Management of Electromagnetic Interferences in Healthcare Facilities – A review

Gnahoua Zoabli[1], and Nabilath Akimey A.[2]

[1]CSSS du Lac-des-Deux-Montagnes, St-Eustache, Québec;
[2]Institut de génie biomédical, Université de Montréal, Montréal, Québec

Abstract

Management of electromagnetic interference has become a major issue in Quebec hospitals. Several discussions on this issue have been held between managers of medical technologies departments. Some hospitals tend to allow a more widespread use of wireless technologies while others continue to formally ban them. As a contribution, we present a review of literature on devices that may transmit frequencies that can interfere with medical devices, such as pagers, cordless phones, cell phones, tablets, portable radio transceivers, tracking devices, laptop computers, telecommunications antennas and medical equipment. Because of its wide availability, portability and accessibility, cell phone is the most popular wireless technology in healthcare facilities. The greatest distance of immunity known to date is 6 m, excluding the combination effect of the agglomeration of several electromagnetic sources in the same area. From our literature review, it is safe to allow cell phones in a healthcare facility if the usage is made out of a nursing unit, regardless of the vocation (critical or general Medicine) or outside of a diagnostic or medical department (medical imaging and laboratories). By cons, for medical imaging technologists carrying a pocket dosimeter (immunity of 38 cm), the use of cell phones should be banned while still carrying the dosimeter. The nuisance caused by cell phones, their need for regular disinfection by their owners and the patient privacy safeguarding concerns should be considered by healthcare managers in preparation of regulations, procedures or policies on health and safety at work. A subsequent study should analyze electromagnetic interference of medical equipment between them. Hospitals that have already authorized the use of cell phones on the care units would benefit requiring phones with Flight mode enabled, pending the development of a Hospital mode that should inhibit, in addition, sound recording, video camera and force the phone ring mode to vibration.

Keywords: **Electromagnetic Interference, Health and Safety, Cell Phones, Hospital Mode, Privacy**.

I. INTRODUCTION

Wireless technologies are increasingly available to the general public and are found in hospitals (employees, patients and visitors) because of their portability and accessibility. Local policies prohibit entirely or partially the use of cell phones in the hospital compound or only in some critical care units [1]. The disparity of these policies from one institution to another commends to look for the best safety practices in the management of electromagnetic interference (EMI) in a healthcare facility. The electric field strength of a radio frequency transmitter device decreases proportionally to the square of the distance. Thus, the standards defined point to point immunity distances. The clinical reality becomes complex with the proliferation and combining of electromagnetic communication devices of various generations and operating frequencies. From a clinical point of view, it is important to know the conditions of safe use of cell phones or other devices emitting frequencies in hospitals and establish an updated list of their effects on medical equipment. In each study, the manufacturer and the year of manufacture of the tested devices will not be taken into account despite of the disparity in technology generations during the period of interest.

II. MATERIALS AND METHODS

A. Review of gray literature

Databases from Health Canada, Emergency Care Research Institute (ECRI), Institute of Electrical and Electronics Engineers (IEEE), Medicine and Healthcare Products Regulatory Agency, Food and Drug Administration (FDA) and the Google search engine were investigated to identify medical technologies sensitive to electromagnetic waves.

B. Review of the scientific literature

A literature search of studies on EMI with medical equipment identified during the preliminary review was conducted in SUMSearch databases, Trip Database, The Cochrane Library, PubMed and Quebec Institute in Excellence in Healthcare and Social Services (INESSS). The literature search was performed using combinations of the following keywords: cellular phone, smart phone, wireless, interference, electromagnetic interference, electromagnetic compatibility, radiofrequency, RFI, EMI, EMC, medical devices, equipment failure, equipment safety, infection control, distraction, hospital, healthcare center. Further to an initial review of literature on this subject [1], our research was limited to studies published between 2004 and 2014, regardless of the country.

The selection of items of interest was performed by prioritizing the following three criteria: date of publication is

recent; number of medical devices tested is consistent; measured interference metrics are available and detailed.

III. RESULTS

Most listed studies addressed the electromagnetic interferences and their frequency of occurrence. Few studies have provided clear and precise measured interference metrics.

