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DEVICE THERAPY

EMERGING TECHNIQUES

Real-Time Remote Interrogation and Guided Reprogramming of Cardiac Implantable Electronic Devices

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ABSTRACT. *Background: Cardiac implantable electronic device (CIED) evaluation in a hospital setting is inefficient and leads to delays in patient management. We present a new model, the remote K-viewer, which provides real-time visualization of the CIED programmer screen by a remote iPad. This allows immediate CIED testing, diagnosis, and reprogramming by a remote cardiac electrophysiologist (EP).* ***Methods:*** *Forty-one consecutive patients who presented to Boca Raton Regional Hospital and required urgent CIED evaluation were evaluated. Each CIED was interrogated utilizing both the remote-K-viewer system and the conventional mode using a company representative.* ***Results:*** *Mean response time of remote real-time evaluation using the remote K-viewer was 2.3 min (range 0–8 min). Mean response time for conventional interrogation was 60.9 min (range 10–120 min) ($p<0.0001$).* ***Conclusion:*** *Real-time remote evaluation of CIEDs using the remote-K-viewer system is efficient and allows for immediate EP directed patient evaluation and management.*

KEYWORDS. *cardiac implantable electronic devices, programming, remote monitoring.*

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Introduction

The current model of CIED evaluation in emergency room (ER) and operating room (OR) settings is inefficient and delays patient care. In most hospitals, a company representative is usually contacted to evaluate the patient's CIED. After interrogating the CIED, the company representative contacts the cardiac electrophysiologist (EP) to discuss the results and guide further CIED programming. The cardiac EP then contacts the treating nurse and physician to review the results and discuss plan of care. This takes time and relies on company representatives to interpret CIED data. We present a new model that provides immediate real-time remote EP evaluation and management of CIEDs.

The remote-K-viewer[1–3] is a system that combines hardware and software to allow a real-time visualization of the CIED programmer screen from a remote site using an iPad (**Figure 1**). This model involves a bedside, non-specialized operator such as an ER nurse or physician and a remote cardiac EP. The bedside operator interacts with the patient and CIED programmer, which is connected to a laptop using its video graphics array (VGA) output. The laptop displays a mirror image of the programmer screen which can be visualized remotely on an iPad (**Figure 2**). Both operators also maintain a telephone communication. The remote operator controls the pointer of the bedside laptop using the iPad via an encrypted service network. The bedside operator is guided in real time how to operate the programmer. At the end of the device check,

Dr. Kloosterman discloses he is an independent consultant for Medtronic, Boston Scientific and St. Jude Medical.

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Figure 1: "K-cart" showing set-up of programmer/laptop, second shelf hosts printer and UPS unit (A). Close up of programmer and laptop mirror screens (B). Remote iPad showing real time programmer's screen by connecting to the laptop via WiFi/3G (C).

the remote operator can generate a report of the findings and interventions that is printed locally. This process allows the cardiac EP to independently perform the device check without delay or need of a company representative.

Materials and methods

Patients presenting to Boca Raton Regional Hospital ER or OR with Medtronic (St. Paul, MN) pacemakers or defibrillators requiring evaluation were included. Patients who had non-Medtronic devices and patients who had other cardiac EPs involved in patient care were excluded. The study protocol was approved by the hospital IRB.

A dedicated K-cart was constructed for this study (**Figure 1**). A Medtronic programmer (Model 2090) was connected via the VGA output port to a tablet touch screen laptop (Hewlett-Packard TouchSmart tm2-2050us) using a VGA2USB device (Epiphan, Ottawa, ON, Canada). Both the laptop and programmer were also connected to a printer via a switcher for alternating use. All devices were connected to a power unit (APC Back-UPS ES 550) which allowed the mobility of working with the cart without the need of resetting devices or a cable connection. The laptop was wirelessly online using a Wi-Fi local network and accessed remotely using a commercial service with an encrypted protocol. The laptop's touch screen was specifically ergonomically positioned to allow simultaneous visualization and access to the touch sensitive programmer screen. A specific software program was created for this protocol which was run with a one finger touch of the bedside operator (**Figure 3**). The remote operator for the purpose of this study used an iPad allowing a remote interface using either a Wi-Fi or 3G connection.

