

Use of Cellular Telephones in the Hospital Environment

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OBJECTIVE: To determine whether cellular telephones used in a normal way would cause interference with medical devices located in patient care areas of hospitals.

METHODS: Two cellular telephones from different cellular carriers were tested in various patient care areas between February 15, 2006, and June 29, 2006. To monitor the medical devices and equipment in the patient care areas during testing, we observed the device displays and alarms.

RESULTS: Interference of any type occurred in 0 of the 75 patient care rooms during the 300 tests performed. These 300 tests involved a total of 192 medical devices. The incidence of clinically important interference was 0% (95% confidence interval, 0%-4.8%).

CONCLUSIONS: Although cellular telephone use in general has been prohibited in hospitals because of concerns that these telephones would interfere with medical devices, this study revealed that when cellular telephones are used in a normal way no noticeable interference or interactions occurred with the medical devices.

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CDMA = code division multiple access; ECG = electrocardiograph; GSM = global system for mobile communication; RF = radiofrequency; RSSI = received signal strength indication

Multiple studies have investigated the potential of interference from cellular telephones in the clinical environment.¹⁻⁵ We have conducted 2 *in vitro* studies^{1,2} that were designed with the medical devices connected to simulators and with the cellular telephone placed in a position that would not normally occur during cellular telephone use. In these previous studies, interference was seen on one occasion when the cellular telephone was placed behind the ventilator within 2 inches of the serial or data port¹ and during another test when the cellular telephone was within 2 inches of the top of a ventilator and the telephone was ringing or operating in an analog mode.² The interference ceased in both situations when the cellular telephone was moved.

The purpose of the current *in vivo* study was to determine whether cellular telephones used in a normal way would interfere with the medical devices located in patient

care areas of hospitals. For this study, we defined normal use as the way in which physicians, nurses, and other medical staff would use a cellular telephone as they moved around a patient's room. The locations within the room varied from bedside near the medical devices to the doorway entrance.

METHODS

This Mayo Clinic Institutional Review Board–approved study, performed at the Mayo Clinic in Rochester, Minn, between February 15, 2006, and June 29, 2006, was completed in the following patient care areas: medical cardiology intensive care unit, medical cardiology unit, echocardiography laboratory, neuroepilepsy monitoring unit, transplant critical care unit, cardiovascular surgery step-down unit, cardiovascular surgery intensive care unit, neurosurgery intensive care unit, medical intensive care unit, vascular surgery postoperative care unit, and pulmonary ventilator rehabilitation unit. This study used 2 different telephones (Nokia models 3587i and 3120, Nokia Head Office, Espoo, Finland), each with a different cellular technology protocol. One telephone used a code division multiple access (CDMA) protocol; the other telephone was based on a global system for mobile communication (GSM) protocol. Testing with these 2 telephones allowed investigation of both the protocol (CDMA vs GSM) and the impact that radiofrequency (RF) power levels have on the medical devices. Varying RF levels are inherent to the cellular system design (ie, the cellular telephone will emit different power levels based on the strength of the incoming cellular signal from the cellular tower it is being served by). In our study, the telephones were served by different tower sites. The signal strength received by the CDMA telephone was measured using a special network menu option that provides field service measurement capability. The GSM telephone did not provide similar capability. Although we could not quantifiably measure the RF signal level received by both telephones, the principles of physics dictate that we would experience different signal levels for each telephone. This difference is due to the diverse paths from the cellular tower to that patient care area and the fact that each path will encounter different amounts of steel and concrete before arriving at the patient care area based on its location within the building.

