AHA Science Advisory

Latency of ECG Displays of Hospital Telemetry Systems

A Science Advisory From the American Heart Association

Endorsed by the American College of Cardiology Foundation and Heart Rhythm Society

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Recent observations indicate that some hospital telemetry systems used for monitoring of patient heart rhythm have clinically significant latency, or delay between the real-time status of the patient and the ECG information displayed on the patient monitor. If these systems are used for clinical care that requires instantaneous monitoring, then patient safety may be compromised. The purpose of this advisory is to inform healthcare providers about this potential problem, clarify the intended use of the systems, detail measures to reduce risk, and recommend steps to manufacturers and stakeholders to minimize this problem in current and future telemetry systems.

Background

Wireless telemetry electrocardiographic monitoring is a cornerstone of hospital management for patients with cardiovascular conditions or at risk for cardiovascular conditions. Since the first transmission of an ECG by telephone wire by Willem Einthoven was reported in 1906,[1,2] advances in signal processing and communications have led to rapid innovation in wireless communication for telemetry systems in acute care settings.[3] The first wireless systems introduced in the 1970s were fairly simple in design. They transmitted analog telemetry signals using 1 dedicated frequency channel for each patient.[4] In the 1980s, networked telemetry systems led to the creation of centralized telemetry viewing stations in intensive and acute care units. Starting in the 1990s, digital telemetry systems allowed for computerized signal recording, storage, and retrieval.[5,6] As computing power increased, the networking capability of these systems increased, allowing for monitoring of electrocardiographic, hemodynamic, and other clinical data from multiple patients on a single networked system. By 2000, wireless communication in the hospital extended beyond telemetry systems, and the US Federal Communications Commission established a protected range of frequencies for wireless medical devices to minimize electromagnetic interference from other in-band radiofrequency sources.[7,8] Today, networked wireless telemetry systems are widely used in United States acute care hospitals, and international use continues to rise.[9]

Telemetry Delay

Recent observations by healthcare providers indicate that some hospital telemetry systems used for monitoring of patients' heart rhythm, hemodynamic parameters, and oxygen saturation may exhibit clinically significant latency, or delay between the real-time status of the patient and the information displayed on the patient monitor.[10–12] The problem has been reported with wireless networked systems. Unlike older hard-wired systems, wireless networked systems do not transmit directly from the patient's ECG leads to the viewing screen in the patient's room. These digital systems wirelessly transmit data from the patient telemetry transmitter to a central monitor station or network server. The data are then processed on the server and sent back to the

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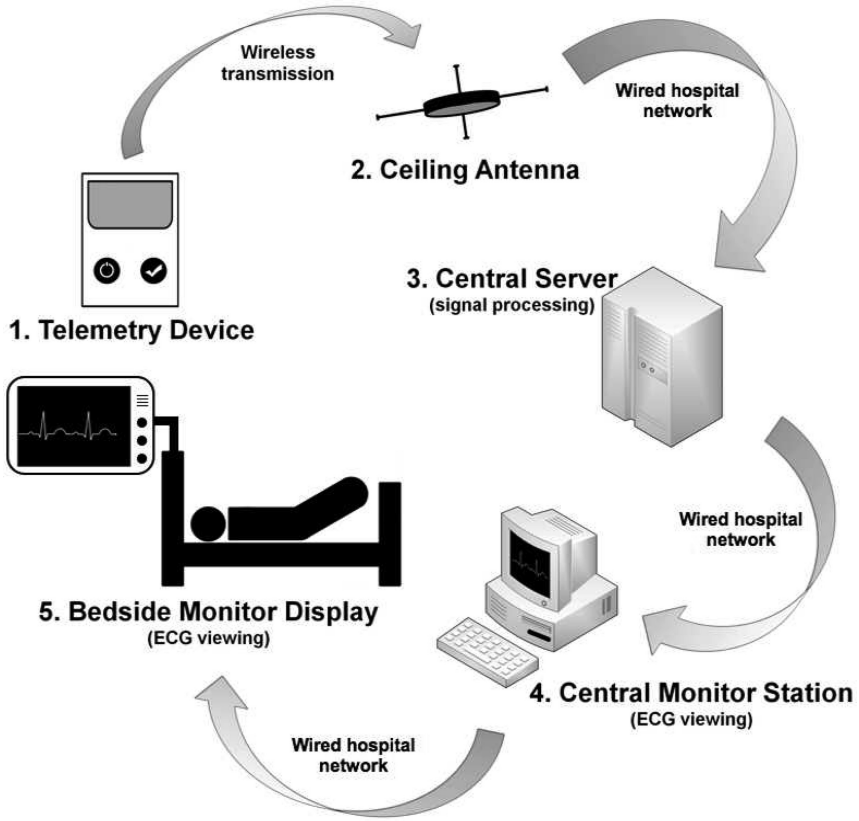