EMI susceptibility is observed over a distance of less than a meter for most of the affected equipment, except for: defibrillators (6 m), anesthesia machines (6 m), volumetric respirators (4 m) and ultrasonic Doppler (4 m). Table 1 lists the main radiosensitive medical devices documented to date.

IV. DISCUSSION

A. Restrictions suggested for the safe use of wireless phones

Until this study, the distance of 1 m was the standard used for managing proximity of a cell phone with an electrical medical device. Since the ultrasonic Doppler (4 m, 802.11b) and defibrillator (6 m, GSM, RFID) can be on any care unit and that the respirator (4 m, RFID, GSM, Bluetooth, Radio) and the anaesthesia machine (6m, GSM, RFID) are found mainly in intensive care and operating rooms, it is clear from this study to ban the wireless communications devices on all nursing units. The largest minimum distance established to date is 6 m. It can be observed if the cell phone is used inside any care unit, including critical or diagnostic ones: emergency, intensive care, operating room, endoscopy unit, electrophysiology and imaging. As for the patient, he would simply be prohibited from using a cell phone on the unit and when he comes out to smoke with an infusion pump or other affected equipment listed in Table 1.

Our study does not establish restrictions for pharmacy (see Table 1). An update of the data is to be done in the future to justify the extension of restrictions on pharmacy or other technology departments (IT, Facilities/Building Management). A tendency of some healthcare facilities is to ease their use of cell phones policy; allowing cell phone in areas where there are few medical devices: Waiting, rest areas, private offices and cafeterias [26].

In addition, hospitals that allow cell phones on care units may face the problems of noise, digital distractions and breach of confidentiality.

B. Noise nuisance

In a clinical area, silence is an element of comfort and patient recovery. Cell phone can be a noise nuisance and thereby impair the well-being of patients, especially during the night shift. It is therefore recommended that any employee, patient and visitor ensures that the volume of his mobile phone be either discrete or off.

C. Digital distractions

Spontaneous use of cell phones in the exercise of a function could affect cognitive performance by increasing the professional response time and decreasing the concentration during the return to performing of precision tasks. It has been reported by various sources that smart cell phones contribute to distract the hospital staff during the execution of important tasks.

According to Katz-Sidlowet and al. [30], 90% of junior doctors admit, through an anonymous survey that they had been distracted by smart phones during the patients' tour and thus have missed some vital information about some patients. Also, there was a case of distraction by texting, where a medical resident forgot to stop an anticoagulant drug for a postoperative patient. This messaging case has made headlines in the United States [31-32]. In a survey conducted in 2010 among 439 perfusionists [31-32], 49% admitted to having sent text messages; 21% viewed their emails; 15% have accessed the internet; 3% visited social networking sites, while performing a cardiopulmonary bypass procedure. In addition, 7.3% of perfusionists confessed that the cell phone had a negative impact on their performance and 33.7% said they had seen a colleague distracted by the cell phone. Other examples of unprofessional conduct listed in the clinical setting include [31]: checking e-tickets and personal phone calls using a wireless earpiece during surgery. In light of these findings, it seems clear that the use of cell phones could be a major distraction from the medical staff. The provision of care is hampered, in addition to patient harm. It is highly recommended to implement a strict policy of using smart phone by health care providers and visitors.

D. Confidentiality and privacy

Most mobile communication devices allow photographing, filming and recording. The privacy of personal, medical and social data as well as any other information concerning the patient shall be secured in compliance to the rights for respect, confidentiality, image, privacy and dignity.

The intimacy and privacy of patients and their families must be preserved.

E. Technical specifications of medical equipment

It would make sense that the service of biomedical engineering (BIOMED) of the hospital shall ensure upon the acquisition of medical equipment that the manufacturer specifies the minimum separation distance between the equipment and any other medical device emitting electromagnetic radiation. This information should be available for the range of radio frequencies most commonly used today spanning at least from 800 MHz to 2.5 GHz. On the other hand, the IEC 61000-4-3 standard of IEC 60601-1-2: 2014 for electrical medical equipment requires immunity to radio frequency as follow [25]:

• 3V / m (80-2700MHz, 1kHz 80% AM modulation) in a clinical setting;

• 10V / m (80-2700MHz, 1kHz 80% AM modulation) in a care home.

The BIOMED should maintain and update a cumulative electromagnetic spectrum emitted by medical or telecommunications devices in the health facility (Fig. 1). This ensures to address the problems of EMI before the acquisition of new medical and telecommunications devices.