The ER and OR nurses and physicians received an instructional in-service about the study protocol and the use of the K-cart. For patients who met inclusion criteria, the K-cart was mobilized to the bedside. The company representative was contacted in the standard way and the cardiac EP was called at the same time. The initiating phone call from the hospital to the EP was continued throughout the device check period. The bedside operator followed the EP's verbal and pointer commands (**Figure 4**). Using a "drag and tap" technique, the bedside operator would drag the programmer pointer to the position indicated by the laptop pointer. Once adequate position of the pointer was confirmed by the remote operator, the bedside

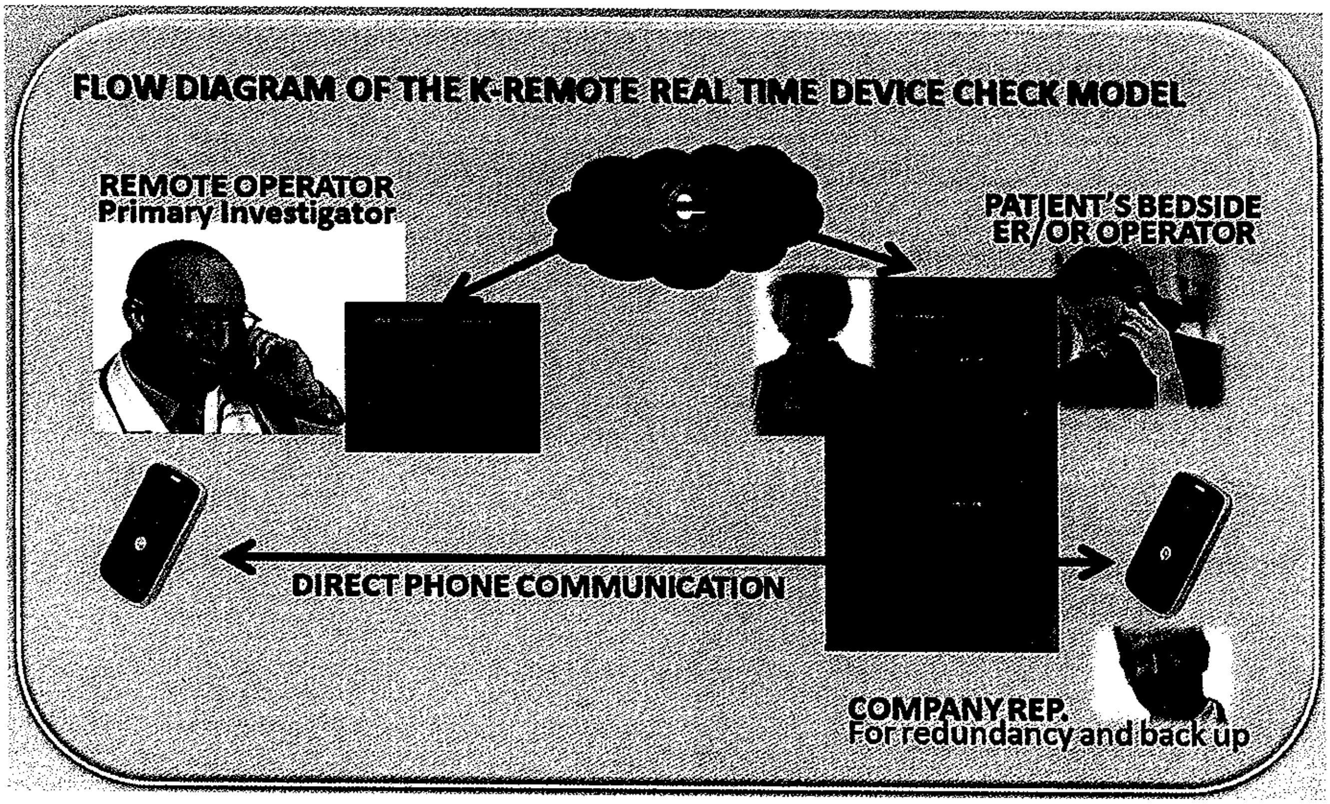

Figure 2: "K-cart" flow diagram: On the right hand side the patient's device is interrogated by a nurse (bed side operator) using the K-cart. On the left hand side the doctor (remote operator) is able to visualize real time the programmer screen on an iPad with mobile connectivity. By controlling the laptop pointer the remote operator is able to directly guide and supervise the moves of the remote operator on the programmer. There is also a direct communication phone line between the operators. In this study protocol the company representative was present for redundancy and back up.

