

APPARATUS

Mobile phones in the hospital – past, present and future

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Summary

The phenomenon of electromagnetic interference by mobile phones is real and potentially clinically significant. This has been recognised by the Department of Health and the Medical Devices Agency, leading to bans on phone use in hospitals. Current evidence suggests that mobile phones can cause malfunction of medical equipment, but only when used in close proximity. Allowing phone use in non-patient care areas and improving staff education may improve compliance with hospital policies.

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Most hospitals in the UK have introduced a blanket ban on the use of mobile phones in the last 10 years, with varying degrees of success. Over 27 million people in the UK have a mobile phone, and are increasingly reliant on this form of communication. Many use their phone as their primary means of contact, and continue to do so wherever they are, despite warning signs or notices. Bans on mobile phones began to be applied after reports of interference with medical equipment by early analogue models. There followed highly publicised cases of malfunctions reported by the Medical Devices Agency (MDA) and, in 1994, the MDA recommended that bans should be applied in limited but specific areas of hospitals for staff, and that patients, visitors and contractors should be discouraged from using mobile phones at all [1].

In 1999, an independent expert group chaired by Sir William Stewart was set up by the government to examine the impact of mobile phone technology on health. The detailed document produced the following year concluded that 'the balance of evidence does not suggest that mobile phone technologies put the health of the general population of the UK at risk'. They stipulated that all hospitals should follow health authority policy, as instructed by the MDA, including the placement of warning signs indicating that mobile phones should be switched off. The Department of Health reinforced this policy in their response to the Stewart report, saying that they were 'aware that the use

of mobile phones in hospitals could possibly interfere with sensitive equipment' [2]. The first case of successful prosecution occurred in November 2000, when two men were jailed for three months after refusing to switch off their mobile phones in the waiting area of the accident and emergency department of the Edinburgh Royal Infirmary [3]. A month later, the Department of Health issued another warning, stating that 'radio signals emitted by mobile phone systems can interfere with sensitive electronic equipment; always observe the warning signs and switch off mobiles when required.' [4].

In France and Germany, mobile phones are prohibited in hospitals, clinics and nursing facilities. In contrast, North American hospitals have introduced more selectively worded policies allowing the use of mobile phones in non-direct treatment areas of the buildings. This review examines the current evidence on electromagnetic interference (EMI) and other safety aspects of mobile phone usage.

The technology

Mobile phones and their base stations transmit and receive signals using electromagnetic waves created by the movement of electrical charge in antennas. These waves are also referred to as electromagnetic radiation or radio waves. The first cellular system employed in the UK

was the analogue Total Access Communication System (TACS), which is still in use in North America. It uses frequency channels of around 800 MHz. In Europe, TACS has mainly been replaced by the digital system known as Global System for Mobile communications (GSM), which operates in the 900 or 1800 MHz frequency band. These phones have stronger peak electromagnetic fields than the older analogue telephones [5].

All mobile phones emit radiofrequency waves in standby mode as well as when in use. Their power increases when an incoming call or other communication from the base station is received. At this point, fluctuating signals are produced as rapid two-way communication continues, whether the call is answered or not. This means that to eliminate the production of electromagnetic waves by the phone, it must be switched off completely.

Any length of wire in an electronic circuit or in an integrated chip can act as an antenna when exposed to radio waves. This can give rise to electric currents that may interfere with the normal operation of the circuit. Hence, it is an inherent property of radio waves, such as those transmitted by mobile phones, that they can cause EMI. The chance of EMI occurring increases with the power of the transmission and decreases with the distance from the antenna. All medical electrical equipment is prone to EMI. Some devices have been 'hardened' to minimise unwanted interference by shortening internal wires or by enclosing the circuitry in a metal case or shield. These precautions do not entirely prevent problems, particularly if phones are used in close proximity to the device.

Malfunction and unexpected behaviour may occur if the medical device interprets corruptions of its electronic signals as actual data or as coded computer instructions [6]. This may lead to improper self-adjustment, failing to alarm or shutting down.

Interaction with equipment

The United States Food and Drug Administration has received reports of > 100 cases of suspected EMI with medical devices up to 1993 [7]. This led to a front page article in the *Wall Street Journal* [8] citing some of the more extreme (and sensational) cases. Even the popular medical soap *ER* ran a storyline that included a case of EMI. Following a succession of similar reports in the UK, the MDA tested 178 models of electronic devices. Twenty-three per cent of these devices suffered EMI from handsets; 43% of these interference incidents would have had a direct impact on patient care and were rated as serious. However, they did state that interference only

occurred at distances < 2 m [9]. The majority of publications about EMI appear in journals not widely read by anaesthetists or in journals aimed more specifically at medical engineers.