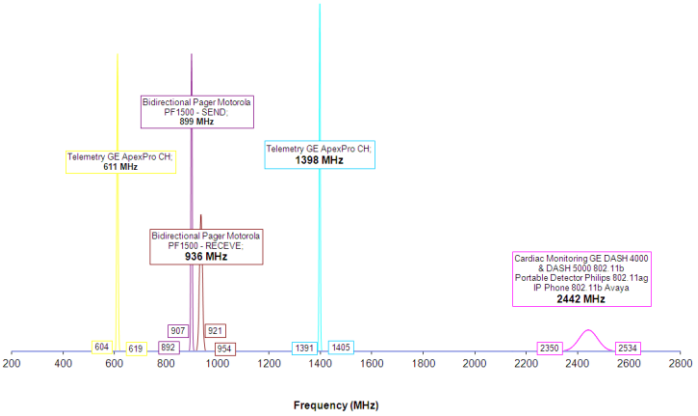

Fig. 1: Devices Electromagnetic Spectrum at CSSS LDDM

F. Disinfection

Mobile communication devices of hospital employees are rarely targeted for disinfection. However, several studies have shown that these are vehicles of microbes or cross infections [27-28-29-31-32]. A bacteriological analysis of surfaces of 75 mobile communication devices carried by clinicians found that 90% were contaminated with bacteria [31, 32]. Ustun and Cihangiroglu in 2012 [32] led to the isolation of 179 pathogens samples from 183 cell phones of medical personnel in a referral hospital including: 17 samples of Methicillin-resistant Staphylococcus aureus (MRSA) and 20 samples of Extended Spectrum Beta Lactamase (ESBL) producing Escherichia coli specimens, which can cause nosocomial infections.

Education to employees is therefore important to limit the spread of infections.

G. Interference between medical devices

In addition to measures surrounding the safe use of mobile telecommunication devices in hospitals, other major challenges are to consider. An operating room, for example, comprises a plurality of medical radio transmitters and radio receivers devices, all confined in a small space. It is therefore important to focus on the risks of electromagnetic incompatibility between biomedical devices sharing the same frequency ranges within the hospital (Fig. 1).

H. Vectorial and harmonic analysis in the presence of multiple sources of electromagnetic signals

So far we have considered a single EMI source at a time. However, in situations of permission for the use of wireless communication devices in a clinical setting, several different radiofrequency (RF) sources of various electromagnetic powers will be present at different frequencies: cordless phones for home, CB, GSM, RFID, Bluetooth, GPRS, 802.11abgn, IT systems, medical equipment, frequency generators, etc. In such an environment, it is realistic to assume that the result of all these signals could be a resultant signal whose power and / or frequency may interfere with critical equipment. Current standards do not legislate on the maximum number of RF sources allowed per area. The distance of 6 m becomes plausible if we refer to the recommendations of the IEC for a power of 600 mW and immunity 3V / m for critical medical equipment such as defibrillators (6 m), anesthesia machine (6 m), and volumetric respirator (4 m).

I. Suggested technological development

Like the airplane mode that allows to turn ON / OFF the communication capabilities of a wireless device [GPS, smart phones, tablets, Windows 8.1], a Hospital mode should be created. Thus, cell developed with Hospital Mode could be automatically deprived of their ability to communicate at the entrance of the department and restored when returning back to the permitted area.

To ensure the confidentiality and privacy of patients, the Hospital Mode disables the camera functions. However, games and music via earphone remain functional. Emails and texts can be written and recorded. They will be sent later when back in the public corridor. To handle the noise, the ring mode is deactivated and replaced by the vibration at all times.

This is equivalent to a flight mode which, in addition, prevents the cell from its audio, photo, and video recording capabilities and forces it on vibrate. Such a design would be possible within the update of the current flight mode. A new mobile App could be developed to emulate Hospital mode on any smartphone.

