INTRODUCING MULTIPLE WIRELESS CONNECTIONS TO THE OPERATING ROOM, INTERFERENCE OR NOT?

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Abstract: The wireless evolution has given rise to concern regarding interference problems when wireless devices are located in heavily equipped medical rooms. A pilot study was designed to scrutinize this topic and to reveal possible interference problems during surgical procedures as a result of introducing wireless equipment in the operating room.

Twelve locations on the floor were marked with numbers from one to twelve, forming a grid around the operating table. Two mobile GSM-base stations were moved from location to location, two WLAN computers were placed on each side of the operating room sending data continuously to a WLAN receiver located near the wall. Finally, invasive arterial blood pressure was measured with a wireless biomedical sensor, transmitted by Bluetooth, and reference pressures from the cabled monitoring system in the OR was logged.

Data from the wireless networks was logged and analyzed retrospectively with respect to interference. No severe effects could be observed on the medical equipment present during the procedure.

Today's wireless standards with moderate output power represents little danger for medical equipment and seems suitable for medical environments even with several wireless devices used simultaneously.

Introduction

Hospitals all over the world have been reserved including wireless solutions, even if wireless communication solutions are now common in the society. Undocumented stories of medical device failure as a result of interference with wireless equipment like mobile phones have scared hospital staff and been a primary cause of restrictions in use of mobile phones in hospitals. More and more people are now questioning the restrictive policy of wireless equipment in hospitals [1]. Even if some studies provide support for a total ban of mobile phones [2][3], there is a lack of reliable evidence proving that wireless solutions or mobile phones have caused patient injury as a result of interference problems [4]. On the other hand, the question whether or not wireless equipment is suitable for medical rooms or not appears unanswered. Even though the medical equipment is not affected of wireless devices, it might be that the wireless equipment is affected by medical devices.

We decided to scrutinize this topic introduced several wireless devices with high emitting power into the operating room during animal procedures, with a standard setup of medical equipment. The aim of the pilot study was to reveal if the medical equipment was affected by electromagnetic interference and to see if several wireless devices used simultaneously was suitable for the operating room.

Methods

Two animal procedures were scheduled and it was decided to incorporate our testing simultaneously. Twelve locations on the floor were marked with numbers from one to twelve as shown in Figure 1. Two mobile GSM base stations (TEMS transmitters) were moved from point to point with two defined levels of output power and frequencies. The reason for choosing TEMS-transmitters instead of regular GSM-mobile phones was the continous transmission from theTEMS-transmitters as opposed to regular mobile phones transmitting only 1/8 of the time. Another advantage of the TEMS-transmitter was the possibility of choosing frequency and level of emitting power, factors hard to set on a regular mobile phone. The last argument for the transmitter was that the output power is several times higher than for a mobile phone, and the output level is constant in contrast to a mobile phone which turns down the emitting power as soon as communication is established. When using two TEMS-transmitters simultaneously, a wider frequency band

