

Brief Review ■

Cellular Radio Telecommunication for Health Care: Benefits and Risks

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Abstract Cellular radio telecommunication has increased exponentially with many applications to health care reported. The authors attempt to summarize published applications with demonstrated effect on health care, review briefly the rapid evolution of hardware and software standards, explain current limitations and future potential of data quality and security, and discuss issues of safety.

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Radiotelephony has been used in health care since it was first introduced commercially in the 1950s,¹ but it was not until the introduction of hand-held transceivers and nation-wide cellular network coverage in the last decade that communication using these devices has become ubiquitous in the United States.²

Evolution of Applications

From the first words spoken by telephone in 1876 when Alexander Graham Bell reportedly spilled battery acid and called for assistance, communication technology has been used to facilitate health care. The spoken word is still by far the major health care application of telephony. Cellular mobile has facilitated urgent communication between consumers, providers, and health care facilities.³ Telephone consultations for health advice in the Kaiser Permanente HMO system to specially trained nurses using online management protocols have been analyzed recently. Although the percentage of calls initiated from cellular phones was not reported, selected characteristics of more than 4,000 encounters studied are germane to considerations of cellular voice teleconsultation. Mean call length was 5.9 minutes; 42% of calls required some further medical management, but only 18% resulted in urgent disposition; only 3% involved referral to emergency medical services. Most calls (93%) were to report a symptom, ask medication questions, or seek medical advice after an office visit or procedure.⁴

Data transmission of limited electrocardiographic (EKG) data from a moving ambulance became commonplace after 1970⁵ and now transmission of complete EKG by cell phone before hospital arrival has had a major impact on the management of acute coronary syndrome patients.⁶ Continuous transmission of multichannel physiologic monitoring data from a passenger on a commercial airliner using the cellular telephone installed in the seat back was demonstrated as early as 1997.⁷ A study transmitting cerebral computerized tomography im-

ages from 20 cases to a neuroradiologist using a PDA cell phone with 600 x 200 pixel display suggests that this technology may provide sufficient information for decision making in neurologic and neurosurgical emergencies.⁸ Digital video transmission over cellular network from home-bound patients has been judged to be of sufficient quality for clinical use by a small sample of home care nurses and physiotherapists in Japan.⁹

In Warsaw, Poland, 15 pregnant women with insulin-dependent diabetes were supplied with blood glucose meters that allowed recording of insulin dose and meal data in addition to self-monitored blood glucose. Those data were uploaded each night using either cellular or fixed modems in response to automated polling from a central computer. The data were analyzed by a rule-based program, which was integrated with an electronic medical record system to determine diabetes control, trends, and compliance with monitoring and treatment recommendations. Endocrinologists telephoned the patients the next day with advice on any needed change in therapy. The overall technical effectiveness of the communication system was estimated as 91.5% with a standard error of 6.1%; the authors state that the results obtained were not statistically different between the subgroups using dial-up or mobile cellular phones. The patients' metabolic control was significantly improved compared with control in the same patients before the intervention.¹⁰ Continuous ambulatory peritoneal dialysis has been monitored by cellular transmission of such data as heart rate, blood pressure, body weight, ultrafiltration volume, and urine volume to an Internet data server in Japan at a cost estimated at U.S. \$3.00 or less per month.¹¹ Remote control of medical devices (e.g., insulin pump, mechanical ventilator) might require review by the U.S. Food and Drug Administration of the communication system as a medical device. To date, we are not aware of any usage of cellular communication to automate a clinical decision.

Adjuncts to the conventional telephone system such as interactive touch-tone response, voice mail, and speech recognition are accessible by cellular units and have enhanced the accessibility of health care applications to a mobile population.¹² Features unique to newer cellular phones such as short text messaging have been used in health care applications such as daily medication reminders.¹³

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Spectral analysis of voice mail messages recorded from asthmatics using global system for mobile communication (GSM)-compressed digital cellular transmission can reliably detect those whose peak expiratory flow was reduced by independent measure.¹⁴

The potential of combining cellular technology with geographic positioning satellite (GPS) transmitters could lead to automated notification of emergency medical personnel in the event of auto accidents or cardiac arrest.¹⁵

A novel approach to high bandwidth data, such as video-over-cellular networks, multiplexed commercially available digital cell phones to transmit images from a moving ambulance for prehospital assessment of stroke.¹⁶

Evolution of Technology

The technical advance that made the limited radio spectrum assigned for telephony available to the millions of current subscribers is automated frequency reassignment. Automated switching servers rapidly reassign frequency channels across a geographic network of relatively low-power, short-range, static transceivers to very-low-power, short-range, mobile transceivers so that each mobile is sufficiently separated to avoid radio channel interference. Each static transceiver uses an array of directional antennae (usually mounted on towers) to sense frequency shifts and signal strength of the mobile units within adjacent geographic cells, so that the system can track and "hand off" a moving call.

First-generation (1G) cellular systems used analog signal transmission for voice; digitized data were transmitted by modem similarly to wired telephony; however, reliable data speeds did not exceed 10 kilobits per second. The 1G networks developed in the United States in the 1980s have largely been replaced by digital second-generation systems, which further subdivide and multiplex concurrent transmissions over the limited bandwidths assigned to radio telephony by the Federal Communications Commission.