V. CONCLUSION

Distance seems the most important parameter to watch and make sure to minimize the adverse effects of cellular waves on medical equipment. According to this review, it's safe to allow mobile communication devices in a health facility if the use is made out of a nursing unit, regardless of its vocation (critical or general practice) or a diagnostic department. Since a very small distance usually separates a pocket dosimeter and a cell phone when both are carried by a technologist, we recommend the formal prohibition of a cell phone for technologists carrying a dosimeter. To limit the nuisance caused by cell phones, we recommend that healthcare institutions develop a policy to reduce their use by the staff and ensure their regular disinfection. For hospitals with a policy which already allows the use of cell phones on the care units, airplane mode will solve the issue of EMI, pending the development of the Hospital Mode which covers, in addition, the noise and privacy.

Table 1: Medical devices affected by electromagnetic interference

Group	Equipment	Center frequency of received electric field	Wireless type	Maximum electric field intensity	Malfunction	Maximum distance with EMI (cm)	Reference #	Country
Dialysis	Dialysis machine	125kHz,868Mhz/ 900 Mhz	RFID/GSM		Screen wobbled/Inacurate pressure readings/Pump slowed and stopped working	20/50	Van der Togt et al., 2008/Bit-Babik G et al,, 2007	Netherlands/USA
Dialysis	Blood electrolyte analyseur		GSM		Error in potassium reading		MDA, 1999	UK
Electrophysiology	Remote patient monitor (telemetry)	441.3 MHz		86.8 V/m	Observed electromagnetic waves emitted from the device		Hanada E. et al., 2004	Japan
Electrophysiology	External pacemaker	125kHz,868Mhz	RFID		Pace pulses given erroneouosly	30	Van der Togt et al., 2008	USA
Electrophysiology	EEG/ECG	900,1800Mhz/900 MHz	GPRS/GSM		Signal distorsion and noise from the monitor	4/50	Iskra S, et al., 2007/Bit-Babik G et al., 2007	USA/Australia
Medical Imaging	Electronic pocket dosimeter (EPD)				EPD malfunctioned, but recovered by resetting after the exposure ceased.	38	Deji S. et al., 2005	Japan
Medical Imaging	Ultrasound imaging device	2,4-5MHZ/1802.1 MHz	802,11 (a,b,g)/ GPRS		Unclear images	20 et 10	TNO quality of life, 2007 /Wallin M. et al, 2005	Danemark/USA
Medical Imaging	Ultrasonic doppler		802,11b		Unclear images	400	Wallin M. et al,, 2005	USA
Medicine	Infusion pump	80-2500 MHz	GSM	10 V/m @ 1m @ 2W	False alarm buzzing and stopped pumping	0,1/30	Calcagnini G. et al., 2008	Italy
Medicine	Syringe pump	80-2500 MHz / 2.45,5.2 GHz	GSM/802.11b	10 V/m @ 1m @ 2W/ na	False alarm buzzing and stopped/incorrect lighting	10/40	Calcagnini G. et al., 2004/ Hanada E, et al., 2004	Italy / Japan
Medicine	Incubator	900 Mhz	GSM		Temperature settings fluctuated /Heating element and alarm turned on	25	Bit-Babik G et al,, 2007	USA
Medicine	Oxymetrer	900 Mhz	GSM		Saturation reading increased/Inappropriate reboot/Sound distorsion	25	Bit-Babik G et al,, 2007	USA
Medicine	External defibrillator	125kHz,868 MHz/900 MHz	RFID/GSM		Noise, graph distorsion and audio buzz	125/600	Van der Togt et al., 2008/Bit-Babik G et al,, 2007	Netherlands/USA
Medicine	Thermometer		GSM		Error log/blank display out	0,1	MDA, 1999	UK
Medicine	Infant incubator		GMRS		Pressure display and alarm malfunctions	80	Kok-Swang Tan, 2007	Canada
Medicine	Insuflator	80 MHZ - 2,5 GHZ	GSM	10 V/m		n/a	W.O.M. WORLD OF MEDIINE AG. 2013	Germany
Medicine	Blood Warmer	125kHz,868Mhz	RFID		Resets automatically and resumes operating normally when signal is removed.	50	Van der Togt et al, 2008	Netherlands
Operating Room	Electric Knife - mono-polar	500 kHz		97.4 V/m	Observed electromagnetic waves emitted from the device		Hanada E. et al., 2004	Japan
Operating Room	Electric Knife - bi-polar	461.8 kHz		104.5 V/m	Observed electromagnetic waves emitted from the device		Hanada E. et al., 2004	Japan
Operating Room	Electric Knife - argon beam coagulator	620 kHz		91.1 V/m	Observed electromagnetic waves emitted from the device		Hanada E. et al., 2004	Japan
Respiratory	Ventilator	868 Mhz,125 Khz/ na	RFID/GSM, Bluetooth, Radio		Incorrect graphical and numerical display / stopped and reboot, (lower)	400/100	Van der Togt et al., 2008/ Jones RP and Conway DH, 2005	Netherlands/UK
Respiratory	Apnea	80 MHZ - 2,5 GHZ	GSM	10 V/m 3A/M	False apnea alarm		Carrenza, 2011/ ResMed Germany Inc., 2012	USA/ Germany
Respiratory	Anaesthesia machine	na/125kHz,868Mhz	GSM/RFID		Innacurate pressure value and graph displayed	50/600	MDA, 1999/Van der Togt et al., 2008	United Kingdom/ Netherlands
Respiratory	Nébuliseur		GSM		Motor speed increased when running/exces of energy	n/a	MDA, 1999	United Kingdom
Other	Microwave oven A	2.465 GHz	802.11b, 11ch	121.3 V/m	Observed electromagnetic waves emitted from the device		Hanada E. et al., 2004	Japan
Other	Microwave oven B	2.472 GHz	802.11b, 13ch	117.2 V/m	Observed electromagnetic waves emitted from the device		Hanada E. et al., 2004	Japan
Other	mecanichal wheelchair				uncontrolled motion		Pride Mobility Products Ltd., 2011	USA
Other	Fluorescent bulb	80 MHz-2.5 GHz		3 V/m			Stephen E, et al	Canada
Other	Humidifier		GSM,GPRS, Radio			9	Iskra S, et al., 2007	Australia