Pacemakers

The potential for mobile phones to interfere with pacemakers has been recognised since 1994. Studies have shown that interference can only be caused by digital phones [10–13]. Such interference may cause inappropriate inhibition of pacing or triggering of pacing stimuli. It may also cause reversion to asynchronous ('noise-mode') pacing, switching to another pacing mode or changes in the pacing rate [14]. Assessments have been made of the effect of GSM phones on different pacemaker types in a variety of conditions and sensitivity settings. It appears that EMI occurs most often when the phone is close to the pectoral site of device implantation, and more frequently when the device is programmed to a high sensitivity or when the lead is unipolar [15]. In a study of four digital phones and one analogue phone tested at the ipsilateral ear or directly over the pacemaker, the incidence of any type of interference was 20%, causing symptoms in 7.2% of cases. No symptoms were reported when the telephone was placed at the contralateral ear [16].

Recommendations to minimise the risk of interference include the increased use of low-sensitivity bipolar pacemakers and advising patients to carry their phone at a site distant to the pacemaker, and use it at the contralateral ear [17]. Mobile phone manufacturers recommend keeping a distance of at least 15 cm between the phone and a pacemaker.

External (temporary) pacemakers are also susceptible to EMI. The most serious effects seen in testing are sensing of false pulses in the demand mode leading to no paced output, and mode changing between fixed rate pacing and sensing [9].

Implantable defibrillators

Interference with an implantable cardiac defibrillator (ICD) has potentially fatal consequences. EMI could lead to inappropriate sensing and unwarranted shocks or suspension of arrhythmia detection. Occetta *et al.* [18] reported that GSM digital phones interfere with the programming of ICDs, causing significant noise in the telemetric transmission and loss of telemetry. However, they also concluded that ICDs are well protected from EMI caused by phones, with no instances of false arrhythmia detection. Another study that tested both North American and European digital phones found no interference with ICDs *in vivo* or *in vitro*. The report concluded that although damage or reprogramming of

ICDs was unlikely, a safe distance of > 15 cm should be kept between the phone and the device [19].

Concerns about interference with ICDs have not been completely laid to rest, as a recently published study reported a case of electromagnetic radiation produced by an antitheft surveillance device in a bookshop causing EMI. In this instance, a patient received four shocks from the device in reaction to a perceived complete atrioventricular block. A passing nurse dragged him out of the shop doorway where he had collapsed and away from the source of the interference. The patient recovered [20]. Since then, the United States Food and Drug Administration has recommended that patients with an ICD should not linger in shop doorways!

Ventilators

Two recent studies have shown significant EMI between ventilators and mobile phones. Barbar *et al.* [21] tested four European GSM mobile phones (including models from Nokia, Motorola and Ericsson) with 22 commonly used ventilators, such as the Siemens Servo 900C, Drager PhysioFlex and Puritan-Bennett 7200. Twenty-one of 22 (95%) ventilators tested showed EMI effects. Monitor and alarm system malfunction was seen commonly, including triggering of alarms and parameter display errors. Furthermore, ventilator settings were altered, producing considerable ($> 20\%$) changes in delivered minute volume, inspiratory peak flow, respiratory rate and inspiratory peak pressure. Three ventilators were shut down completely when a phone was used up to 1 m away, requiring manual resetting. No interference of any type was found at distances > 1 m. Tri *et al.* [22] found that of six mobile phones used at the back of a Hamilton Veolar ventilator, five caused it to shut down. The ventilator recovered once the phone was removed or turned off. There have also been case reports of high-frequency ventilators being turned off and reset by mobile phones, such as that highlighted in the Health Devices Alert of December 1992. MDA testing [9] showed that seven of eight ventilators tested were affected by phones used within 1 m. A Puritan-Bennett 7800 ventilator lost the ability to differentiate between forced, assisted and free ventilation, and alarms were randomly set off, with no correspondence with the displayed values. The Siemens Servo 900C ventilator produced increased mean airway pressure and tidal volumes, but the low volume alarm was activated.

