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Review

Remote monitoring of cardiac implantable electronic devices

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ABSTRACT

Patients with cardiac implantable electronic devices (CIEDs) have been followed with periodic clinic visits. The number of patients with CIEDs has been increasing and CIEDs have become more complex. The workload of both medical staff and patients for CIED follow-up has also been increasing. Remote monitoring (RM) technology has undergone many developments, and RM has been used since 2008 in Japan. The benefits of RM are evident, but there are also problems with the technology. Different systems and various skills are required for RM management compared to conventional follow-up methods.

Contents

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1. Introduction

Patients with cardiac implantable electronic devices (CIEDs) have been followed with periodic clinic visits and have received direct interrogation by a programmer which checks the battery, lead impedance, sensing amplitude, pacing threshold, and arrhythmic events. The number of patients with CIEDs has been increasing and CIEDs have become more complex. Follow-up frequency varies depending on the facility, physician preference, and available resources. Checks at clinics every 3–6 months have been recommended with increased frequency in response to product advisories and recalls [1]. The workload of both medical staff and patients for CIED follow-up has also been increasing. Technology-assisted medicine has provided many benefits. Remote monitoring (RM) technology has undergone many developments from the original transtelephonic monitoring of pacemakers for battery levels to currently available CIEDs with wireless telemetry capabilities. Various developments have occurred over the past decade, from fax reports to a social networking service system, from wired interrogation to wireless interrogation, and from one-direction transmission to bidirectional transmission. In Japan, RM has been used since 2008. Currently, 5 CIED companies in Japan use RM, and 27,700 patients in total have been followed as of December 2013. Because RM is a new technology, it has both benefits and problems.

2. Technological aspects of remote monitoring

RM data are transmitted from CIEDs to a transmitter station (Fig. 1) either by wired or wireless communication. Two types of transmitters exist: stationary and mobile transmitters. Only stationary transmitters are used in Japan. In addition to scheduled data transmission, alert-triggered data can be transmitted depending on the CIED [2]. Such a transmitter is linked by a telephone line to a central secure server website to store the transmitted data for further analysis. Companies use various telephone line types, including analog landlines, digital landlines, and a global system for mobile communications (GSM) network. It is sometimes difficult to set up a landline transmitter because a cable must connect the transmitter and the landline connector. Since RM data are likely to be transmitted at night, the transmitter should be set up in the bedroom rather than the living room. However, in traditional Japanese homes, there are no landline connectors in bedrooms. A GSM transmitter would be appropriate for such homes. After successful transmission of RM data, medical staff can check detailed RM data on a website from anywhere. The volume and nature of transmitted data are almost the same as those of the data obtained from direct interrogation. Medical staff can receive alert notifications by fax, SMS, voice message, or email. Occasionally, we can receive precise RM data immediately following an event such as appropriate implantable cardioverter defibrillator (ICD) therapy, inappropriate ICD therapy, and CIED abnormality. Medical staff can also manually or automatically activate message calls to patients to remind them of abnormalities. However, since elderly patients may be unaware of an abnormal signal, a telephone call may be necessary to notify them of abnormalities. The Table 1 shows RM characteristics by company.

3. Remote monitoring advantages

3.1. Reduced workload and costs associated with CIED follow-up for patients and medical services

RM can reduce the workload associated with CIED follow-up. Before RM became available, patients with CIEDs had to visit hospitals for periodic CIED checks. It is burdensome for patients living in rural areas to visit hospitals for CIED interrogation. Visiting hospitals is also burdensome for patients' families, because about half of the patients must be escorted by family members, primarily the patients' children, who must take time off work to escort the patients. It is also becoming difficult to make appointments for CIED checks because of the increasing number of patients with CIEDs caused by the aging society and expanded indications for CIED implantation. Patients must spend several hours and sometimes even half a day in the hospital to have their CIEDs checked, but the rate of intervention is very low [3].

However, the burden of visiting a hospital is greatly reduced by using RM. RM use reduces the burden of overloaded clinics and saves valuable time and resources. Varma et al. [4] reported that RM reduced total in-hospital CIED evaluations by 45% without affecting morbidity. In their study, 1339 patients with high-energy CIEDs were randomized 2:1 to home monitoring (HM) or conventional follow-up. Thirty-one patients in the HM group (3.4%) and 21 patients in the conventional group (4.9%) died ($P=0.226$). The overall adverse event rate was 10.4% for HM versus 10.4% for conventional care over 12 months (non-inferiority $P<0.005$, 1-sided; $P<0.010$, 2-sided) (Fig. 2). Crossley et al. [5] also reported that wireless RM with automatic clinician alerts was associated with a significant reduction in mean length of cardiovascular hospital stay. The CONNECT (Clinical Evaluation of Remote Notification to Reduce Time to Clinical Decision) study was a multicenter, prospective, randomized study that included 1997 patients with high-energy CIEDs who were followed for 15 months. The study revealed a decrease in mean length of stay per cardiovascular hospitalization visit from 4.0 days in the in-office arm to 3.3 days in the remote arm ($P=0.002$). Hindricks et al. [6] reported that in prophylactic ICD recipients with automatic daily RM, extension of the 3-month in-office follow-up interval to 12 months appeared to safely reduce the ICD follow-up burden during a 27-month period after implantation. The 12-month interval resulted in a major reduction in total number of in-office ICD follow-ups (1.60 vs. 3.85 per patient-year; $P=0.001$). No significant difference was found between the 2 groups in mortality, hospitalization rate, or hospitalization length during the 2-year observation period. Landolina et al. [7] reported that RM reduces the number of emergency department/urgent office visits and total healthcare use in patients with high-energy CIEDs. Thus, introducing RM in patients with high-energy CIEDs can safely reduce the office visit burden.