CONFLICT OF INTEREST

The authors declare no conflict of interest.

REFERENCES

Electromagnetic Compatibility

1. Recommandations relatives aux interférences électromagnétiques, CSSS du Lac-des-Deux-Montagnes, Politique cellulaires pagettes, Sept. 2010.

2. Zoabli, G., Knights J., Giguère, D., and Thomason, K. (2008) Interconnection of 802.11b wireless physiologic monitors with a 802.11a/b/g wireless VoIP network at Santa Cabrini Hospital's emergency care unit. In Proceedings of The Canadian Medical and Biomedical Engineering Society (CMBES), Montreal, Vol. 31, June 2008.

3. R. Hensbroek, 96 Medical Apparatuses tested for interference by WLAN/Wi-fi signals, Leiden, 2007.

4. Canadian Agency for Drugs and Technologies in Health, Wireless Device Use and Patient Monitoring Equipment in Any Healthcare Delivery Setting: A Review of Safety and Guidelines, Ottawa, 2014.

5. FDA, Electromagnetic Compatibility (EMC) FDA/CDRH Recommendations for EMC/EMI in Healthcare Facilities. U S Food and Drug Administration 13 January 2014. Available: http://www.fda.gov/Radiation-EmittingProducts/RadiationSafety/ElectromagneticCompatibilityEMC/ucm116566.htm. [Acceded Online May 31, 2014].

6. Radio Frequency identification devices (RFIDs) – Effect of RFIDs on lifesaving equipment, 2012.

7. E. Hanada and al, Safe introduction of in-hospital wireless LAN, Stud Health Technol Inform, vol. 107, no. Pt 2, pp. 1426-1429, 2004.

8. ResMed Ltd., Guidance and Manufacturer's Declaration Electromagnetic Emissions & Immunity, 2012.

9. N. Carranza and al, Patient safety and electromagnetic protection: a review, Health Physics, vol. 100, n° 15, pp. 514-530, May 2011.

10. S. Helhel and al, Distance and Location of Both Mobile Phones and Health Care Units: Determines the Interference Level, vol. 1, n° 12, pp. 78-82, 2011.

11. Moubarak and al, Défibrillateur implantable et interférences, Archives des maladies du coeur et des vaisseaux. Pratique, pp. 31-32, January 2010.

12. Westek Electronics, RFI testing of fluorescent lighting, 8 August 2008. Available: http://www.electricalsolutions.net.au/articles/26466-RFI-testing-of-fluorescent-lighting. [Acceded Online May 29, 2014].

