

Computed tomography continues to be the preferred tomographic imaging technology for patients with cardiac implantable electronic devices despite a potential risk of electrical interference by irradiation

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Over 2 million patients in the United States have cardiac implantable electronic devices (CIEDs), including pacemakers and implantable cardioverter defibrillators (ICDs).^{1,2} A majority of these patients with CIEDs subsequently have a clinical indication for diagnostic imaging such as computed tomography (CT) and magnetic resonance imaging (MRI).^{3,4} However, there have been major concerns that those scans might interact with and cause malfunction of the CIEDs or permanent damage to the device, leads, or heart at the lead-tissue interface.⁵ Because there were early reports implicating MRI scans in the death of several patients with implanted devices,^{6–9} it has been considered that MRI is contraindicated in patients with a CIED. However, MRI scans were inadvertently performed without any significant complications in some patients with CIEDs. Based on that experience, several studies were undertaken to evaluate the safety of MRI scans in patients with non-MRI-conditional CIEDs. Most recent studies have reported no long-term clinically significant adverse events in patients with non-MRI-conditional CIEDs that underwent thoracic and non-thoracic MRI

exams.^{4,10} On the other hand, MRI-conditional CIEDs have been developed to extend an MRI indication to patients with CIEDs, and currently are clinically available. Several studies have proved the safety of MRI scans in patients with the MRI-conditional CIEDs.^{11–14}

CT has been recognized as a safe imaging technology for patients with a CIED, and has been used as an alternative of MRI. However, the US Food and Drug Administration (FDA) has recently announced that CT imaging can cause adverse events in some implantable and wearable electronic devices (e.g., insulin pumps, CIEDs, and neurostimulators).¹⁵ When a CT scanner directly irradiates the circuitry of certain implantable or wearable electronic medical devices (i.e., when the device is visible in the resulting CT image), it can cause sufficient electronic interference to affect the function and operation of the medical device. In the CIEDs, an over-sensing should be the biggest issue as an electronic interference. Over-sensing occurs when the CIED inappropriately recognizes radiation-induced electrical signals as native cardiac activity. In bradycardia therapy with pacemaker devices, an over-sensing can inhibit pacing, resulting in a long pause. Therefore, this sort of interference should be a more serious concern in pacemaker-dependent patients. In tachycardia therapy with ICD devices, an over-sensing can be recognized as a ventricular tachycardia or ventricular fibrillation, resulting in an inappropriate shock.

In this issue of the Journal, Pan et al published an interesting article where they discussed the potential effects of low-dose average CT on CIEDs by providing the results of a bench study that investigated the relationship between the radiation dose rate and occurrence of electrical interference.¹⁶ Because a larger amount of direct irradiation of a CT scanner over the CIEDs has a

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higher risk of causing electrical interference, multiple factors such as the duration, total dose, dose rate, and direction of the radiation by the CT scanner may affect the occurrence of the electrical interference.^{17,18} These factors can also determine the resolution of the CT images. Those factors may be individualized according to the purpose and subject of the CT examination, although a standard protocol should exist.^{19–21} A CT examination is typically performed with a helical CT in which the patient is irradiated while the table moves at a constant speed that is determined by the pitch factor equal to the ratio of the patient table advancement per gantry rotation to the x-ray beam width. The electrical interference can occur only when the CIED is inside the primary x-ray beam of the CT scan. Because there is more attenuation of radiation through the thicker tissue in the posterior-anterior direction, the CIEDs are exposed to more radiation in the anterior-posterior direction than the posterior-anterior direction. In CT imaging, an image can be reconstructed with a minimum of 180° of acquired data. Therefore, the temporal resolution should be one half of the rotation speed/360°. For a typical protocol with an x-ray collimation of 2 and 4 cm at a pitch factor of 1 and gantry rotation time of 0.5 second (temporal resolution = 0.25 second), the table moves at a speed of 4 and 8 cm per second for the 16- and 64-slice CT scanners, respectively. Therefore, the CIED with a side of < 4 cm is irradiated for < 0.5 and 0.25 second for 16- and 64-slice CT scanners, respectively. On the other hand, in an average CT from a low-dose cine CT, which is more accurate than a conventional helical CT for the quantitation of the positron emission tomography data, the temporal resolution is one breath cycle of several seconds.^{22,23} Therefore, the CIED can be irradiated for a couple of seconds for the average CT scanners. Considering the duration of the radiation exposure, electrical interference of over a breath cycle for an average CT could impose a risk on a CIED patient, although that with a helical CT is unlikely.

The risk of CT irradiation of a CIED causing an adverse event may be extremely low, and is generally outweighed by the clinical benefit of a medically indicated CT examination.¹⁵ However, the potential risk of such adverse events should be understood, and when it is considered to be significant in patients with an ICD and pacemaker-dependent patients, some measures may be taken to reduce such a risk and prevent those adverse events. Such an electrical interference is completely avoided when the CIEDs are outside of the primary x-ray beam of the CT scanner. Therefore, the area of the CT scan should be planned in order not to include the site of the CIED if possible. Pan et al reported that the number of over-sensing events by CIEDs due to CT irradiation increased in proportion to the dose rate of the

radiation and a low-dose average CT of over a breath cycle at 0.9 mGy/s could eliminate the electrical interference of the CT radiation on the CIED. Yamaji et al reported that over-sensing during the CT scan with a radiation dose of 17.5 mGy at a dose rate of 35 mGy/s and exposure time of 1 second with a Siemens Somatom 4-slice CT scanner could be prevented by lead shielding.¹⁷ Therefore, reducing the dose rate and duration of the CT irradiation may lower the probability of such electrical interference. In the studies investigating the safety of MRI scans in patients with CIEDs, the protocols typically involved device interrogation and reprogramming to an asynchronous pacing mode (SOO, AOO, VOO, and DOO) in pacemaker-dependent patients, inhibited modes (SSI, AAI, VVI, and DDI) in non-pacemaker-dependent patients, and disabling the tachyarrhythmia detection and therapies in ICDs prior to the MRI study. When it is not desirable to reduce the dose rate and duration of the CT irradiation for the purpose of a CT examination, the same protocols as for an MRI scan may be used to prevent any adverse events with the CIEDs caused by the CT irradiation.

Disclosure

The author declares no conflict of interest.

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