operator would then tap on the programmer screen function. The process would then continue in a tagging along fashion where the EP would move the laptop pointer and the bedside operator would replicate it on the programmer (**Figure 2**). During the process the EP was able to see in real-time all the diagnostic data, do a function test and guide reprogramming as needed. At the end, a report was produced remotely by the EP and printed locally to be added to the patient's chart. The study protocol was based on a redundancy concept so that every patient was checked using the K-cart and again using the conventional method with a device representative.

Results

Forty-one consecutive patients/devices were successfully evaluated: 29 were ICDs and 12 were pacemakers (DDD ICD: 17; VVI ICD: 5; DDD BIV ICD: 5, VVI BIV ICD: 2; DDD PM; 11 DDD BIV PM: 1). Thirty-three devices were evaluated in the ER and eight in the OR. One patient had two devices, a DDD-BIV-PM and VVI-ICD which were interrogated one after the other. Twenty-seven patients were enrolled at the time of the company representative arrival (the ER/OR physician was unaware of the study and did not contact the EP until the device company representatives arrived). Fourteen patients were enrolled at time of initial phone call to the company representative.

Twenty-eight devices were interrogated, tested, and required no reprogramming; 13 devices underwent guided reprogramming. Three patients had 6,949 Fidelis lead malfunction with active problems requiring urgent reprogramming. For the 41 patients, the average remote session with the remote cardiac EP and K-cart was 14.5 min (range 5–40 min). The average programmer interaction time was 9.8 min (range 3–28 min). There were no hardware, software, or communication problems. For the 14 patients enrolled at time of the initial phone call, the average time to communication with K-cart was 2.3 min (range 0–8 min). The average time of device company arrival to patient bedside was 60.9 min (range 10–120 min; $p<0.0001$) (**Figure 5**).

Limitations

Late enrollment occurring after the device company representative arrival was due to unawareness by medical staff of the study protocol, the patient's device company, and/or the EP involvement in the patient's care. Only one company was used for this study. However, the system can work with any company, as presented in a previous experience with a K-cart connected simultaneously to three different programmers.[4]

