International Journal of Cardiology 179 (2015) 510–513

Contents lists available at ScienceDirect

International Journal of Cardiology

journal homepage: www.elsevier.com/locate/ijcard

Letter to the Editor

Electromagnetic interference between continuous-flow left ventricular assist device and cardiac resynchronization therapy defibrillator due to an unrecognized mechanism

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ARTICLE INFO

Article history:
Received 22 October 2014
Accepted 3 November 2014
Available online 5 November 2014

Keywords:
Electromagnetic interference (EMI)
DuraHeart®
Left ventricular assist device (LVAD)
Cardiac resynchronization therapy defibrillator (CRT-D)
COGNIS®
Telemetry failure

Overall efficacy and safety of combined continuous-flow LVAD and ICD were recently reported [1]. However, several cases of electromagnetic interference between ICD and LVAD have been reported, such as telemetry instability between ICD and its programmer or inappropriate ICD therapies caused by noise arising from LVAD [2–6]. However, these reports were cases which used HeartMate® II (Thoratec Corporation, Pleasanton, CA, USA) or HeartWare® (HeartWare International, Inc., Framingham, MA, USA) with ICD (St. Jude Medical Corporation, Sunnyvale, CA, USA or Sorin Group, Milan, MI, Italy). Here we report novel electromagnetic interference between CRT-D (COGNIS®, Boston Scientific, St. Paul, MN, USA) and LVAD (DuraHeart®, Terumo Corporation, Shibuya, Tokyo, JAPAN). A 35-year-old man who had been diagnosed in a health examination in 2001 with premature ventricular contraction, was then diagnosed with dilated cardiomyopathy, by endomyocardial biopsy, in 2003. Whereas the best medical treatments for severe heart failure had been done, he was repeatedly hospitalized. Left ventricular ejection fraction was reduced to 20% with wide QRS complex, and non-sustained ventricular tachycardia was also observed. CRT-D: Contak RENEWALl® (Boston Scientific, St. Paul, MN, USA) was implanted in 2003. CRT-D generator was replaced by COGNIS 100-D® (Boston Scientific, St. Paul, MN, USA) due to low battery in 2010. However, the frequency of hospitalization was gradually increased and a LVAD (DuraHeart, Terumo Corporation, Shibuya, Tokyo, Japan) was implanted as a bridge to transplantation (Fig. 1A). During LVAD implantation surgery, ventricular arrhythmia therapeutic capability was turned off to avoid inappropriate therapy caused by electromagnetic interference of the electrocautery scalpel. Just after the LVAD was inserted and started, the programming head of CRT-D programmer (Boston Scientific, St. Paul, MN, USA) was placed on the skin above the CRT-D generator to communicate with the CRT-D, and incessant intermittent telemetry failure was observed (Fig. 1B). In the perioperative period, power delivery was supplied by hospital console, which is the attached power supply and modulator of rotation setting of the LVAD. During telemetry failure, no information was obtained by the programmer and any manipulation from the CRT-D programmer could not be accepted. Abnormal pacing or sensing manner was not suspected by other biomonitors. Even after moving to the cardiac care unit, incessant intermittent telemetry failures were also observed in the same action. We tried to move the cable of the programming head and programmer itself from VAD insertion site to avoid this telemetry failure. However, no position could resolve this intermittent telemetry failure. We tested shielding of these devices by steel shielding [7] (Fig. 1C). When we

Abbreviations: LVAD, Left ventricular assist device; ICD, Implantable cardioverter defibrillators.