Figure 1. Illustration of configuration of a typical networked wireless telemetry system. This schematic is for illustrative purposes and does not represent the system of any single manufacturer. The patient's ECG signal is acquired with electrodes and lead wires connected to the telemetry device (1) and transmitted to ceiling antennae (2) via radio frequencies federally allocated to wireless medical telemetry services. The ECG is then transmitted directly over computer cables that link the ceiling antennae, central server (3), and central monitor station (4). The bedside monitor display typically receives the data from the central server or monitor station via a wired hospital network. There may be significant delays of up to several seconds from the time that a heart rhythm is experienced by the patient (step 1) to the time that the rhythm is displayed on the bedside monitor (step 5).

monitor or display at the patient's bedside via a wired network (Figure 1).

Delays of up to 5 seconds of continuous ECG data have been reported.[11] For pulse oximetry waveforms, delays of 8 seconds and loss of synchronization to the displayed ECG waveform have been reported.[12] Although this may appear to be clinically insignificant, there are circumstances when several seconds from the time the rhythm is experienced by the patient to the time the rhythm is displayed on the bedside monitor may have important clinical consequences (Table 1). Healthcare providers may not be aware of these delays. Specific situations are described below.

Table 1. Clinical Situations in Which Instantaneous Monitoring is Recommended

Emergency situations
Resuscitation
Hospital "codes"
Defibrillation
Assessment of pacemaker function
Interrogation or reprogramming of implantable pacemakers, defibrillators, and cardiac resynchronization devices
Assessment or reprogramming of temporary pacing devices
Termination or cardioversion of arrhythmias
Electrical cardioversion
Administration of intravenous adenosine or other short-acting antiarrhythmic drugs
Bedside procedures
Insertion of central venous or pulmonary artery catheters from jugular or subclavian approach
Insertion of transvenous pacemakers
Carotid sinus massage

Systems Affected

Any telemetry system that relies on wireless transmission and a data network is potentially vulnerable to these delays, because transmission errors are inherent to wireless or network communication. The amount of delay observed in a patient or across the system may vary depending on wireless interference, network load, and server processing time or an interaction of these factors. Even if a telemetry device is within its design specification, external factors such as network traffic could result in latency. The performance of the same system could be different in different locations or wards. Delays can therefore be unpredictable in timing, frequency, and duration. Moreover, there has been no systematic evaluation of approved or commercially available wireless monitoring systems with respect to telemetry delays. Newer wireless modalities and network architectures for personal and wide-area network ECG transmission may also exhibit these delays.[13]

Intended Use and Clinical Consequences

Wireless hospital telemetry systems are used for continuous ward monitoring of cardiac arrhythmias in appropriate patients. They are designed to monitor physiological parameters over a distance and transmit information and alerts to a

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Table 2. Recommendations for Use of Wireless Networked Telemetry Systems

Healthcare providers
Use hard-wired bedside monitor when instantaneous rhythm assessment is preferable or necessary (Table 1)
For cardioversion or defibrillation, use monitor of external defibrillator
For implantable pacemaker and defibrillator interrogation, connect ECG leads to device programmer
For assessment of temporary pacemakers, use hard-wired monitor, particularly in patients without stable underlying rhythms
Hospitals and care facilities
Contact the system manufacturer to determine the extent, if any, and severity of delays and to obtain product-specific recommendations
Educate clinical personnel about potential for delays
Consider protocol or guidelines on appropriate use of hard-wired monitors
Regularly evaluate wireless interference and network congestion, which can cause delays
Industry and manufacturers
Clearly communicate intended use, disclose potential for latency, and where possible, work toward improvement in design to minimize delays