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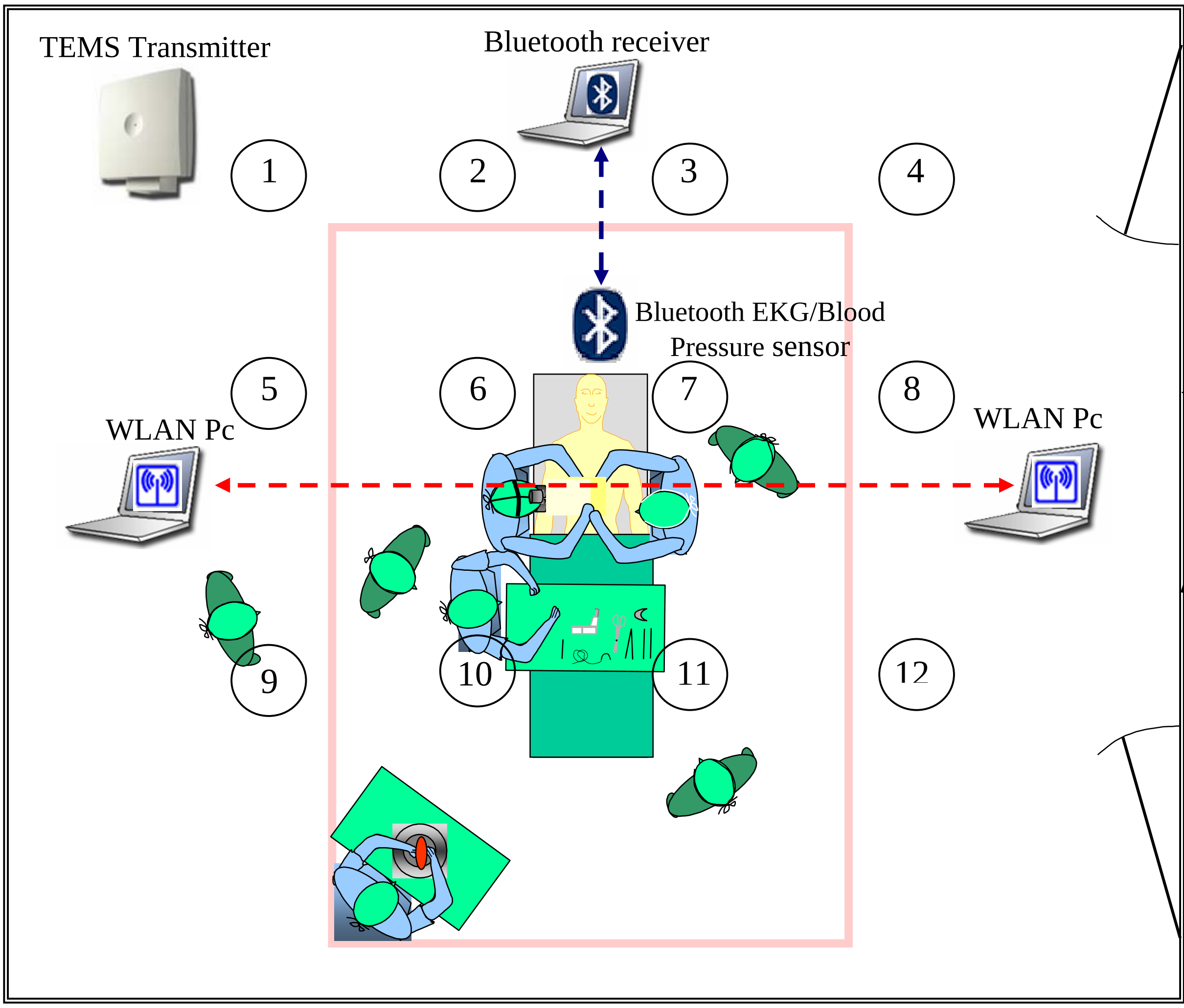

Figure1: Test setup. Two TEMS transmitters (mobile GSM base stations) with high output power and selectable frequency were moved from point to point in the operating room. For each position, data from the medical equipment were recorded together with data from the wireless devices. The medical equipment was inspected continuously during the procedure

could be covered, and vulnerability of cross interference would be revealed. We used two different sets of frequencies, one set with a low frequency of 935.200 MHz and a high frequency of 959.800 MHz and the other set with 959.600 MHz low and 959.800 MHz high. The output effect was switched between 10 and 6 W. Two computers were communicating simultaneously through a Wireless Local Area Network (WLAN). The WLAN communication was a predefined series of numbers transmitted from one computer to the other which allowed us to verify the communication afterwards. A newly developed EKG and Blood-pressure sensor prototype called WisMos, communicating with a PC through a Bluetooth interface, was the last wireless standard used for our testing [5]. WisMos is designed and manufactured by MEMSCAP A/S as a part of a Norwegian study called “Wireless Health and Care” [6], supported by the Norwegian research council. It is important to stress that the WisMos is a prototype only and is not commercially available. This means that no electromagnetic compatibility tests have been done and design elements like housing and sealing are temporary. The readings from the Bluetooth sensor were recorded and were compared to the recordings from a Siemens Sc-9000 patient monitor. This setup allowed us to use GSM,