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http://dx.doi.org/10.1016/j.ijcard.2014.11.021
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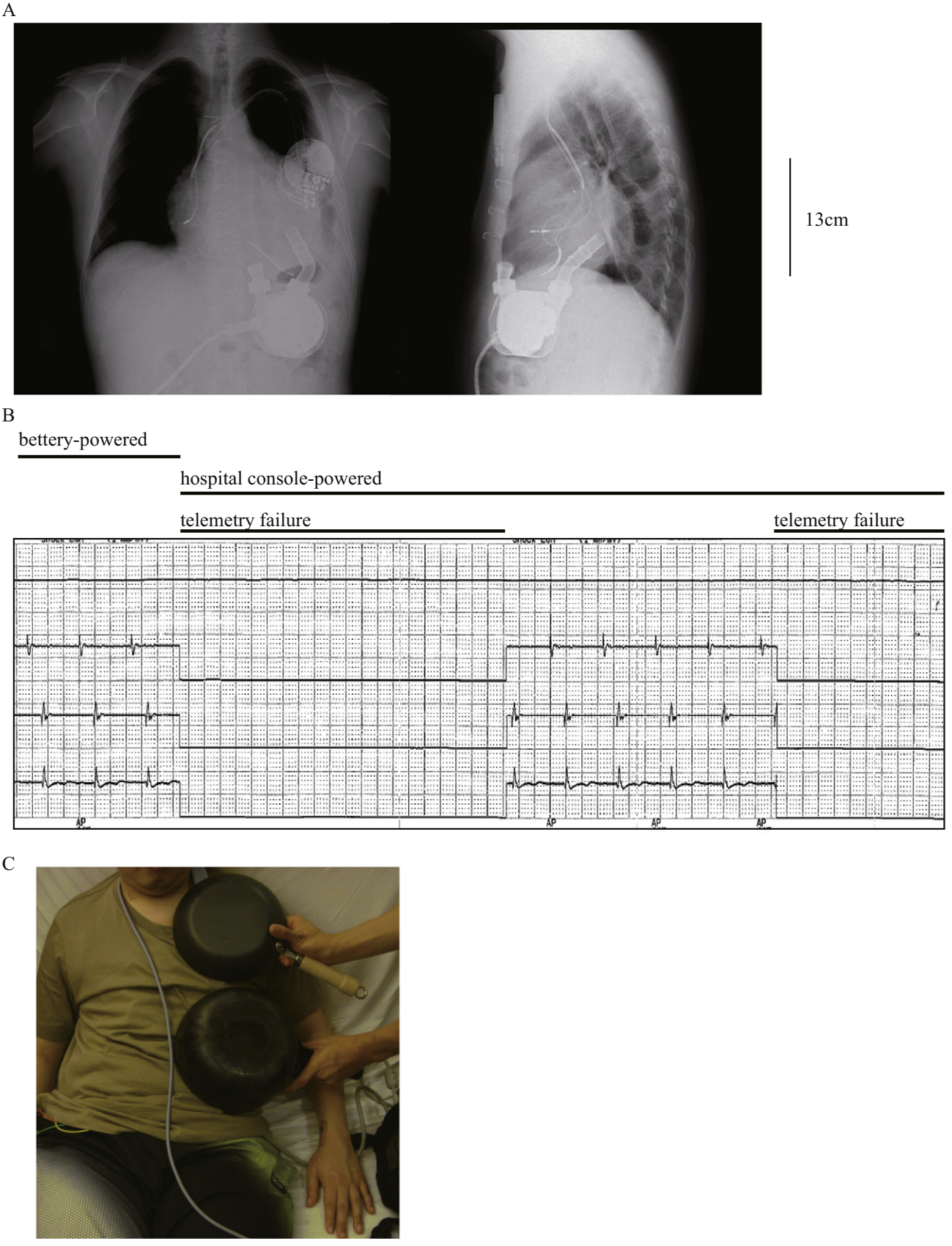
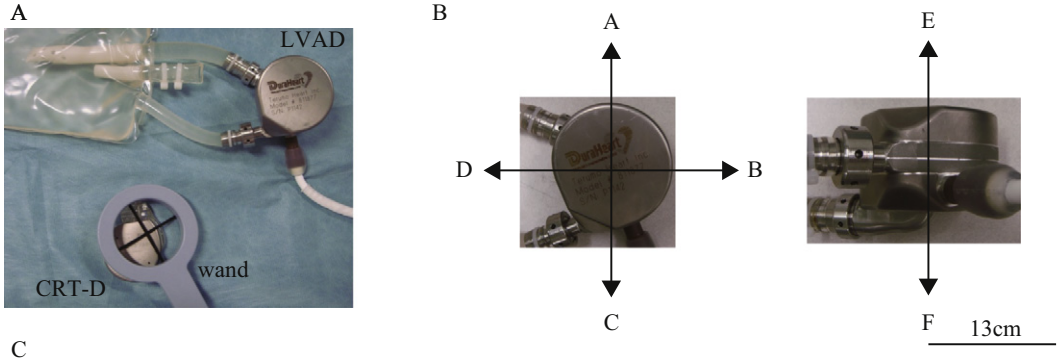


Fig. 1. Telemetry failure between cardiac resynchronization therapy defibrillator (CRT-D) and its programmer in patient with continuous-flow left ventricular assist device (LVAD) powered by hospital console and a way of preventing. a) Posterior-anterior and right-left chest X-ray images of the respective CRT-D and LVAD. Distance between CRT-D and LVAD pump was 13 cm. b) The loss of telemetry of cardiac resynchronization therapy defibrillator (COGNIS®, Boston Scientific) using wired programmer head (wand) was observed in a patient who had left ventricular assist device (LVAD) (DuraHeart®, Terumo Corporation, Shibuya, Tokyo, JAPAN) when the source of power supply was switched from battery to hospital console. This intermittent telemetry failure was reproducible. Pacing and sensing behavior remained normal as evident in the other ECG recording. To communicate to CRT-D, commercially available 3120 ZOOM programmer and the telemetry wand were normally used. When switched back to battery supply, telemetry failure disappeared.

