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Disruption of an Infrared Capnograph Monitor by Hand-held Radio Transceivers

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THERE is growing awareness regarding potential problems that may be induced with two-way radios and cellular telephones if used in critical-care and telemetry units and in nurseries,§ but electromagnetic interference has not been reported as a source of error in capnometry. We report three incidents in which hand-held radio transceivers, in use outside the operating room, interfered with the output of a capnographic monitor, resulting in false readings that could have compromised patient management. Given the proliferation of radiofrequency devices in and around the operating room, these incidents may warn of a problem more serious than a design error by a single manufacturer. In other reported incidents that could have had serious clinical implications, cellular telephones caused an infant incubator to increase the heat to maximum setting, a ventilator to change its delivered gas volume, and a dialysis machine to sound an "air-in-blood" alarm and stop its blood pump.[1]

Case Reports

Case 1

A 4-kg, 4-month-old infant (postconceptual age 38 weeks) was anesthetized for an exploratory laparotomy. A 3.5-mm ID nasal endotracheal tube was in place and the lungs were being mechanically ventilated *via* a pediatric circle system. A CO_2 monitor (Marquette Advantage, Milwaukee, WI) indicated the end-inspired CO_2 (PI_{CO_2}) was 0 mmHg and the end-expired (PET_{CO_2}) was 25 mmHg. During surgery, the CO_2 monitor suddenly indicated that the PI_{CO_2} was 24 mmHg and that the PET_{CO_2} was 60 mmHg. The peak and end-expiratory pressures had not changed. Oxygen saturation, blood pressure, heart rate, and temperature also remained normal. We recalibrated the CO_2 monitor manually, and it indicated inspired and expired end-tidal CO_2 levels of 0 and 24 mmHg, respectively. Later, the hospital patient transport personnel used a two-way radio transceiver outside the operating room, and the CO_2 monitor again indicated increases of 20 and 25 mmHg in inspired and expired CO_2, respectively.

Case 2

A 65-yr-old, morbidly obese woman underwent surgery to remove a parathyroid adenoma. After a somewhat difficult intubation, and for the first 30 min of surgery, she had low blood pressures (80/55 mmHg), despite intravenous infusions, intermittent phenylephrine administration, and light anesthesia (0.4–0.6% isoflurane and O_2 and N_2O in a 1:1 ratio). The surgeon requested that the patient not receive muscle relaxants. Suddenly, the patient started "bucking," and the lungs became difficult to ventilate. We wondered if the endotracheal tube had become dislodged. At this moment, the CO_2 monitor (Marquette Advantage) suddenly displayed a continuous, high PET_{CO_2} pattern that filled the entire CO_2 display area and a "no-breathing" warning appeared, despite cycling of the mechanical ventilator and, eventually, manual ventilation. The abnormal readout persisted. While this was happening, a patient transportation crew was using a "walkie-talkie" in front of the operating room door, which was open. The patient's obesity made auscultating the lungs difficult. We therefore performed a direct laryngoscopy, to make sure the endotracheal tube was still in place. The capnography pattern spontaneously returned to normal after several minutes, and the remainder of the operation was uneventful.

Case 3

A 57-yr-old man was scheduled for colorectal surgery. Ten minutes after induction of anesthesia (which was uneventful), he had a blood pressure of 145/85 mmHg, a heart rate of 98 beats/min, and an esophageal temperature of 36.5°C. Suddenly, the PET_{CO_2}, as measured by a Marquette Advantage monitor, appeared to increase from 32 to 75 mmHg. The capnography tracing showed a rebreathing pattern and an PI_{CO_2} of 25 mmHg, but all other clinical measurements were normal. Arterial blood gas analysis was normal: the Pa_{CO_2} was 28 mmHg. By the time the blood-gas results were available (10 min),

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§ Anonymous: Exploring Medical Technology with Hewlett Packard; Managing EMC: Issues and challenges, PROBE. Andover, Hewlett-Packard Company Medical Products, 1995, pp 1–3 the $P_{ET_{CO_2}}$ reading had decreased spontaneously to 23 mmHg. The entire event coincided with the testing of a two-way radio transceiver by a clinical engineer in an adjacent operating room, which shares a walk-through utility room with our operating room.