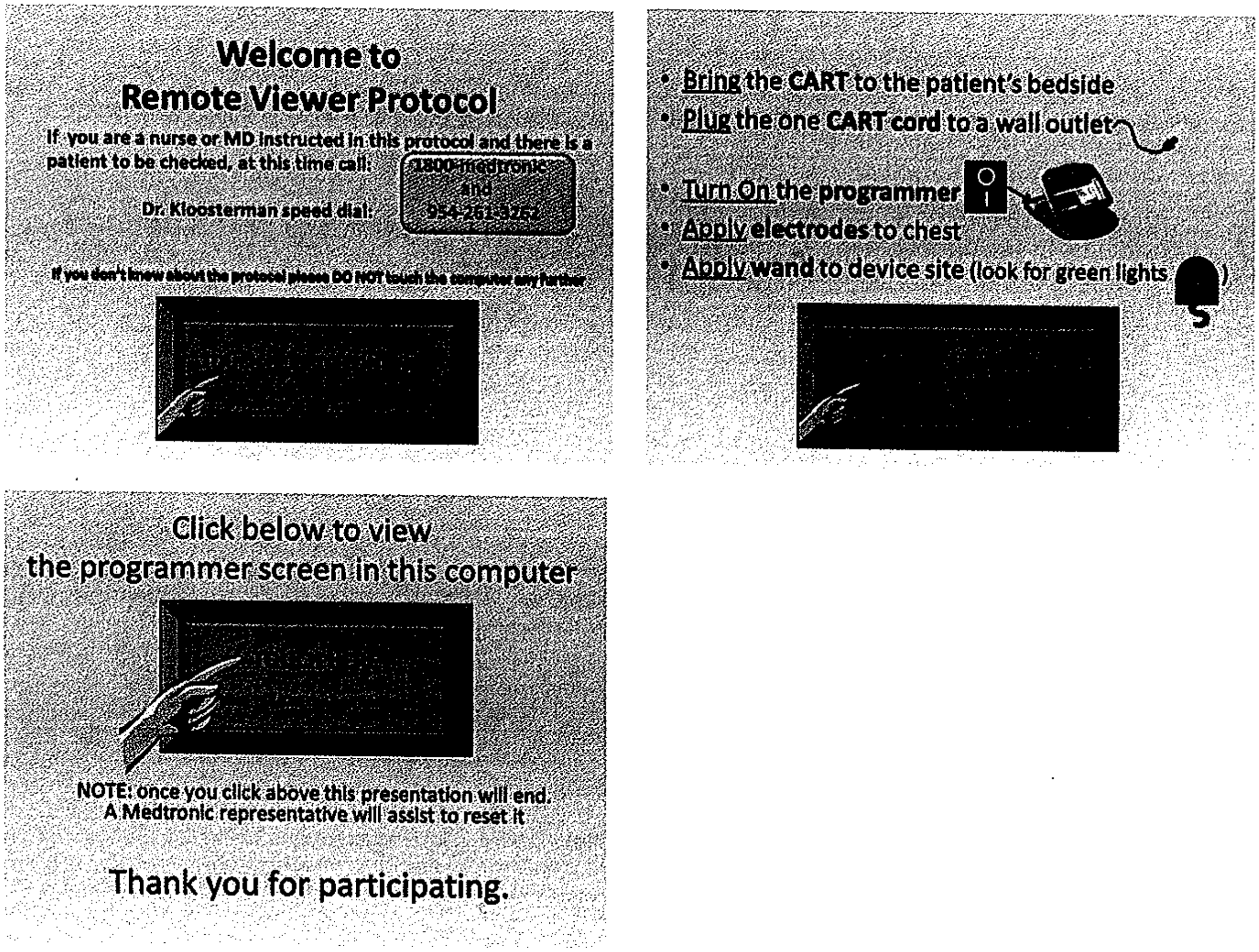

Figure 3: Dedicated sequence of laptop touch screens encountered by the bedside operator to guide the use of the "K-cart". Intuitive, user friendly, "kiosk" feeling interface.