covered the skin above the CRT-D generator and that above the LVAD pump, this telemetry failure disappeared. In addition, when we switched the origin of power supply to battery, this telemetry loss also completely disappeared. After discharge, this patient had no problems with CRT-D and LVAD function including wand-based telemetry, because the patient always used a battery-derived power supply. We confirmed this interference in vitro using the same models of LVAD, CRT-D, and programmer (Fig. 2A). In this case, distance between the CRT-D generator and the LVAD pump was 13 cm (Fig. 1A). We tested whether the CRT-D generator located at 13 cm away from the LVAD pump was affected (Fig. 2B). As expected, the hospital console-powered LVAD repeatedly interfered with the communication of the CRT-D and its programmer (Fig. 2C). This phenomenon is only observed when the CRT-D generator is located in a horizontal direction to the LVAD, but not in a vertical direction (Fig. 2C). Battery-powered LVAD did not provoke this interference as clinically observed (Fig. 2C). In addition, we measured the power of electromagnetic waves generated from currently used LVASs including DuraHeart using originally-developed equipment. Dominant frequency from DuraHeart was 100 kHz and those of HeartMateII and EvaHeart are 7.2 KHz and 30 Hz as manufacture's report, respectively. Whereas electromagnetic wave from HeartMate II was detected to 24 cm from LVAS pump, those of DuraHeart and EvaHeart were not detected over 8 cm (Fig. 2D). These results suggested that electromagnetic wave from DuraHeart could not reach the location of CRT-D generator.

There are many reports of electromagnetic interference between an ICD and a LVAD [2–6]. The most frequent combination which provoked electromagnetic interference between a LVAD and an ICD was HeartMate II (Thoratec Corporation, CA, USA) and Atlas (St. Jude Medical, MN, USA) [2–6]. The mechanism by which LVAD interference communicates between an ICD and its programmer telemetry could be explained by the fact that the pulse-width modulator (PWM) of transmitting power to rotate the motor generates a similar frequency to hand shake and the operating frequency of the programmer. The notion that the shielding of the CRT-D generator and the LVAD could block this interference, suggests that the mechanism of this interference might be electromagnetic interference. The communication frequency of COGNIS and its programmer by wand is 102.4 kHz, and the PWM control frequency of DuraHeart is 25 kHz. Theoretically, coidentity of frequency from devices is not relevant in explaining this interference. We measured the generated wave from LVADs (HeartMateII, EvaHeart and DuraHeart) using originally-developed equipment. DuraHeart generated



C

	power origin	A	B	C	D	E	F
telemetry failure	bettery-powered	-	-	-	-	-	-
	hospital console -powered	+	+	+	+	-	-

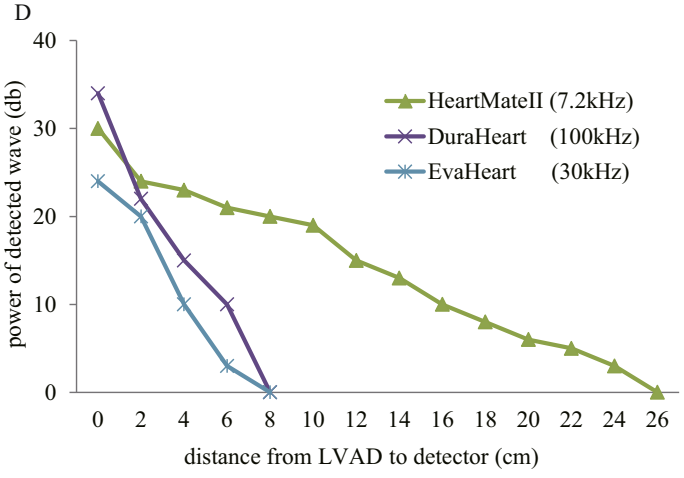


Fig. 2. Confirmation of telemetry failure between CRT-D and hospital console-powered LVAD by ex vivo experiments. A. Configuration of ex vivo experiments. The same model of LVAD, CRT-D generator and its programmer in this case was placed at the same distance as in vivo. B. Indicated alphabets were CRT-D generator placed-positions for evaluation whether LVAD affects telemetry of CRT-D. C. Summary of emergence of telemetry failure between CRT-D and its programmer. During investigation, whether telemetry failure was provoked or not, LVAD was continuously run, powered by battery-power or hospital console-power. "+" indicates provocation of telemetry failure and "−" indicates no provocation of telemetry failure. D. Relationship between detected power of electromagnetic wave from LVADs (HeartMateII (7.2 kHz), EvaHeart (40 kHz) and DuraHeart (100 kHz) in the hospital console-powered situation) and distance from LVAD to originally-developed electromagnetic wave detector.

25, 50, 75, 100, 125, 150, and 175 kHz waves with LVAD running (1800 rpm). However, even the most dominant wave of 100 kHz did not reach 8 cm from the LVAD (Fig. 2D) and these waves were not changed by the switching of power source. These results suggested that the mechanism in this case might not be quite the same and simple mechanism observed in HeartMate II. Other possibilities including the emergence of null point [8] around wand or CRT-D generators by using hospital console-powered LVAD should be the subject of future investigation. The present case suggests no similar mechanism of close frequency between LVAD and telemetry of CRT-D. Accordingly, DuraHeart powered by hospital console should be used with caution in Boston CRT-D implanted patients. Even if telemetry failure has occurred, CRT-D function is not diminished and switching to battery-powered running of LVAD or shielding both devices by steel completely resolves this telemetry failure.

Conflicts of interest

There is no conflict of interest to disclose.

Acknowledgments

We gratefully acknowledge the excellent assistance of E. Hasumi, K. Yamagata and T. Kojima with manuscript preparation.

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