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WLAN and Bluetooth communication simultaneously during a surgical procedure and check both the influence of the medical equipment and the stability of the wireless communication. The WLAN and Bluetooth units were locked in fixed positions while the TEMS-transmitters were moved from point to point as shown in figure 1. The medical equipment present during surgery is shown in Table 1

Table 1: list of the medical equipment used for the actual surgical procedure.

Group	**Type**
Vaporizer	Siemens
Patient monitor	Siemens SC 9000 XL
Patient monitor	Siemens SC 7000 XL
Anesthesia Workstation	Siemens KION
Pressure module	Siemens Hemo2 Pod
Monitor	Siemens Simomed HM
Syringe pump	Ivac P7000
Pressure infusor	Alton Dean
Harmonic ultrasound Scalpel	Ultracision
Invasive bloodgas analyzer	Neurotrend
Flowmeter, blood	Medi-Stim, VeriQ
X-ray contrast injector	Medrad Mark V Plus
Electrosurgical unit	Valleylab, Force 40 AS
X-ray table, movable	Siemens 57 67 046 G5482
Docking station	Siemens Infinity

The actual field-strength was measured with an EMR-300 radiation meter [7]. A spectrum analyser [8] connected to a computer nearby was used to characterise all the frequencies and power output in the actual test area.

All system clocks were synchronised with the master clock, defined as the Bluetooth PC internal clock. Adjustments were made retrospectively in order to optimise time synchronisation.

Results

Despite short distances between the TEMS-transmitters and the medical equipment, none of them malfunctioned seriously during testing. The only visible sign of interruptions were a slight flicker on some monitors. This flickering was not a real problem for the medical personnel, it could hardly be seen. No other effects were observed and all medical devices seemed to perform excellently throughout the procedure.

The Bluetooth sensor seemed to be affected when the TEMS-transmitters were operating at point 6 or 7. (See Figure 1). No clear failures were observed at the other positions. An accurate analysis of the numerical data is being performed and the quantitative results are yet to come. Looking at the data for some selected points reveal signs of irregular behaviour from the Bluetooth sensor (Figure 2). Divergence shown in figure 2 was also observed visually on the Bluetooth computer during the procedure, supporting the suspicion of interference in the system. When TEMS-transmitters were moved or switched off, Bluetooth readings returned to normal.

The WLAN connection failed from time to time neglecting to transmit a sample or two. As opposed to the Bluetooth sensor, regularity is hard to find so far. It might be a result of external influence but we are not confident to conclude in this matter. To summarize our results, there are signs of interference with the Bluetooth sensor system, and possible divergence in the WLAN communication. No signs of serious interference with the medical equipment were found. In our opinion it is a valid declaration that the wireless communication systems used for this procedures was no risk for the patient.

Discussion

Although interference was observed in the Bluetooth sensor system it is too early to conclude that Bluetooth as a communication standard is vulnerable to electromagnetic interference. As mentioned earlier, the WisMos system is a prototype made for 'proof of concept' situations more than extensive interference compatibility tests. In fact, the most likely explanation of the observed errors is interference with the active measuring bridge in the sensor element. This element is relatively unshielded and obviously vulnerable to electromagnetic influence. An important observation is that short distances between the sensor element and the TEMS-transmitters resulted in signs of interference. Short distances between the Bluetooth computer and the TEMS-transmitters gave no signs of interference or irregularities.

Another topic is the use of TEMS-transmitters instead of GSM-mobile phones. An objection to this method might be that the TEMS-transmitters are representing the base-stations and thus operating at different frequencies than the mobile phones. And the output power is four to five times higher than can be achieved from a regular mobile phone.

