

ELECTROMAGNETIC INTERFERENCE AND THE PACEMAKER PATIENT

While clinically significant problems with electromagnetic interference (EMI) are rare, a pacemaker's response to EMI becomes more diverse as technology advances. Pacemaker manufacturers continue to develop interference protection circuitry to keep up with these vast sources of EMI.

The pacemaker's response to EMI is dependent on the characteristics of the EMI, proximity to the interference, available shielding, and the sensing characteristics and polarity of the pacemaker. The pacemaker circuitry is designed to attenuate any interference outside the normal intracardiac range (10 Hz - 100 Hz). This is achieved by using bandpass filters.

EMI sources can be broadly classified as galvanic, electromagnetic or magnetic.

- Galvanic interference requires direct contact with electrical current. This is most often seen in defibrillation/cardioversion, cautery, Transcutaneous Electrical Nerve Stimulator units and diathermy.
- Electromagnetic or electrically coupled interference does not require direct body contact. This interference is most often seen with arc welders, radio transmitters, electrical appliances, metal detectors, therapeutic ultrasound and high voltage power lines.
- Magnetic interference occurs when a patient comes in close proximity with an intense magnetic field. This is often seen in nuclear magnetic resonance imaging (NMR/MRI) and steel mill induction furnaces.

EMI with signal modulation can mimic normal intracardiac signals. When detected, the response to EMI may present itself as a single beat inhibition, total inhibition, noise reversion/asynchronous pacing, rate increase, erratic pacing, or no output. These responses are usually temporary, but can be permanent if the pulse generator circuitry is damaged.

A pacemaker's response to EMI is highly dependent on the specific EMI source, the pacemaker's mode, and sensing polarity. Included is a list that details the interaction of commonly encountered pacemaker EMI sources. Accompanying this list is a summary table of these common EMI sources and the potential device responses. For specific instructions for use and suggested recommendations for a given pacemaker model, please refer to the manufacturer's User's Manual.

If you have any questions or would like to discuss this topic in greater detail, please do not hesitate to contact Technical Services at 800-722-3774.

Common Sources of EMI

- Ablation (RF):** Loss of capture - exit block is frequently seen during RF ablations. Arrhythmia induction, undersensing, inhibition, rate increase and noise reversion pacing are also possible. Circuit damage is less likely than DC ablation.
- Acupuncture:** Low frequency electroacupuncture may cause inhibition and noise reversion at high frequencies.
- Airport detector/Metal detectors:** Single beat inhibition is rare and seen only on unipolar devices.
- Anti-theft devices/Electronic Article Surveillance (EAS):** Possible inhibition or rate increase reported primarily on unipolar devices especially if patient leans or lingers near EAS. An increased incidence of cross-talk is seen on unipolar DDD pacers.
- Arc welders:** Single beat inhibition is commonly seen on unipolar devices each time the arc is struck. High magnetic fields from the cables may cause reed switch closure resulting in asynchronous pacing.
- Auto Smart Key:** No effect.
- Bone Stimulator:** Possible inhibition on unipolar devices.
- Cardioversion:** Cardioversion, performed at high energies similar to that of defibrillation or performed directly over the pulse generator, may damage circuitry resulting in no output, erratic pacing, or rate increases. Energy conducted through the lead may cause arrhythmias and myocardial burning.
- Cautery:** Cautery used near the pacing system may result in inhibition, asynchronous pacing and/or circuit damage. Energy conducted through the lead may cause arrhythmias and myocardial burning. Impedance-based rate responsive pulse generators may exhibit erratic pacing or rate increases. A Shaw scalpel uses non-electric cautery that is thermally coupled and will not cause any interference.
- CB radio:** Single beat inhibition may be seen with microphone keying on unipolar devices.
- Cellular Phone:** Total inhibition or asynchronous pacing is possible with some digital cell phones if placed within 6 inches of the pacemaker. SJM pacemakers implanted since the late 1980's are cellular tested and should not be affected by cellular phones.
- CT Scan/PET Scan:** No documented reports of capture or sensing anomalies. Possible sensor driven pacing up to programmed Maximum Sensor Rate.
- Defibrillation:** Defibrillation performed at high energies, or defibrillation directly over the pulse generator, may damage circuitry resulting in no output, erratic pacing, or rate increases. Energy conducted through the lead may cause arrhythmias and myocardial burning.
- Dental scaler:** Older ferromagnetic ultrasonic scalers may cause single beat inhibition on unipolar pacemakers. Piezo-electric scalers have no effect. Activity rate responsive devices may exhibit increased pacing rates.
- Diathermy:** Used in the near vicinity of the pacing system, diathermy may result in inhibition, asynchronous pacing, and/or circuit damage. Energy conducted through the lead may cause arrhythmias and myocardial burning.
- Diving (SCUBA):** SJM pacemakers are tested to 7 atmospheres of pressure, which equates to 198 feet of depth. Possible rate increase up to programmed Maximum Sensor Rate in devices that have piezoelectric crystal activity sensors.
- Electric accessories (blanket/heating pad/shaver, etc.):** Single beat inhibition is rare and seen only on unipolar devices.
- Electric tools:** Single beat inhibition is rare and may be seen on unipolar devices during use of power tools like drills and saws.
- Electric toothbrush:** No effect from standard or ultrasonic models.
- Electro-convulsive shock therapy (ECT/EST):** Inhibition and/or noise reversion is possible, especially with unipolar pulse generators. Activity sensor rate responsive pulse generators may track the seizure activity.
- Fluoroscopy:** See Radiation, Diagnostic.
- Ham radio:** Single beat inhibition may be seen on unipolar devices during microphone keying.