Discussion

Normally, inspired gas in an anesthesia circle system contains no CO_2. A real increase in inspired CO_2 in a circle system may indicate rebreathing (the failure of a one-way valve), administration of CO_2, and/or CO_2 production greater than the CO_2 absorbent's capacity. Numerous other technical factors can also falsely alter the CO_2 readout, but the absolute increases are usually small.

The Marquette-Advantage monitor contains two systems that measure CO_2, a time-shared mass spectrometer, and an infrared analyzer that provides a breath-to-breath readout. Abel and Eisenkraft[2] reported that, if the mass spectrometer in the Marquette Advantage monitor is not properly configured, desflurane or sevoflurane can produce small, spurious increases in the end-tidal CO_2 reading. Also, the $P_{ET_{CO_2}}$ may be falsely increased as a result of a high respiratory rate in a mass spectrometry system that uses long sampling catheters.‖

Raemer and Calalang[3] analyzed different technical factors that can induce errors in CO_2 measurements in uncompensated infrared analyzers; inaccuracies ranged from 0.5 to 6.5 mmHg. However, other factors, such as a faulty algorithm for end-tidal CO_2 detection, poor calibration technique, or water contamination, can all lead to gross inaccuracies in CO_2 monitoring. Radio-frequency waves have not been reported as a source of error in CO_2 readings. Medical personnel should be aware of this increased radio-frequency "pollution." Cellular telephones may interfere with medical electrical equipment, and restriction of use in hospitals has been suggested.[1,4]

To speed operating room turnaround times and to facilitate patient transport, our institution recently purchased 4-watt, UHF FM two-way hand-held radio transceivers (Kenwood TK-320, Long Beach, CA; and Motorola Visar, Schaumburg, IL) which both operate in the 450–480 MHz frequency band. We were surprised to discover that, if used in or near the operating room, these transceivers can cause inaccuracies in end-tidal CO_2 readings as measured by the infrared analyzer of the Marquette Advantage monitor.

After the events described above (cases 1–3), we found we could reproduce the problem by transmitting with different transceivers at varying distances from the CO_2 monitor (fig. 1). We were able to reproduce these changes from any place in our largest operating rooms (8–10 meters). The lead-shielded and grounded door of the operating room blocked radio-frequency interference when it was closed, but when it was open, we