13. E. VanLieshout, Intensive Care Volwassenen, MICU-department of the Academic Medical Center, Amsterdam, 2008.

14. G. Calcagnini and al, Electromagnetic interference to infusion pumps. Update2008 from GSM mobile phones, Conference proceedings: IEEE Engineering in Medicine & Biology Society, vol. 2008, pp. 4503-4506, 2008.

15. R. Van der Togt and al, Electromagnetic Interference from radio frequency identification inducing potentially hazardous incidents in critical care medical equipment. JAMA, vol. 299, n° 124, pp. 2884-2890, 2008.

16. S. Iskra and al, Potential GPRS 900/180-MHz and WCDMA 1900-MHz interference to medical devices, IEEE Trans Biomed Eng., vol. 54, n° 110, pp. 1858-1866, October 2007.

17. T. Kok-Swang, EMI Studies: Wireless Technologies, Electromagnetic Compatibility and Medical Devices, EMC in Healthcare Roundtable Conference, Ottawa, 2007.

18. G. Bit-Babik and al, Electromagnetic compatibility management of wireless transceivers in electromagnetic-interference-sensitive medical environments, vol. 43, n° 13, pp. 218-224, 2007.

19. R. Jones and D. Conway, The effect of electromagnetic interference from mobile communication on the performance of intensive care ventilators, vol. 22, n° 18, pp. 578-583, August 2005.

20. M. Wallin and al, Modern wireless telecommunication technologies and their electromagnetic compatibility with life-supporting equipment, vol. 101, n° 15, pp. 1393-1400, November 2005.

21. S. Deji and al, Abnormal responses of electronic pocket dosimeters caused by high frequency electromagnetic fields emitted from digital cellular telephones, Health Physics, vol. 89, n° 13, pp. 224-232, September 2005.

22. G. Calcagnini and al, Electromagnetic interference to infusion pumps from GSM mobile phones, Conference proceedings: IEEE Engineering in Medicine & Biology Society, vol. 5, pp. 3515-3518, 2004.

23. Pride Mobility Products Ltd, Jazzy 1400 Owner's manual, 2001.

24. Medical Device Agency (MDA), Emergency service radios and mobile data terminals: compatibility problems with medical devices, UK, 1999.

25. VH. Kee, EMC requirements for medical devices,

Ultratech Engineering Labs Inc, May 2014.

26. Canadian Agency for Drugs and Technologies in Health,

Politiques des hôpitaux canadiens sur les appareils de communication sans fil, Numéro 31, November2011.

Infection Control

27. M. Manning and al, iPads, droids, and bugs: Infection prevention for mobile handheld devices at the point of care, vol. 41, n° 111, pp. 1073-1076, November 2013.

28. G. Moore and al, The type, level, and distribution of microorganisms within the ward environment: a zonal analysis of an intensive care unit and a gastrointestinal surgical ward, Infection Control and Hospital Epidemiology, vol. 34, n° 15, pp. 500-506, May 2013.

29. D. November-Rider and al, Massachusetts dental public health program directors practice behaviors and perceptions of infection control, Journal of Dental Hygien, vol. 86, n°13, pp. 248-255, 27 August 2012.

Mobile Distraction

30. R. Katz-Sidlow and al, Smartphone use during inpatient attending rounds: prevalence, patterns and potential for distraction, Journal of Hospital Medicine, vol. 7, n° 18, pp. 595-599, October 2012.

General Issues

31. SG Preetinder and al, Distraction: an assessment of smartphone usage in health care work settings, Risk Management and Healthcare Policy, Vol. 2012, n°5, pp 105—114, December 2012.

32. ECRI Institute, Judgment call : smartphone use in hospitals requires smart policies, vol.41, n° 10, pp.314-329, October 2012.

ABBREVIATIONS

INESSS : Institut national d'excellence en santé et en services sociaux

RFID : Radio frequency identification

GSM : Global system for mobile communications

GPRS : General packet radio service

BIOMED: Service of biomedical engineering

CORRESPONDING AUTHOR

Author: Gnahoua Zoabli

Institute: CSSS du Lac-des-Deux-Montagnes

Street: 520 boul. Arthur-Sauvé

City: St-Eustache

Country: Quebec, Canada

Email: gnahoua.zoabli.hse@ssss.gouv.qc.ca