Hyperbaric Oxygen Therapy: Possible rate increase up to programmed Maximum Sensor Rate in devices that have piezoelectric crystal activity sensors. Pacemakers are tested to 7 atmospheres (approx. 103 psi) of pressure.

iPod/mp3 players: No effect. Possible disruption of telemetry if used during device evaluation in hospital or clinic.

Lithotripsy - ESWL: No interactions expected on newer systems such as Siemens Lithostar and Wolf Piezolith. The Dornier HM3 lithotripter (used in a non R-wave triggered mode) shock wave may cause a single inappropriate myocardial depolarization. In the non-triggered mode it also may cause single beat inhibition. Additionally, the Dornier HM3 lithotripter has the potential to cause permanent damage (piezoelectric, silicon circuitry, and other hardware components) if the ESWL focal point is directed towards the device.

Magnet therapy: Asynchronous pacing possible if magnetic pads/objects are used within 18 inches of pacemaker. Prolonged asynchronous pacing from magnetic mattress pads is not recommended. Magnetic pads used below the waist will not interfere with pacemaker operation.

Microwave ovens: In 1976 the FDA stated there is no longer substantial risk of pulse generator interference from microwave ovens which are now built with leakage protection. Pulse generators are now manufactured to prevent interference from microwaves.

MRI (Magnetic Resonance Imaging): Frequent effect from MRI is asynchronous pacing. Reed switch magnetization, rate increases in DDD, single beat inhibitions, component damage, lead dislodgment, rapid pacing (300 PPM), lead heating possibly leading to tissue damage and pacing threshold changes, and generator movement within the pocket are also possible but not common.

Power lines, high voltage: 400 kVolt high voltage power lines may cause asynchronous pacing, especially if patient is near a large metal object (e.g. car).

Pulp tester: Single beat inhibition is rare but may be seen on unipolar devices.

Radar: Single beat inhibition is rare but may be seen on unipolar devices.

Radiation, Diagnostic: No effect. Sustained diagnostic radiation such as fluoroscopy may cause possible temporary increased sensor rate.

Radiation, Therapeutic: Damage to the CMOS circuitry can occur. Effect is cumulative in dose and affects both bipolar and unipolar pulse generators. Failure modes include temporary increased sensor rate, circuit damage, run-away pacer, erratic pacing, sensing anomalies, memory corruption, and no output.

Radio transmitter, AM: If signal modulation occurs, inhibition may be seen on unipolar pulse generators, relative to power, frequency, modulation, and proximity. Noise reversion pacing is possible.

Radio transmitter, FM: If signal modulation occurs, inhibition may be seen on unipolar pacemakers relative to power, frequency modulation, and proximity. Noise reversion pacing is possible.

