Investigating Electromagnetic Interference of Oscillating Ventilators by Radio Transmitting Devices

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Scope:

Understanding the electromagnetic interference associated with Clinical Mobile Computers and Oscillatory Ventilators

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Abstract

Introduction: The purpose of this study is to determine the effect of radio transmitting devices (i.e. cell phones, mobile computers, etc.) on high frequency oscillating ventilators (HFOV) used in the neonatal intensive care unit. Studies have shown significant EMI between ventilators and communication devices, which disrupt normal operation by creating modular malfunctions, change in parameter settings, and random shut downs and reboots. HFOVs are categorized as life safety equipment, so it is imperative to ensure normal operation.

Methods: To perform this study and directly relate any interference to the radio transmitting (RF) devices, all tests will be performed in a controlled, RF isolated environment. Both clinical mobile computers (up to 6), smart phones (up to 6), and two-way radios (up to 2) will be used with Wi-Fi, LTE, and Bluetooth connectivity (if applicable). The phones will be set to use certain applications, browse websites, and make phone calls, in an attempt to increase the output power of each phone. The two portable radios will be used to transmit and receive signals in close proximity with the devices. Each radio transmitting device will be tested at ranges of 4 feet, 2 feet, 1 foot, 6 inches, 3 inches, and 0 inches away from the medical equipment. At each specified distance, the RF devices will be swept horizontally and vertically to achieve a more comprehensive coverage of the environment surrounding the medical equipment. These sweeps will be performed at the specified distances from all sides of the oscillatory ventilators. The two-way radios will be tested in order to validate reproducibility of electromagnetic interference.

Results: A total of 30 combinations of RF transmitting devices were tested on 2 types of oscillatory ventilators and demonstrated 20 incidents in 180 cases (11.11%); 7 (35%) were categorized as hazardous, 6 (30%) as significant, and 7 (35%) as light. The GPRS signals from the two-way radios induced all (100%) of the hazardous incidents, a majority (83.33%) of the significant incidents, and a minority (42.86%) of light incidents. The UMTS signals from the smart phones produced a limited (16.67%) amount of significant incidents and a majority (57.14%) of the light incidents. The Wi-Fi only signals did not cause an interference incident (0%).

Conclusions: HFOVs are vulnerable to EMI from GPRS and UMTS telecommunication signals, however, appear to not be affected by Wi-Fi channel signals from the clinical mobile computers and the smart phones. The IEEE standard of practice to keep mobile phones and computers approximately 1 meter from a life safety device (i.e. oscillatory ventilator) should still be in effect in combination with easily accessible areas of unrestricted use.

Introduction

The primary focus for this study will be to test two types of oscillatory ventilators (neonatal and adult) and the electromagnetic interference (if any) between clinical mobiles computers. Smart Phones and two-way radios will be used as baseline data for comparison of interference incidents. All of the devices being tested have published warnings regarding the potential for radio interference. This potential for interference has become an important patient safety issue and ultimately led to the creation of this study.

Methods

Medical Equipment

In all, 180 scenarios for 2 types of oscillatory ventilators (neonatal and adult) were tested for EMI (Table 1). The adult ventilator was designed for adults/children while the neonatal was designed only for children. The major differences between the two medical devices are the ability to change the centering position of the piston and the automatic shut off feature for the neonatal series when the mean pressure parameter falls below 10.6 cm H2O. The ventilators were removed from service in order to perform this study.

Signals

The general packet radio service (GPRS) were generated from two-way digital portable radios. The available 3W frequency used was 764-870MHz with a rated RF output power of 1-3W and a receiver rated output power of 500mW.

The Universal Mobile Telecommunications System (UMTS) had a bandwidth frequency of 5MHz and a carrier frequency of approximately 850MHz. The average output was 0.75-1W and the Bluetooth frequency was 2.4GHz with 10mW output power. The Wi-Fi only operating frequencies abide by FCC standards 802.11b and 802.11g were channel 7 (2442 MHz) and channel 11 (2462 MHz). In attempt to maximize the power of each mobile device, several applications were used at any particular time during testing. The maximal performance was chosen to mimic the worst-case scenario for EMI incidents.