Monitoring

Monitoring devices are particularly at risk, as they measure very small electrical signals, and the wiring between patient and machine can act as an antenna [23]. Telemetry monitoring, in which the ECG is transmitted

from a patient-located device to a central monitoring area (commonly the nurses' station), is used increasingly. This system is prone to EMI, as the device itself communicates with the monitoring station using radiofrequency waves. In a high dependency unit equipped with telemetry monitoring, alarms and related printouts were suspended during the use of mobile phones by several visitors. Appropriate central station functions were restored when the phones were turned off [24].

A North American study [22] tested for interference between both digital and analogue phones and ECG monitoring equipment, leading to baseline movement and noise that significantly affected device function. They found that interference occurred in 41% of the devices tested. The devices included 'portable' ECG monitors as well as 'bedside' monitors (both Hewlett-Packard and Protocol Propaq models), telemetry packs, an intra-aortic balloon pump and mobile 12-lead ECG recorders. This interference was not seen > 1.5 m from the equipment. Baba *et al.* [25] tested 366 different types of medical devices by turning a mobile phone on and off at varying distances from the devices. The authors found that interference, e.g. defibrillator dysfunction, occurred in 66% of the devices; 90% at < 1 m and none at > 4 m.

Pulse oximeters show low signal amplitude and erroneous readings in the presence of a mobile phone [25]. In a case reported to the United States Food and Drug Administration, a pulse oximeter was observed to display a heart rate and oxygen saturation for a dead patient when a phone was used nearby [7].

Infusion pumps

Infusion pumps are particularly prone to EMI. Several case reports have highlighted that the rate of delivery or alarm settings may be altered by a mobile phone used in close proximity to the device [26,27]. In one instance, the rate of delivery was set to maximum without the display being altered [28]. In laboratory tests, infusion was halted by the device alarm when a phone was brought near the syringe holder. The pumps had to be reset manually before normal function could be restored [25]. MDA testing [9] showed that 54% of infusion pumps were affected at a distance of < 0.5 m. The most serious effects included a reversal in the motor drive of an IVAC 960, causing the syringe plunger to be drawn back; many pumps were shut down or displayed an 'error mode', needing to be switched off and restarted.

Other equipment

Mobile phone use may cause EMI in neonatal units by resetting incubator heater elements to maximum output

[29] and causing apnoea monitors to fail [30,31]. Furthermore, they interfere with ionizing radiation dose-monitoring equipment, causing over-reading, especially if kept adjacent to the device [32]. Even a Psion Series 3a microcomputer can be totally reset, potentially losing all stored data [33].

Discussion

The evidence presented above shows that EMI by mobile phones is a real and significant phenomenon. Many medical devices are affected, especially if the phone is near the device when signals are emitted. Studies show that EMI does not occur at > 2 m.

To date, there have been no documented cases of deaths caused by EMI in hospitals. However, some of the devices affected are vital to patient care, and EMI may lead to considerable harm if immediate action is not taken. The current body of evidence strongly suggests that mobile phones should not be used in any areas where electronic devices are used in patient care. In addition, they should not be carried in the stand-by or silent mode, and must be switched off to avoid potential EMI. Hospital staff should be educated about the invisible effects of mobile phones and should be encouraged to reinforce phone bans. They must also be aware that sudden changes in observed parameters or malfunctions in equipment may be caused by EMI. However, there seems to be no reason to ban the use of phones in non-patient care areas of the hospital, including offices, relaxation areas and on-call rooms. By allowing phone use in some areas of the hospital, there may be increased compliance with bans in sensitive areas. With increasing education, selective mobile phone policies could be implemented and would certainly be more popular than total bans.

Mobile phone detection devices are commercially available, and have been installed in some UK hospitals. They are designed to sense the operation of both analogue and digital phones in the continuous frequency range of 400–2000 MHz. They detect both active and standby modes. Detectors are often placed near entrances to the hospital and can be programmed to emit a warning sound or a verbal message. Whether this 'Big Brother' approach improves compliance with phone bans remains to be seen. Location of these devices in the entrance to sensitive areas may be more sensible.

Standards for a third generation of mobile telecommunications technology have now been agreed and these devices will be introduced in the next few years. In Europe, this is called the Universal Mobile Telecommunication System. The frequency bands identified for this system are 1885–2010 and 2110–2200 MHz. The safety profile of these phones is as yet unknown.

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