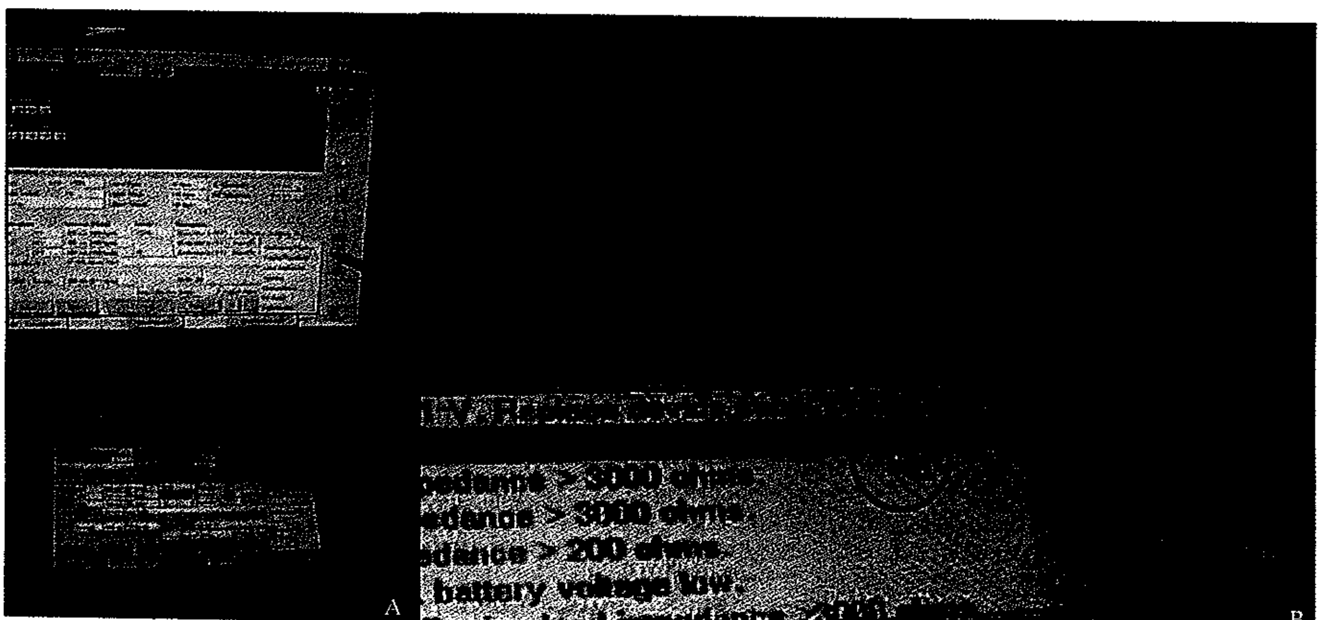

Figure 4: Bedside operator following the remotely moving pointer on the laptop operates the programmer (B). Close up of the laptop screen depicting two arrows. Arrow 1 is the one from the programmer (A). Arrow 2 is the one of the laptop which is controlled remotely by the remote operator, indicating the next stop where the bedside operator has to move the programmer arrow to.

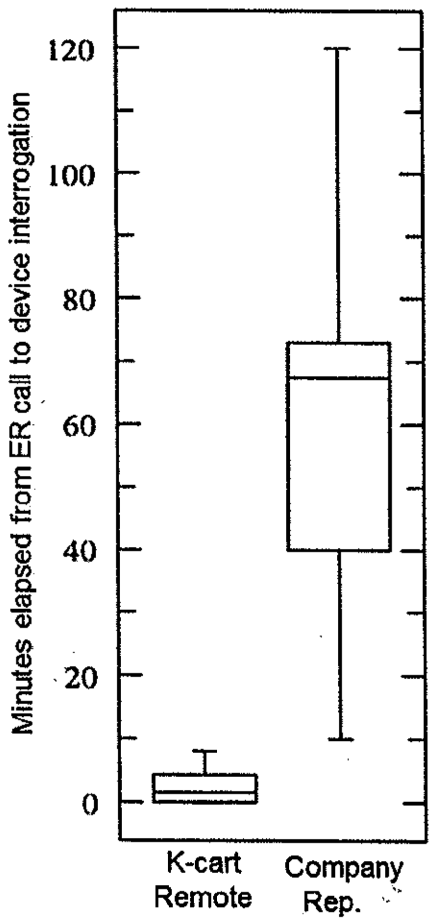

Figure 5: This illustrates the response time comparison from call to device interrogation, between the K-cart real-time remote model and the company representative physical presence at bedside. Unpaired t-test: t, −7.89; SD, 19.4; n=14. K-cart remote response: mean 2.29 min. Company Representative response: mean 60.9 min. p<.0001.

Although the iPad was chosen for this study for practical purposes, the system was also tested and can work with a remote laptop; PC or iPhone. It was not tested but its use with other mobile devices like tablets or smart phones is feasible.

Discussion

We present a novel approach to provide real-time physician guided CIED testing and management. By allowing a cardiac EP to remotely evaluate CIEDs, the remote K-viewer system obviates the need to rely on a company representative. In addition, it allows for immediate patient treatment which is critical in patients with ventricular arrhythmias and lead problems. The system was conceived and developed with elements and technology readily available today. The K-cart concept should serve as a platform to explore the challenges of real-time cardiac device interaction and contribute to develop a new generation of programmers and service model.

Conclusion

The remote K-viewer is efficient, safe, and reliable and can be used to improve patient care. This model may help with the future development of a new generation of programmers and service model incorporating the concept of real-time management of patients with cardiac implantable electronic devices.

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