‖ Eisenkraft JB: Monitoring gas/vapors. ASA Refresher Courses 1994;125:1–7

A

B

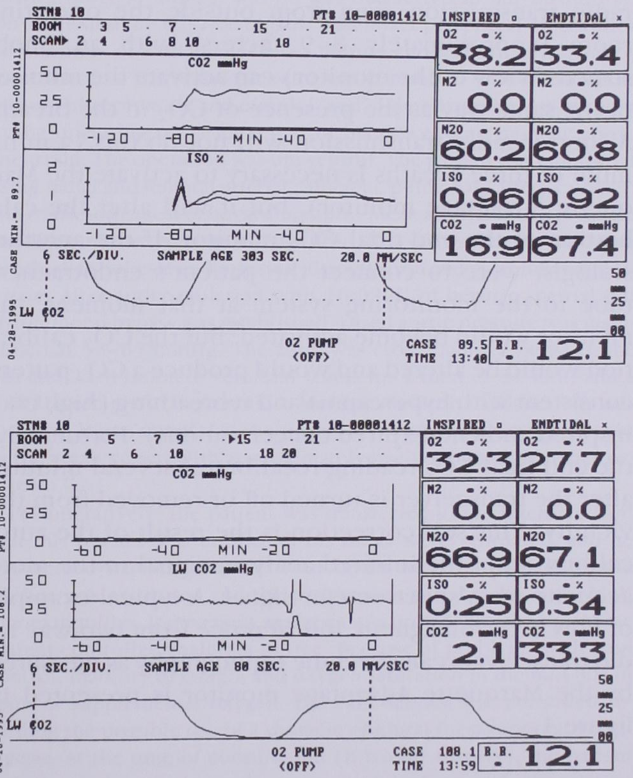

Fig. 1. Capnographic tracings from an anesthetized patient after a 4-watt hand-held radio transceiver was activated 10 feet from the monitor and following its inactivation. (*A*) Less than 1 min after radio transceiver activation, the $P_{I_{CO_2}}$ appears to be 16.9 mmHg and the $P_{ET_{CO_2}}$ appears to be 67.4 mmHg. (*B*) The radio transceiver was turned off, and the falsely elevated $P_{ET_{CO_2}}$ (measured by the infrared analyzer) autocalibrated to the mass spectrometer signal (33.3 mmHg). The $P_{ET_{CO_2}}$ trends were obtained from the mass spectrometer (*B*, CO_2 mmHg) and from the infrared analyzer (*B*, LW CO_2 mmHg). The mass spectrometer trend indicated no change in $P_{ET_{CO_2}}$. In the trend depicted by the infrared analyzer, immediately after the −20-min mark, the baseline of the CO_2 suddenly shifted to approximately 20 mmHg, which coincided with activation of the radio transceiver. Over the next several minutes, the transceiver was not used and the infrared analyzer signal recalibrated its $P_{ET_{CO_2}}$ to slightly above zero, corresponding to the mass spectrometer signal.

were able to induce the interference from outside the operating room, 10 meters from the monitor.

These radio-frequency transmissions typically interrupted and distorted the end-tidal CO_2 waveform and then abruptly increased the PI_{CO_2} and PET_{CO_2} readings to between 20 and 25 mmHg and between 65 and 75 mmHg, respectively. Occasionally, the monitor continuously displayed a PET_{CO_2} tracing and a high CO_2 level, and a "no-breathing" warning appeared, such as in our second patient.

If the Advantage monitor is in a stand-by mode (as it is when not connected to the patient), a 5- to 10-s radio transmission even from outside the operating room (approximately 8–9 meters, with an unobstructed view of the monitor) can activate the monitor in the same way as the presence of CO_2 in the breath. A shorter radio transmission will not do this (a minimum of three breaths is necessary to activate the Marquette Advantage monitor), but it will alter the calibration of the end-tidal CO_2 monitor. If the anesthesiologist were to connect the patient's endotracheal tube to the monitoring system at that moment, the monitor would become activated, but the CO_2 calibration would be altered and would produce a CO_2 pattern consistent with hypercapnia and rebreathing (high end-inspired and end-expired concentrations). Fortunately, the end-tidal CO_2 reading recalibrates several minutes after the transceiver is turned off or removed from the vicinity. This self correction is the result of the autocalibration of the infrared analyzer signal to the more accurate mass spectrometer signal. A typical example of how electromagnetic interference from two-way radio transceivers can affect the capnography as measured by the Marquette Advantage monitor is presented in figure 1.

We also tested a 2-watt hand-held radio transceiver (Johnson, Waseka, MN; operating frequency band 450–480 MHz) and found that, in contrast to the 4-watt transceivers, it had minimal impact on the Marquette Advantage CO_2 monitor, and then only when placed several centimeters from the monitor screen. We also tested a different monitor (Datex, Instrumentarium Corp., Helsinki, Finland) that appeared to be properly shielded against radio-frequency signals; not even use of a 4-watt radio transceiver in the immediate vicinity influenced its function.

In conclusion, radio interference from 4-watt hand-held radio transceivers can cause spuriously high PET_{CO_2} readings on the Marquette Advantage monitor, shifting PI_{CO_2} reading from zero to between 20 and 25 mmHg. If these high CO_2 values are taken seriously, the patient may be mismanaged.

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