central monitoring station in near real-time ("near-time").[8] These systems were neither designed nor intended for instantaneous ("real-time") assessment of rhythm disturbances. When they are used for instantaneous monitoring, the delay that can occur between the patient's real-time status and the ECG or rhythm displayed on monitor could result in an incorrect patient assessment, which could lead to an inappropriate treatment. For example, in 1 case of electric cardioversion reported to the Food and Drug Administration, a physician prepared to apply an unnecessary second cardioversion shock to a patient after the first shock appeared to fail to cardiovert atrial flutter.[10] After delivering the first synchronized shock, the physician observed continued atrial flutter on the wireless telemetry display. The physician therefore concluded that the shock failed to convert the rhythm and prepared to deliver a second shock. Approximately 5 seconds after the first shock, the bedside telemetry monitor displayed the shock artifact and conversion to sinus rhythm from the original shock. Although no harm was caused, the situation could have been avoided if a hard-wired ECG monitor on the external defibrillator had been used by the clinician to confirm the rhythm, rather than the bedside telemetry monitor.

Other situations in which wireless telemetry systems may not be suitable and may result in harm to the patient include pacemaker or defibrillator testing, insertion of temporary pacing electrodes, cardiac resuscitation, and acute treatment of hemodynamically significant or unstable arrhythmias (Table 1). In these situations, failure to instantaneously ascertain the rhythm could result in inappropriate therapies or adverse patient outcomes such as syncope. For example, a patient with no underlying rhythm and a functioning pacemaker could experience prolonged asystole or syncope during pacemaker threshold testing if there is a significant delay in the display and recognition of loss of capture.

Figure 2. Example warning label affixed to the telemetry bedside monitor.

Recommendations

Recommendations for healthcare providers, for hospitals and care facilities, and for industry are summarized in Table 2 and detailed below.

Recommendations for Healthcare Providers

When instantaneous assessment of the rhythm is preferable or necessary, telemetry systems with the potential for clinically significant latency or data dropout should not be used. Patients should be hard-wired to a bedside monitor in plain view of care providers. In addition, for cardioversion or defibrillation, it is advisable to connect separate monitoring leads directly to the monitor of the external defibrillator to ensure instantaneous assessment. When doing so, disconnection from the wireless telemetry system is not required as long as the hard-wired monitor is used for clinical assessment and care. For pacemaker or defibrillator testing or reprogramming, ECG leads should be connected directly to a monitor that displays the rhythm without delay, such as a pacemaker/defibrillator programmer. These same considerations apply to insertion of temporary pacing electrodes and central venous catheters, because arrhythmias can be provoked by cardiac instrumentation.

Recommendations for Hospitals and Care Facilities

Medical facilities with wireless telemetry systems should contact the manufacturers of their telemetry systems to determine the extent, if any, and severity of delays and to obtain product-specific recommendations. Facilities should educate clinical personnel with patient care responsibility (nurses, physicians, allied health professionals, trainees) about these delays. They should be instructed to avoid reliance on these systems for instantaneous rhythm assessment. Protocols or guidelines for appropriate use of hard-wired real-time monitoring may improve adherence to these recommendations. A warning label affixed to the telemetry monitor that describes the problem and outlines recommendations for instantaneous monitoring may be an effective tool to alert and continue to remind care providers (Figure 2). Finally, wireless interference, network congestion, and duration of telemetry delays should be evaluated carefully at the time of installation and at regular intervals. Measures to reduce interference and congestion may result in substantial improvement in telemetry delays.

Recommendations for Industry

Although telemetry system manufacturers recognize the problems of latency and data dropout, these issues may not be clearly understood by purchasers or healthcare providers. In the above reported clinical example, the manufacturer responded by referring the reporting clinician to a page in the

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system's technical instruction manual (Richard L. Page, MD, personal email communication, 2011). We recommend that manufacturers communicate transparently and educate healthcare personnel about the delays that may be observed in their monitoring systems. Manufacturers should make it clear in all promotional materials and product specifications that use of these systems may result in latency. Although some manufacturers do appropriately differentiate real-time or instantaneous telemetry from near-time or near real-time use, the clinical implications of these differences should also be articulated during training and in-servicing. We also recommend that the regulatory standards of delay in display of the patient's cardiac rhythm and other hemodynamic and physiological parameters be reconsidered by industry and regulatory bodies, with guidance from clinicians, in an effort to reduce these delays to as short a time as is technically feasible. Specifically, regulatory standards should not only address individual component delays but also articulate the total acceptable delay from the time the rhythm occurs to the time it is displayed, based on intended use. We also recommend that a consistent regulatory definition of *near-time* and *real-time* be used.