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TABLE 1. Medical Devices Tested*

Device	Manufacturer	No. of patients connected to the device	
		Cellular telephone tests	Wireless handheld device tests
Xltek EEG system with Mobee Amp	Xltek, Oakville, Ontario	4	3
Philips VS1 vital signs monitor	Philips, Andover, Mass	3	
Respironics CPAP machine	Respironics, Inc, Murrysville, Pa	1	
Philips IntelliVue MP30 and MP70 patient monitors	Philips, Andover, Mass	59	7
Baxter COLLEAGUE Volumetric Infusion Pump	Baxter Healthcare Corp, Deerfield, Ill	81	9
Siemens ACUSON Sequoia ultrasound system	Siemens Medical, Mountain View, Calif	2	
GE Vivid 7 cardiovascular ultrasound system	GE Medical, Jupiter, Fla	2	
Medtronic 5388 external pacemaker	Medtronic, Minneapolis, Minn	1	
Puritan Bennett 7200 Ventilatory System	Nellcor Puritan Bennett Inc, Mansfield, Mass	1	
Ross Patrol enteral feeding pump	Hospira, Lake Forest, Ill	1	1
Bard CritiCore System urine output monitor	Bard Medical, Covington, Ga	6	2
Abbott LifeCare PCA Plus 3 Infusion Pump	Hospira, Lake Forest, Ill	5	1
Philips Model M4841A Telemetry Pack	Philips, Andover, Mass	4	
Philips Viridia 1176 Patient Monitor	Philips, Andover, Mass	6	
Baxter blanket heater and water pump	Baxter Healthcare Corp, Deerfield, Ill	3	
Abbott LifeCare PCA3 Infusion System	Hospira, Lake Forest, Ill	4	
Puritan Bennett 840 Ventilator System	Nellcor Puritan Bennett Inc, Mansfield, Mass	1	
Philips IntelliVue with intracranial pressure monitoring capability	Philips, Andover, Mass	2	
Aircast VenaFlow System	Aircast Inc, Summit, NJ	2	
Nellcor OxiMax N-595 pulse oximeter	Nellcor Puritan Bennett Inc, Mansfield, Mass	3	
GE DINAMAP PRO 100 noninvasive blood pressure monitor	GE Medical, Jupiter, Fla	1	
Datascope CS100 with IntelliSync counter pulsation balloon pump	Datascope, Fairfield, NJ		1
Total No. of medical devices		192	24

*CPAP = continuous positive airway pressure; EEG = electroencephalography; PCA = patient-controlled analgesia.

The medical devices tested (Table 1) were used in a normal manner and were configured normally for each patient care area. If the equipment was of a type that would normally be connected to or monitoring the patient, the test was performed with the equipment operating in the usual manner. For example, the patient monitoring system would typically display electrocardiograph (ECG) waves,

noninvasive blood pressure, and oxygen saturation in the medical cardiology intensive care unit and ECG waves only in the medical cardiology step-down unit.

The testing procedure followed an 8-step protocol (Table 2). This procedure emulated the various functions provided by a cellular telephone: initiating a telephone call, using or talking on the telephone, the ringing of the telephone in response to an incoming call, and answering a call on the telephone. In the latter portion of the study, permission was obtained from the Mayo Clinic Institutional Review Board to add testing of wireless handheld devices. Ten patients were tested, and although the total number of tests is too small to be statistically significant, the results are reported because of the growing use of this type of communications device.

RESULTS

The study involved 75 patient care rooms. A total of 11 patient care areas were tested. The patient care areas were chosen to represent as many clinical scenarios as possible that would contain significant types and/or quantities of electrical equipment and devices used for patient care or diagnostics. Of note, some patient care areas for which testing was planned but initial analysis of the area determined

TABLE 2. Cellular Telephone Testing Procedure

1. Obtain informed consent of patient
2. Measure and document the received signal strength indicator (RSSI) value at 3 different locations within the room; the RSSI signal will be measured with a similar cellular telephone as the test telephone used to originate and receive calls
3. Begin testing procedure within patient care area in the room; while the telephone is in use, roam around the room simulating movement by medical staff
4. Turn on the telephone and establish a connection to a wired telephone
5. Study personnel with the telephone will now move around the room while observing for interference on the various medical devices
6. Determine whether there is any adverse effect on the equipment being tested. If any adverse effects are observed, stop and document the effect. Then, while the effect is still present, back the telephone away from that area to determine the distance at which onset of the interference occurs. Record results of the test. Disconnect the call
7. Repeat steps 5 and 6 while a wired telephone is used to call the telephone and it is ringing
8. Repeat steps 2 to 7 with the second telephone