The signals were transmitted near the ventilators in an RF isolated environment to prevent outside noise. The RF transmitting devices were tested by placing them closest to the poorest shielded locations (as shown in Appendix G) on all sides by vertically and horizontally sweeping the devices across these areas. Areas of the device that were shield protected to RF transmission were not applied to the findings. Each radio transmitting device will be tested at ranges of 4 feet, 2 feet, 1 foot, 6 inches, 3 inches, and 0 inches away from the medical equipment. In the event of interference, the test was repeated 3 times to assess reproducibility. Change in amplitude, % inspiratory time, frequency and bias flow was observed, but the mean pressure monitor was observed and documented as the main parameter to show the effect of EMI. Prior to each scenario test, the oscillatory ventilator was set to the parameters listed below:

- Mean Pressure Monitor: 29 cm H2O
- Amplitude: 44 cm H2O
- % Inspiratory Time: 33
- Frequency (two settings): 15 Hz and 8 Hz
- Bias Flow: 20

Test Procedures for Each RF Device

- Two-way Digital Portable Radios
  - Turn on two radios and set one radio across the room.
  - The other radio will be used for testing. At the specified distances shown in Appendix B & E, the "Talk" button will be pressed and the resulting effect on the ventilator operating at 15Hz will be documented.
  - Repeat this test with the ventilator operation frequency at 8Hz.
- 2,4,6 smart phones with Wi-Fi only (without Bluetooth/LTE connectivity)
  - 2 smart phones with Wi-Fi only will be brought to specified distances shown in Appendix C & F away from the ventilator (ventilator operates at frequency of 15Hz).
  - At each distance, the phones will be used to browse websites, use applications, and call each other.
  - The resulting effect on the mean pressure monitor (mm H2O) will be documented.
  - Repeat this test with 4 and 6 phones.
- 2,4,6 smart phones with Bluetooth/LTE connectivity
  - 2 smart phones with 3G and Bluetooth capabilities will be brought to specified distances shown in Appendix A & D away from the ventilator (ventilator operates at frequency of 15Hz).
  - At each distance, the phones will be used to browse websites, use applications, and call each other. Bluetooth connectivity will also be activated at each distance.
  - The resulting effect on the mean pressure monitor (mm H2O) will be documented.
  - Repeat this test with 4 and 6 phones.
- 2,4,6 Clinical Mobile Computers with Wi-Fi only (without Bluetooth/LTE connectivity)
  - 2 clinical mobile computers with Wi-Fi only will be brought to specified distances shown in Appendix C & F away from the ventilator (ventilator operates at frequency of 15Hz).
  - At each distance, the phones will be used to browse websites, use applications, and call each other.
  - The resulting effect on the mean pressure monitor (mm H2O) will be documented.
  - Repeat this test with 4 and 6 phones.
- One-to-one of a Clinical Mobile Computer and smart phone with Wi-Fi only
  - One clinical mobile computer and one smart phone with Wi-Fi only will be brought to specified distances shown in Appendix C & F away from the ventilator (ventilator operates at frequency of 15Hz).
  - At each distance, the phones will be used to browse websites, use applications, and call each other.
  - The resulting effect on the mean pressure monitor (mm H2O) will be documented.
  - Repeat with a two-to-two ratio of mobile devices.

Classification of Incidents

Incidents involving EMI between the RF transmitting device and the ventilator were documented for change in mean pressure monitor and observed for fluctuations in the other parameters. The four classifications of incidents were: light, significant, hazardous, and none. Light incidents were categorized as a mean pressure monitor value less than or equal to 2 cm H2O change. Significant incidents were categorized as a mean pressure monitor value less than or equal to 10 cm H2O change. Hazardous incidents were categorized as a mean pressure monitor value greater than 10 cm H2O or complete shut off of the ventilator.

Results and Discussion

EMI by GPRS and UMTS signals on oscillatory ventilators created 8.33% and 2.78% of the total number of incidents (including "none") while the Wi-Fi frequency signals created no observable EMI.

