryngologist, one rheumatologist, one hematooncologist, and one pulmonologist) performed the scheduled scanning.

Although stroke evaluation was the main reason for emergent scanning, there were significantly different reasons for scheduled scanning ($p=0.03$). Orthopedic and cancer evaluations were important, as well as stroke evaluations, in scheduled scanning. The eight stroke evaluations included a follow up of a previous stroke, and an acute stroke was diagnosed in only one patient.

Scheduled scanning was conducted mainly within office hours (9:00–17:00), whereas emergent scanning was conducted outside office hours ($p=0.03$). The success rates of scanning showed no difference, and no complication was noted in either group.

3.3. Emergent MRI in detail

Table 3 shows the details of emergent MRI. Among the 11 patients who underwent emergent scanning via the emergency room, ten were brain scans and one was a neck scan after trauma for an evaluation of the spinal cord.

Ten out of 11 patients received successful emergent MRI. One patient could not undergo the emergent scanning because of a manpower shortage, but could receive MRI later on the same day. The time from arrival in the emergency room to MRI of the 10 patients was 144 ± 29 min, and the time from the MRI order made by the cardiologist to its actual performance (data available for six patients) was 60 ± 10 min. The emergency physician requested MRI for seven patients and the neurologist ordered MRI for four patients. The timing of MRI varied from daytime hours to midnight.

For brain scanning, four out of nine patients had a diagnosis of an acute ischemic stroke confirmed by emergent MRI, and two had emergent thrombolysis with a complete neurological recovery. An acute ischemic stroke was successfully ruled out by emergent MRI in five out of nine patients.

All emergent scanning was conducted safely with no complications. The pacing threshold, lead impedance, and battery status remained unchanged after the MRI. Although all emergent scanning was conducted safely following confirmation of the compatibility of the devices, three out of 11 patients did not carry the cards indicating that the device was MRI-conditional. In these cases, more time was necessary to confirm device compatibility.

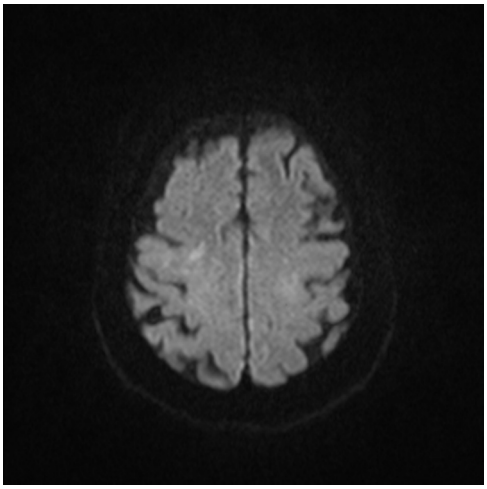

Fig. 1. Brain magnetic resonance imaging (MRI) suggesting stroke.

3.4. Case

An 85-year-old Japanese woman developed sudden-onset dysarthria and was transferred to our hospital. She had a history of pacemaker implantation (Advisa MRI, Medtronic Inc., Minneapolis, MN, USA) due to bradycardia–tachycardia syndrome and had been on an oral anticoagulant for atrial fibrillation. Her dysarthria started at 18:00 and her family made an emergency call. Our hospital was notified by the ambulance and she arrived at our emergency room at 19:20. Following arrival, she received a blood test and emergent computed tomography (CT) of the brain at 19:30. Since cardiologists and allied professionals were promptly notified of her situation and the necessity of MRI by emergency doctors, emergent MRI of the brain was conducted at 19:40 soon after the CT to rule out a brain hemorrhage. Her brain MRI scan (Fig. 1) revealed an occlusion of a peripheral artery on the right side, which could not be diagnosed by CT. According to the MRI, intravenous fibrinolytic therapy, not thrombectomy, was determined to be the optimal treatment for her in terms of safety and efficacy. After the results of her blood test were made available, which was the rate-determining step of this case, the patient received a thrombolytic drug injection for emergent thrombolysis. She was subsequently admitted to the neurology department, made a full recovery, and was discharged home without any stroke sequelae. In this case, the early notification of cardiologists and technicians was key to successful emergent MRI. MRI also enabled neurologists to determine thrombolysis treatment with confidence regarding its safety and efficacy.

4. Discussion

Since emergent MRI for patients with CIEDs comprised 19% (11 out of 57 cases) of the total MRI procedures, our retrospective study revealed the potential demand of the 24-h availability of MRI for patients with CIEDs, especially for brain scanning, as well as for patients without devices. In the emergency room, brain scanning has been shown to be the primary reason for MRI for an acute ischemic stroke evaluation, since brain CT alone may not be able to rule out an early stroke or a small lesion. For a definite diagnosis and the determination of thrombolytic therapy, emergent MRI is required, as was in our case of our 85-year-old patient. Although our study does not have enough data to clarify the effectiveness of emergent brain MRI compared with brain CT alone, an accumulation of cases and prospective observation of patients with CIEDs in the emergency room will demonstrate its effectiveness for the diagnosis and treatment of an acute stroke.

This study also demonstrated the feasibility and safety of emergent MRI with a success rate of 90.1% and no complications, despite a need for an evaluation of MRI compatibility and changes to the device setting.

Although emergent brain MRI has a high potential demand and is feasible to perform, there are several areas requiring improvement and there are hurdles to overcome. First, the sharing of information on patients with CIEDs among emergency physicians, cardiologists, electrophysiologists, clinical engineers, and the radiographer is essential for rapid preparation to conduct emergent MRI. Since speed is essential for brain scans that evaluate a stroke, which is the primary reason for emergent MRI, knowing the relevant information beforehand is useful because of the complicated MRI conditions. Although feasible, the total number of MRI procedures for patients with devices is small. We may need to raise the awareness of MRI-conditional devices among doctors. Although the introduction of a new system in the hospital may pose difficulties, we should positively promote the establishment of an emergent MRI system.

Second, since patients have CIEDs from different manufacturers, and each company and device have different regulations, we should be well-prepared of this complicated situation beforehand in order to save time and perform scanning safely. When patients are transferred from other hospitals, information on the CIEDs of these patients may not be available, and careful determination of their compatibility with MRI is needed.

Third, we should inform patients on compatibility with MRI as three out of 11 patients did not carry MRI cards. The further familiarization of patients and their families with MRI cards is necessary.

5. Conclusion

Emergent MRI of patients with CIEDs has a high potential demand, especially for the diagnosis and treatment of an acute stroke. Even though the precautions to safely conduct MRI were taken, it was feasible to perform 24-h emergent MRI of patients with CIEDs. There will be an increase in the need for emergent brain MRI of patients with CIEDs.

Conflict of interest

All authors declare no conflicts of interest related to this study.

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