ORIGINAL ARTICLE

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Influence of electromagnetic interference on implanted cardiac arrhythmia devices in and around a magnetically levitated linear motor car

Abstract This study was designed to determine the susceptibility of implanted cardiac arrhythmia devices to electromagnetic interference in and around a magnetically levitated linear motor car [High-Speed Surface Transport (HSST)]. During the study, cardiac devices were connected to a phantom model that had similar characteristics to the human body. Three pacemakers from three manufacturers and one implantable cardioverter–defibrillator (ICD) were evaluated in and around the magnetically levitated vehicle. The system is based on a normal conductive system levitated by the attractive force of magnets and propelled by a linear induction motor without wheels. The magnetic field strength at 40 cm from the vehicle in the nonlevitating state was 0.12 mT and that during levitation was 0.20 mT. The magnetic and electric field strengths on a seat close to the variable voltage/variable frequency inverter while the vehicle was moving and at rest were 0.13 mT, 2.95 V/m and 0.04 mT, 0.36 V/m, respectively. Data recorded on a seat close to the reactor while the vehicle was moving and at rest were 0.09 mT, 2.45 V/m and 0.05 mT, 1.46 V/m, respectively. Measured magnetic and electric field strengths both inside and outside the linear motor car were too low to result in device inactivation. No sensing, pacing, or arrhythmic interactions were noted with any pacemaker or ICD programmed in either bipolar and unipolar configurations. In conclusion, our data suggest that a permanent programming change or a device failure is unlikely to occur and that the linear motor car system is probably safe for patients with one of the four implanted cardiac arrhythmia devices used in this study under the conditions tested.

Key words Pacemaker · Implantable cardioverter–defibrillator (ICD) · Electromagnetic interference · Linear motor car

Introduction

From March to September 2005, an international exhibition 2005 (World Exposition, Aichi, Japan) was held in Nagoya Eastern Hills (Nagakute Toyota, and Seto), Aichi, Japan. Japan’s first maglev train service (the Eastern Hill Line) operated between Fujigaoka Station and Yakusa Station, located next to the Expo 2005 site. This transport system (HSST, High-Speed Surface Transport) was brought to Japan after it was first introduced in Shanghai, and this is the second commercial operation of HSST worldwide (Fig. 1). In patients with implanted pacemakers, malfunctions caused by electromagnetic fields are well known.1–3 However, the effect of electromagnetic interference (EMI) from HSST on a patient implanted with a cardiac arrhythmia device such as a pacemaker or implantable cardioverter–defibrillator (ICD) remains uncertain. The aim of this study was to clarify the susceptibility of an implanted cardiac arrhythmia device to EMI from HSST.

The super-high-speed linear motor car (S-Maglev, Superconducting Magnetic Levitation) is still under development and various tests are underway on the Yamanashi Maglev Test Line by the Railway Technical Research Institute. The mechanism of HSST in comparison with S-Maglev is as follows.4,5

Levitation

In HSST, the vehicle levitates as a result of an attractive force between the track and the electromagnets set into the body. The electromagnets are prevented from touching or sticking to the track by control of the electromagnets by a sensor regulating the space between the track and the vehicle. In terms of vertical motion, the controlled attractive
force between the track and the electromagnets naturally corrects the gap size. On the other hand, the S-Maglev vehicle runs levitated from the guideway by electromagnetic forces between superconducting magnets on board the vehicle and the figure-of-eight levitation coils installed on the sidewalls of the guideway. When the on-board superconducting magnets pass at a high speed about several centimeters below the center of these coils, an electric current is induced within the coils, which then temporarily act as electromagnets. As a result, forces are induced that push and pull the superconducting magnets upwards simultaneously, thereby levitating the S-Maglev vehicle.

Propulsion

The HSST vehicle runs using a linear motor and has no wheels. Speed control is performed in the HSST vehicle. A linear motor is an ordinary induction motor laid out flat. An ordinary motor is used as a rotary force, whereas a linear motor delivers a force acting straight ahead. In contrast, in the S-Maglev vehicle, a repulsive force and an attractive force induced between the magnets are used to propel the vehicle (superconducting magnet). The propulsion coils located on the sidewalls on both sides of the guideway are energized by three-phase alternating current from a substation, creating a shifting magnetic field on the guideway. The on-board superconducting magnets are attracted and pushed by the shifting field, propelling the S-Maglev vehicle. Because the levitation force is weak when the vehicle’s speed is less than 150 km/h, S-Maglev has wheels. The speed control system of S-Maglev is situated on the ground in a power conversion substation.

We can describe the differences in the electromagnetic environment between the HSST and S-Maglev as follows (Fig. 2). HSST has six magnetic modules in each vehicle. A module is similar to a railway bogie. One module consists of four electromagnets for levitation and lateral movement, one linear motor, and a brake system. There are four electromagnets for levitation in one module, that is, to say 24 electromagnets in a vehicle. These electromagnets use 275 V direct current. Because HSST has circuits enclosed within the electromagnets and the iron rail, and because the electrical energy used for vehicle levitation is small (around 10% of the total), there is a little risk of EMI. As in a regular train, the effect of the variable magnetic field and direct current magnetic field from the filter electric reactor generated from the variable voltage/variable frequency (VVVF) inverter is significant. In S-Maglev, the superconducting magnet (SCM) is the core element. Two SCMs are mounted on each bogie and each SCM consists of four superconducting coils. Although the magnetic field from the superconducting coil is very strong in S-Maglev, there is a little EMI because the vehicle has magnetic shielding.

Methods

Magnetic and electric field strengths were measured both outside and inside the HSST, and the pacing operations of implantable arrhythmia devices were monitored during the investigation. Three pacemakers and one ICD from three manufacturers were used in this study: the Virtus Plus II DR (Guidant/Intermedics, MN, USA), Affirmity (St. Jude, CA, USA), and Kappa DR (Medtronic, MN, USA), all pacemakers, and the Prizm II DR (Guidant/Intermedics), an ICD (Table 1). Three programmers from the three manufacturers were used for telemetry: Zoom (Guidant/Intermedics), 9790 (Medtronic/Vitatron, MN, USA), and 3022 (Guidant/Intermedics).