Conclusions

Wireless hospital telemetry systems may exhibit clinically significant delays in displaying continuous ECG or telemetry data on the bedside patient monitor. If these systems are used in situations in which instantaneous monitoring is preferable or necessary, then patient safety may be compromised. We recommend that care providers use hard-wired telemetry systems in these clinical situations. We also recommend that hospitals and care systems make an effort to inform care providers and consider implementation of guidelines or protocols for hard-wired or instantaneous monitoring. Manufacturers should clearly declare latency, clarify intended use of their technology and options for real-time monitoring, and collaborate with regulatory agencies and clinicians to reduce these delays in the interest of patient safety.

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*Modest.

†Significant.

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*Modest.

References

1. Einthoven W. Le telecardiogramme. *Arch Int Physiol*. 1906;4:132–164.
2. Hjelm NM, Julius HW. Centenary of tele-electrocardiography and telephonocardiography. *J Telemed Telecare*. 2005;11:336–338.
3. Drew BJ, Califf RM, Funk M, Kaufman ES, Krucoff MW, Laks MM, Macfarlane PW, Sommargren C, Swiryn S, Van Hare GF. Practice standards for electrocardiographic monitoring in hospital settings: an American Heart Association scientific statement from the Councils on Cardiovascular Nursing, Clinical Cardiology, and Cardiovascular Disease in the Young. [published correction appears in *Circulation*. 2005; 111:378]. *Circulation*. 2004;110:2721–2746.
4. Baker SD, Hoglund DH. Medical-grade, mission-critical wireless networks. *IEEE Eng Med Biol Mag*. 2008;27:86–95.
5. Hannibal GB. It started with Einthoven: the history of the ECG and cardiac monitoring. *AACN Advanced Critical Care*. 2011;22:93–96.
6. Kennedy HL. The history, science, and innovation of Holter technology. *Ann Noninvasive Electrocardiol*. 2006;11:85–94.
7. Amendment of Parts 2 and 95 of the Commission's Rules to Create a Wireless Medical Telemetry Service. 2000. ET docket 99-255; PR docket 92-235. http://www.fcc.gov/Bureaus/Engineering_Technology/Orders/2000/fcc00211.doc. Accessed September 28, 2011.
8. FCC Wireless Frequency Report. Radiation-emitting products. http://www.fda.gov/Radiation-EmittingProducts/RadiationSafety/ElectromagneticCompatibilityEMC/ucm116574.htm. Accessed April 1, 2011.
9. Hospital wireless patient monitoring devices: global opportunity assessment, competitive landscape and market forecasts to 2017. GlobalData Web page. 2011.http://www.globaldata.com/ReportStore/Report.aspx?ID=Hospital-Wireless-Patient-Monitoring-Devices-Global-Opportunity-Assessment-Competitive-Landscape-and-Market-Forecasts-to-2017&ReportType=Industry_Report&coreindustry=Industry_Report&Title=Medical_Devices. Accessed March 11, 2012.
10. MAUDE adverse event report #1208513: Spacelabs Healthcare: Remote Display Controller: None. http://www.accessdata.fda.gov/scripts/cdrh/cfdocs/cfMAUDE/detail.cfm?mdrfoi__id=1208513. Accessed April 1, 2011.
11. MAUDE Adverse Event Report #1252144: Philips Healthcare: Philips Cardiac Monitor: Telemetry Monitor. http://www.accessdata.fda.gov/scripts/cdrh/cfdocs/cfMAUDE/Detail.CFM?MDRFOI__ID=1252144. Accessed April 1, 2011.
12. Bracco D, Backman SB. Philips monitors: catch the wave! *Can J Anaesth*. 2012;59:325–326.
13. García CU, Sigler FG, Duran MD, Torre J de L, Aristizabal FC, Parras SP, Miralles RT, Sandoval F. On practical issues about interference in telecare applications based on different wireless technologies. *Telemedicine J E Health*. 2007;13:519–534.

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Correction

In the article by Turakhia et al, "Latency of ECG Displays of Hospital Telemetry Systems: A Science Advisory From the American Heart Association," which published ahead of print on August 27, 2012, and appeared in the September 25, 2012, issue of the journal (*Circulation*. 2012;126:1665–1669), a correction was needed:

On page 1665, the endorsement line read, "*Endorsed by the American College of Cardiology Foundation*." It has been changed to read, "*Endorsed by the American College of Cardiology Foundation and Heart Rhythm Society*."

This correction has been made to the current online version of the article, which is available at http://circ.ahajournals.org/content/126/13/1665.

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