A total of 30 combinations of RF transmitting devices were tested on 2 types of oscillatory ventilators and demonstrated 20 incidents in 180 cases (11.11%); 7 (35%) were categorized as hazardous, 6 (30%) as significant, and 7 (35%) as light. The GPRS signals from the two-way radios induced all (100%) of the hazardous incidents, a majority (83.33%) of the significant incidents, and a minority (42.86%) of light incidents. The UMTS signals from the smart phones produced a limited (16.67%) amount of significant incidents and a majority (57.14%) of the light incidents. The Wi-Fi only signals did not cause an interference incident (0%). This data is presented in Table 2

The neonatal series oscillatory ventilator was more sensitive than the adult series. This may have been due to the automatic shut off feature on the neonatal series. The piston position knob for the neonatal was centered for every experiment, so this was not a cause for sensitivity to EMI. The adult series would not shut the piston off automatically and instead would create an alarm and continue to decrease to hazardous levels for mean pressure monitor.

The neonatal series was more effected hazardously by EMI from the GPRS signal (Avg=0.125 ft) compared to the adult series (Avg=0.083 ft). The UMTS signal only significantly affected the neonatal ventilator's performance one time when 6 phones with LTE/Bluetooth connectivity were touching the front and back of the device in the weak area points (decrease in mean pressure monitor by 3-4 cm H2O). However, 6 network-connected phones still caused a light interference that affected the mean pressure monitor by an average decrease of .788 cm H2O from an average distance of 0.250 ft (these numbers are representative of both ventilator series). Data reflecting the type of incident and the corresponding average distance are given in Table 1.

Some factors that could have led to error in this experiment include using portable air and O2 tanks for the adult series ventilator testing and wall-mounted gas ports for the neonatal series testing. These different sources may have caused the data values to be different and thus not significant. Other RF sources (light, outlets, etc.) may have affected results of the testing when located in the RF isolated environment.

Type of ventilator	Type of incident	Number of incidents	Avg distance (ft)	Type of signal		
				GPRS	UMTS	Wi-Fi
neonatal	Hazardous	4	0.125	4	0	0
	Significant	3	0.333	2	1	0
	Light	4	0.688	2	2	0
	None	79	N/A	4	27	48
adult	Hazardous	3	0.083	3	0	0
	Significant	3	0.417	3	0	0
	Light	3	0.417	1	2	0
	None	81	N/A	5	28	48
	Total	180		15	5	0
	%	100.00		8.33	2.78	0.00

Table 1: Overview of type of incident, average distance (ft), and type of signal causing EMI

Type of Incident	Total	Type of signal		
		GPRS	UMTS	Wi-Fi
Hazardous	7	7 (100%)	0 (0.00%)	0 (0.00%)
Significant	6	5 (83.33%)	1 (16.67%)	0 (0.00%)
Light	7	3 (42.86%)	4 (57.14%)	0 (0.00%)

Table 2: Overview the totals and types of signals corresponding to each type of incident

The lack of EMI incidents from these devices on Wi-Fi only mode demonstrates their electromagnetic safety even while touching the ventilator in the weak areas. LTE connectivity presents the ability to create significant EMI events for ventilators, however, when this mode is disconnected, the devices present much less of an EMI concern for these oscillatory ventilators. The overall ratio for GPRS:UMTS:Wi-FI is 12:5:0. This demonstrates the majority of incidents involve GPRS signals and none of the incidents involve Wi-Fi only signals.

Conclusion

Although EMI has a significant impact on ventilators, GPRS and UMTS were the only incident-causing signals when used in close proximity to the oscillatory ventilators. The clinical mobile computer devices demonstrated no interference on the ventilators when used alone and when in conjunction with other smart phones with no LTE or Bluetooth connectivity. Users of the clinical mobile computer should still be educated about safeguarding the device was life safety devices as much as possible. The IEEE standard of practice to keep mobile phones and computers approximately 1 meter from a life safety device (i.e. oscillatory ventilator) should still be in effect in combination with easily accessible areas of unrestricted use.