The second-generation (2G) cellular systems (used by most current health care applications) use digital signal processing in which voice and other data are transmitted, usually with compression, by one of several algorithms including time division multiple access (TDMA), code division multiple access (CDMA), global system for multiple communications (GSM), and integrated digital enhanced network (iDEN). Although data are encoded in digital packets, these packets are transmitted sequentially over an assigned circuit switched to the individual units for the duration of the connected call. Because of the multiple 2G algorithms, cellular hardware often is incompatible unless connected through the landline-based public switched telephone network (PSTN).

Packet switching labels data so that each unit can be routed over the path of least congestion through a network and reassembled at its destination. Current transmission speeds achieved by 2G cellular systems are not adequate for reliable conversational speech with a packet-switched protocol; so-called "2.5G" networks divide their assigned spectrum into a circuit-switched range for voice and a packet-switched range for other data.¹⁷

Third-generation (3G) cellular systems blur the distinction between wireless networks and radiotelephony. 3G systems will use packet-switched transmission for both voice and other data. A key feature is the integration of wireless local area net-

working having transmission speeds in a gigabit per second range with cellular radio systems having speeds in a hundreds of kilobits per second range. 3G systems are expected to have the following features: fixed and variable rate bit traffic, bandwidth on demand, asymmetric data rates in the forward and reverse links, multimedia mail store and forward, capability to determine geographic position of mobile units and report it to both the network and the mobile terminal, and international interoperability and roaming. 3G-compatible radio protocols already in commercial use include general packet radio system (GPRS), cellular digital packet data (CDPD), and Bluetooth with several others in testing.¹⁸ It is not clear that any of the candidate 3G radio protocols can support mobile units when data rates are high enough that a Doppler shift effect of motion on the frequency-modulated carrier signal can induce errors in reading the pattern of "on" and "off" digits.

In any communication network, transmission speeds are limited by the bandwidth available divided by traffic demands; the available radio spectrum has competing demands from applications such as commercial broadcasting, law enforcement, air traffic control, military, and devices like garage door openers and wireless EKG monitors. New frequencies for wireless communication may be allotted if methods for reliable service without interference with other vital applications are developed.

Risks and Limitations

The most clearly delineated risk of using cellular radio telecommunication is accidental injury or death associated with the distraction of using the technology while driving a motor vehicle. This association is apparently independent of whether the user is holding a phone or has hands free.¹⁹

Because mobile radiotelephones transmit as well as receive, their antennae emit electromagnetic radiation (EMR). There is debate about the human health effects of EMR associated with mobile radiotelephones.²⁰ The Federal Communications Commission (FCC) requires wireless phones used in the United States to report the specific absorption of radiation (SAR) to the head and to comply with a safety limit of 1.6 W/kg of tissue.²¹ There are reports of increased subjective neurologic and psychiatric symptoms in cell phone users^{22,23} with some correlation with estimated radiation dosage, but these epidemiologic studies do not control for such factors as occupation, age, stress, or ergonomics. Case reports of scalp nerve conduction abnormalities are also not clearly related to SAR.²⁴ A retrospective association of habitual handheld cell phone use with risk of malignant brain tumor on the same side has been reported.²⁵ SAR to the user's head is substantially reduced by the use of a wired "hands free" earphone-microphone extension.²⁶

EMR associated with hand-held transmitters can also interfere with electronic medical devices, either by radio frequency interference (RFI) as with devices like telemetry transmitters²⁷ or by induction of current in devices like pacemakers²⁸ and hearing aids.²⁹ RFI is inversely proportional to the square of the distance from the transmitter so that a 2-m buffer is probably safe for any medical devices with any cellular phone.³⁰ Manufacturers are increasingly "hardening" devices to resist RFI, but most hospitals still ban the use of cell phones in all patient care areas.

With the advent of the Health Insurance Portability and Accountability Act (HIPAA), concern over the privacy of both

voice calls involving patient data and other wireless data transmission has increased.³¹ Digital cellular transmission supports encryption of both voice and packet data. Each digital cell phone contains a chip with a unique identifier. Assuming that the chip is not stolen and installed in another phone, the origin of a call can be authenticated. However, that does not guarantee the authenticity of the caller. The caller's voiceprint would be an obvious biomarker if the quality of the sound signal is sufficient to reliably identify individuals. Picture transmission capacity also has a potential of misuse; gymnasias in the Washington, D.C. area have banned the use of cellular equipment in locker rooms for the protection of privacy of clients.³² Geographic positioning systems also have the potential to invade privacy.³³

Implications

Despite current limitations of service for voice and data and health risks to users and bystanders, the social enterprise of health care will likely increase use of cellular radio telephony for communication between patients, providers, and facilities. Hardware features such as built-in digital camera, GPS chips, and higher resolution screens will likely be tested in health care applications. Evidence-based application of this technology, as with any other, is most likely to maximize the benefits and minimize the risks. Because of its familiar interface, affordability, and ubiquity, the mobile telephone may be the best information appliance for populations including elderly, cognitively impaired, and homeless to bridge the "information gap."^{34,35}

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