Even if the frequency band is higher for the TEMS-transmitters (935.200 – 959.800 MHz) than for a regular mobile phone (890.200 – 914.800 MHz) it is almost as close as it can be. Possible effects due to special frequency sensitivity would be achieved as a result of the high output power.

Another interesting topic is that we used two TEMS-transmitters, which means that we exposed the

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equipment to cross frequencies in addition to the clean frequencies set on the TEMS-transmitters.

The two WLAN PC's are configured to send the actual time sampled from the internal clock. This simplifies comparison afterwards and makes it possible to see irregularities visually.

In our opinion, this test setup is a worst-case arrangement with the potential of bringing to light any interference vulnerability of the medical equipment

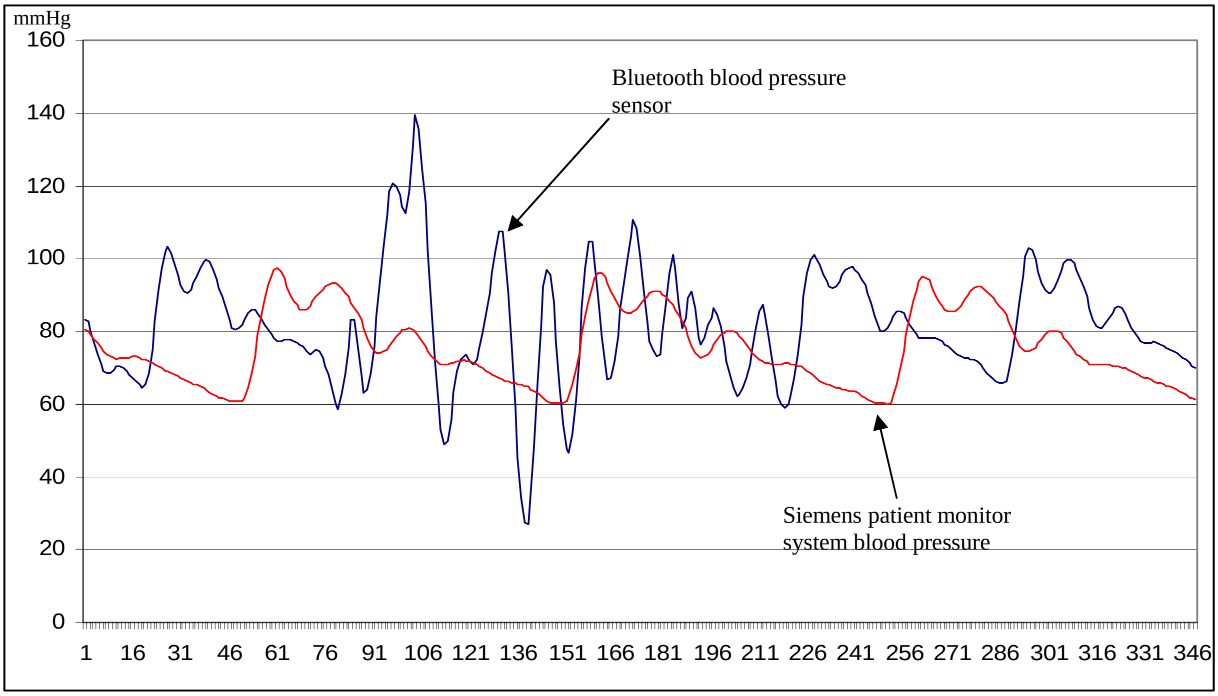

Figure 2: Blood pressure data from Siemens patient monitor system (SC 9000 XL) and a Bluetooth prototype sensor. The Bluetooth sensor fluctuates considerably while the blood pressure from the patient monitor system seems to be more stable

Conclusion

Wireless communication is a promising opportunity for future medical systems in the operating room. Today's wireless standards with moderate output power represents no real danger for the operation of medical equipment and seems to be suitable for medical environment even with several wireless devices used simultaneously. More tests are needed to verify this suitability and assure the reliability of wireless communication in order to implement wireless solutions in all kind of medical equipment.

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