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Appendix A – *UMTS Signal EMI Data Table for neonatal Series Ventilator*

Distance (ft)	2 smart phones	4 smart phones	6 smart phones	One to One*	Two to Two*
0	No effect	No effect	Front: ↓ 3-4 cm H2O	No effect	No effect
0.25	No effect	No effect	Front: ↓ 1 cm H2O	No effect	No effect
0.5	No effect	No effect	Front: ↓ .1-.3 cm H2O	No effect	No effect
1	No effect	No effect	No effect	No effect	No effect
2	No effect	No effect	No effect	No effect	No effect
4	No effect	No effect	No effect	No effect	No effect

Appendix B - *GRPS Signal EMI Data Table for neonatal Series Ventilator*

Distance (ft)	3W Two-Way Radio (@ 8 Hz)	3W Two-Way Radio (@ 15 Hz)
0	Front: instantaneous shut off Back: instantaneous shut off	Front: instantaneous shut off Back: instantaneous shut off
0.25	Front: Rapid decrease of MP until automatic shut off Back: Rapid decrease of MP until automatic shut off	Front: Rapid decrease of MP until automatic shut off Back: ↓ 10-12 cm H2O
0.50	Front: ↓ 9.5-10 cm H2O Back: ↓ 5-6 cm H2O	Front: ↓ 7-8 cm H2O Back: ↓ 3-4 cm H2O
1	Front: ↓ 1-2 cm H2O Back: ↓ 0.6 cm H2O	Front: 1-2cm H2O Back: No effect
2	No effect	No effect
4	No effect	No effect

Appendix C – *Wi-Fi Only Signal EMI Data Table for neonatal Series Ventilator*

Distance (ft)	2 clinical mobile computers	4 clinical mobile computers	6 clinical mobile computers	2 smart phones	4 smart phones	6 smart phones	One to One	Two to Two
0	No effect	No effect	No effect	No effect	No effect	No effect	No effect	No effect
0.25	No effect	No effect	No effect	No effect	No effect	No effect	No effect	No effect
0.5	No effect	No effect	No effect	No effect	No effect	No effect	No effect	No effect
1	No effect	No effect	No effect	No effect	No effect	No effect	No effect	No effect
2	No effect	No effect	No effect	No effect	No effect	No effect	No effect	No effect
4	No effect	No effect	No effect	No effect	No effect	No effect	No effect	No effect

Appendix D– *UMTS Signal EMI Data Table for adult Series Ventilator*

Distance (ft)	2 smart phones	4 smart phones	6 smart phones	One to One*	Two to Two*
0	No effect	No effect	Front: ↓ 1-2 cm H2O	No effect	No effect
0.25	No effect	No effect	Front: ↓ 0.4-0.5 cm H2O	No effect	No effect
0.5	No effect	No effect	No effect	No effect	No effect
1	No effect	No effect	No effect	No effect	No effect
2	No effect	No effect	No effect	No effect	No effect
4	No effect	No effect	No effect	No effect	No effect

Appendix E - *GRPS Signal EMI Data Table for adult Series Ventilator*

Distance (ft)	3W Two-Way Radio (@ 8 Hz)	3W Two-Way Radio (@ 15 Hz)
0	Front: Rapid decrease in MP until it reached alarm limit (↓ 19 cm H2O) Back: ↓ 13-15 cm H2O	Front: Rapid decrease in MP until it reached alarm limit (↓ 19 cm H2O) Back: ↓ 14-16 cm H2O
0.25	Front: ↓ 8-9 cm H2O Back: ↓ 5-6 cm H2O	Front: Rapid decrease of MP until it reached alarm limit (↓ 19 cm H2O) Back: ↓ 6-7 cm H2O
0.50	Front: ↓ 5-6 cm H2O Back: ↓ 1-2 cm H2O	Front: ↓ 8-9 cm H2O Back: ↓ 3-4 cm H2O
1	No effect	Front: 0.3-0.4 cm H2O Back: No effect
2	No effect	No effect
4	No effect	No effect

Appendix F – *Wi-Fi Only Signal EMI Data Table for adult Series Ventilator*

Distance (ft)	2 clinical mobile computers	4 clinical mobile computers	6 clinical mobile computers	2 smart phones	4 smart phones	6 smart phones	One to One	Two to Two
0	No effect	No effect	No effect	No effect	No effect	No effect	No effect	No effect
0.25	No effect	No effect	No effect	No effect	No effect	No effect	No effect	No effect
0.5	No effect	No effect	No effect	No effect	No effect	No effect	No effect	No effect
1	No effect	No effect	No effect	No effect	No effect	No effect	No effect	No effect
2	No effect	No effect	No effect	No effect	No effect	No effect	No effect	No effect
4	No effect	No effect	No effect	No effect	No effect	No effect	No effect	No effect