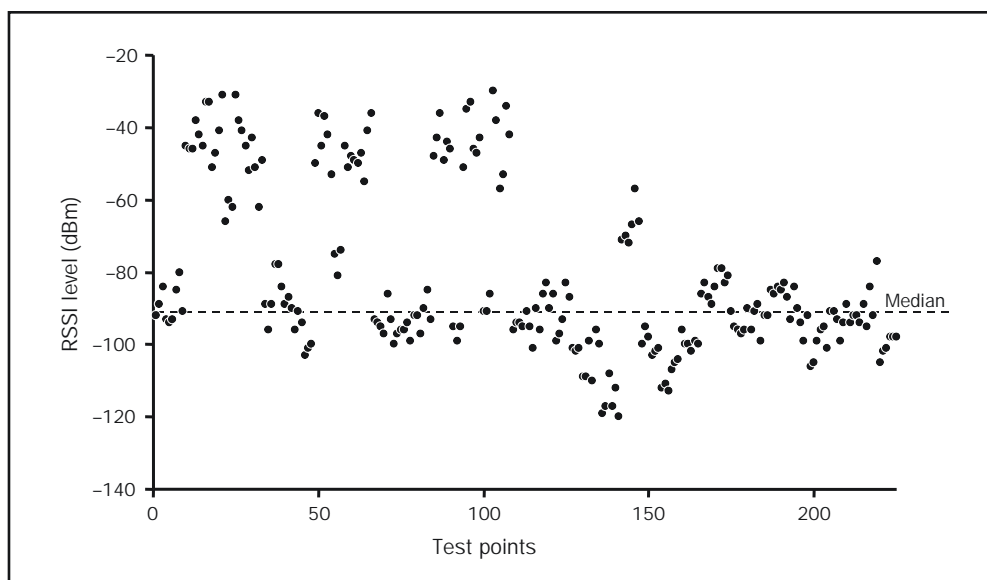


FIGURE 1. Received signal strength indication (RSSI) levels as measured by the code division multiple access telephone. The x-axis represents the 3 different locations within a patient room where the RSSI level was measured. The measurement reference used by the telecommunications industry for the signal level is the RSSI level. The RSSI is an indication of the power level being received by the antenna of the cellular telephone. Generally, the higher the RSSI level, the stronger the radiofrequency signal of the cellular telephone. The RSSI levels range from -30 to -120 dBm (dBm = power ratio in decibel of the measured power referenced to 1 milliwatt). Because the measurement value for the RSSI is in dBm, the smaller the negative number, the greater or higher the signal strength. Many of the patient areas tested had low to minimal RSSI levels, which suggests that the telephone was transmitting at or near the upper quartile of power output.

that no cellular telephone signal was available (because of lead shielding) were not included in the study, including the nuclear cardiology and electrocardiography laboratories.

The only other equipment- and device-laden areas of the hospital not tested were the operating suites and pediatric intensive care areas. We assumed that patients would not have cellular telephone access or need while in an operating room and that family would not be present. The 75 patients were connected to a total of 192 medical devices (Table 1), including blanket warmers, urine output monitors, electroencephalograph systems, continuous positive airway pressure systems, patient-controlled analgesic pumps, mechanical ventilators, feeding pumps, ECG monitors, arterial pressure monitors, oxygen saturation monitors, orthopedic sequential-compression antiembolic devices, ultrasound imaging machines, intravenous pumps, and external pacemakers.

In total, 300 tests were performed (75 for each of the 2 telephones with a call connected and 75 for each of the 2 telephones without a call connected, the ringing test). Interference occurred in 0 of the 300 tests completed. Therefore, the incidence of clinically important interference was 0% (95% confidence interval, 0%-4.8%). No interaction with any of the medical devices present in the patient rooms was found.

Figure 1 shows the received signal strength indication (RSSI) levels as measured by the CDMA telephone. The

power output of the cellular telephone is directly related to the RSSI level. The higher the RSSI level, the less power output the cellular telephone emits; the smaller the RSSI level, the more power it emits. Figure 1 indicates that many of the patient areas where testing was performed had low to minimal RSSI levels, which indicates that the CDMA telephone was transmitting at or near the upper quartile of the power output.