Respiratory/ECG monitors: Impedance based ECG/respiratory monitors may cause upper rate pacing in impedance based pacemakers especially with monitors emitting a current signal parallel to the pacer system.

TENS (Transcutaneous Electrical Nerve Stimulator): Normally used high frequencies (>30 Hz) may cause noise reversion on unipolar pulse generators. Low frequencies (<10 Hz) may cause inhibition on unipolar pulse generators. Burst mode on newer TENS units is contraindicated due to probable device inhibition.

TV transmitter: Although rare, inhibition and noise reversion of unipolar devices has been documented.

Ultrasound, Diagnostic: No effect.

Ultrasound, Therapeutic: Single beat inhibition is rare and may be seen on unipolar devices. Therapy should not be given directly over the pulse generator. Activity sensor rate responsive pulse generators may exhibit piezo crystal shatter.

EMI SUMMARY TABLE

INTERACTION POSSIBILITY OF COMMONLY ENCOUNTERED SOURCES AND RESPONSES

Source	Pacer Damage	Total Inhibition	1 Beat Inhibition	Asynch /Noise	Rate Increase	Unipolar Bipolar
Ablation (RF)	Y*	Y	Y	Y	Y*	U & B
Acupuncture	N	Y	Y	Y	N	U & B
Airport detector	N	N	Y	N	N	U
Anti-theft device(EAS)	N	Y	Y	Y	Y*	U&B
Arc welder	N	Y	Y	Y	N	U & B
Auto Smart Key	N	N	N	N	N	-
Bone stimulator	N	Y	Y	Y	N	U
Cardiokymography	N	Y	Y	N	Y	U & B
Cardioversion	Y	N	N	N	N	U & B
Cautery/coagulation	Y	Y	Y	Y	Y ¹	U & B
CB radio	N	N	Y	N	N	U
Cellular phone	N	Y ⁴	Y ⁴	Y ⁴	N	U & B
CT Scan/PET Scan	N	Y ⁵	Y	N	Y	U & B
Defibrillation	Y	N	N	N	N	U & B
Dental scaler	N	N	Y*	Y*	Y ³	U
Diathermy	Y	Y	Y	Y	Y	U & B
Diving (SCUBA)	N	N	N	N	Y ³	U & B
ECT/EST	N	N	Y	Y	Y ³	U
Electric accessories	N	N	Y*	N	N	U
Electric tools	N	N	Y*	N	N	U
Electric toothbrush	N	N	N	N	N	-
Electrolysis	N	N	Y	Y	N	U
Fluoroscopy	N	N	N	N	Y	U & B
Ham radio	N	N	Y	N	N	U
Hyperbaric Oxygen Therapy	N	N	N	N	Y ³	U & B
iPod/mp3	N	N	N	N	N	-
Lithotripsy	N ⁶	N	N	N ⁶	N	U & B
Magnet therapy	N	N	N	Y	Y	U & B
Microwave	N	N	N	N	N	-
MRI	Y	N	Y	Y	Y ²	U & B
Powerline, high voltage	N	N	N	Y	N	U & B
Pulp tester	N	Y*	Y*	Y	N	U
Radar	N	N	Y*	N	N	U
Radiation - Diagnostic	N	N	N	N	Y	U & B
Radiation - Therapeutic	Y	Y	Y	N	Y	U & B
Radio transmitter AM	N	N	Y*	N	N	U
Radio transmitter FM	N	N	Y*	Y*	N	U
Respiratory Monitor (Impedance based)	N	N	N	N	Y ¹	U & B
TENS	N	Y	N	Y	Y ²	U
TV transmitter	N	Y*	Y*	Y*	N	U
Ultrasound - Diagnostic	N	N	N	N	N	-
Ultrasound - Therapeutic	Y ³	N	Y*	N	N	U

1 = Impedance-based pulse generators
 2 = DDD mode only
 3 = Piezo crystal-based pulse generators
 * = Remote potential for interference

4 = SJM devices implanted since the late 1980's are cellular tested
 5 = Interference not observed in SJM pacemakers
 6 = Assuming newer systems are used, such as Siemens Lithostar and Wolf Piezolith

EMI Bibliography

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