As noted, we also tested 10 patients with 2 wireless handheld devices (Blackberry 7100t and 8700, Research in Motion, Waterloo, Ontario) for a total of 40 tests. These 40 tests involved 24 medical devices. The equipment tested included the following: patient monitors, infusion pumps, balloon pumps, patient-controlled analgesia, urine output monitors, feeding pumps, and an electroencephalograph system. Interference occurred in 0 of the 20 tests completed. Therefore, the incidence of clinically important interference was 0% (95% confidence interval, 0%-8.8%). No interaction occurred with any of the medical devices present in the patient rooms.

DISCUSSION

Cellular telephones alter their power output based on the strength of the incoming signal from the cellular tower. In areas where the incoming signal is strong, cellular tele-

phones transmit at a low power level to conserve battery life. In areas where the incoming signal is weak, cellular telephones transmit at a higher power to ensure reliable communications.

Cellular telephones alter the power output based on the measured RSSI level. This altering or modulated change to the power output of the cellular telephone creates a challenging situation for testing the potential interactions or interference with medical devices by the cellular telephones. If a study is completed only in areas where the incoming signal from the cellular tower is strong (a high RSSI level), the cellular telephone will be emitting minimal power and the impact on the medical devices will be minimal. The current study was designed to simulate real-world scenarios; some of the patient rooms were in areas with strong cellular signals, whereas other patient rooms were in areas with weak to almost no cellular signals.

To ensure that the study was not performed only in patient rooms with strong incoming signal levels, we measured the RSSI levels at 3 different locations within the patient rooms. These measurements indicated that the 75 patient rooms included a broad distribution of incoming signal levels from the cellular tower, with some areas where the signal was very strong (an RSSI level of -31 dBm) to areas where the cellular telephone would barely operate (an RSSI level of -120 dBm) (Figure 1).

Since the inception of cellular telephones, considerable debate has occurred regarding their use in health care settings, specifically in the hospital environment.⁶⁻¹⁰ Many health care organizations have struggled with the most appropriate policy for use of cellular telephones in the hospital and clinical environment. Some organizations ban their use, others allow them in specific areas, and others have no restrictions. For the most part, decisions to date have not been based on any rigorous testing. In our testing, no interference with medical equipment was seen in the patient care areas tested.

Reliance on cellular telephone use in our society has become widespread. In the hospital environment where patients and/or families may otherwise be somewhat disconnected from family and friends, cellular telephones allow a convenience that most prefer to have available. For those organizations with a policy that substantially restricts areas in which cellular telephones can be used, given most people's reliance on cellular telephones, policy compliance has been problematic and difficult to enforce.

Although we evaluated different types of medical devices, our study represents only a subset of the devices found in a clinical or hospital environment. As described, the study did not test devices commonly found in surgical areas, such as cardiopulmonary bypass machines, blood warmers, autotransfusion devices, and bispectral index sys-

tems (used to assess anesthetic depth). As noted, we did not test pediatric hospital environments and further testing may be reasonable, but no categories of equipment unique to these areas were identifiable.

CONCLUSIONS

This study determined that the cellular telephones tested, when used in a normal way, did not cause any interference with the various medical devices present in the patient care areas studied. For institutions that have restricted cellular telephone use, these data support revision or abolition of the existing policy. If no clinically important adverse effects occur as a result of using cellular telephones in the hospital, then it seems that the advantages that this technology brings to institution and patients would be well received. These advantages may be tempered by etiquette and lack of common courtesy by some individuals when using cellular telephones (cellular telephone users talking loudly and obnoxiously, bothering other patients and visitors).

On the basis of the results of this study, we are working with institutional leaders to consider possible revision of our existing cellular telephone policy. This revision would not include a policy change in the surgical suites or the pediatric intensive care units, where we will continue to prohibit cellular telephone use since testing has not been performed in these environments. As cellular telephone technology continues to evolve, periodic testing will be required to determine how those changes affect medical devices.

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