Electrosurgery and ultrasonics on patients with implantable cardiac devices: Evidence of side effects in the dental practice

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Objective: Implantable cardiac pacemakers and cardiac defibrillators (ICDs) have been introduced in the care of patients with cardiac dysrhythmias. Most dental practitioners demonstrate extreme caution when treating patients with ICDs. This paper presents a review of the available literature on these devices and how they interact with dental electrosurgery and ultrasonic device use. Results: Based on the analysis of the literature, this view is not corroborated by the current clinical data, and appears to be misguided. While further in-vivo studies are needed to truly determine the true level of risk, the evidence suggests that there is no contraindication for electrosurgery or ultrasonics use in patients with ICDs. Conclusion: Using the precautions stated in this analysis, the risk of any deleterious effect on ICD function is minimal. (Quintessence Int 2016;47:151–160; doi: 10.3290/j.qi.a34699)

Key words: electrosurgery, implantable cardiac devices, side effects, ultrasonic

Implantable cardiac pacemakers and cardiac defibrillators were introduced in the care of patients with cardiac dysrhythmias more than 50 years ago. More than a million individuals within the United States have pacemakers, a number that is increasing every year, since life expectancy has increased as a result of healthier lifestyles and advances in modern medicine.1 A significant increase in the number of patients presenting for dental treatment with implantable cardiac devices has therefore been seen in recent years.2 Although currently available pacemakers are very sophisticated devices, they may be affected by a variety of external factors,3 including modern surgical tools. When caring for these patients, healthcare professionals are presented with a complex situation, where the interaction between modern surgical tools and implantable cardiac devices needs to be thoroughly understood in order to avoid the potential complications associated with their combined use on a dental patient.

We reviewed the literature available on these devices and how they interact with dental electrosurgery and ultrasonic device use. We focused on reports of any complications, or lack thereof, during dental...
procedures on patients presenting with these implantable cardiac devices. The structure of cardiac pacemakers includes a battery to provide an electrical current, which travels through a conducting wire to the myocardium of the heart. The current continues through the myocardium and stimulates muscle contraction to trigger a heartbeat. The current then travels back to the pacemaker, and the circuit is completed. There are various types of pacemakers available. The first devices were asynchronous and paced the heart at a fixed rate. Newer devices are demand pacemakers, which function by sensing the patient’s heart rhythm and subsequently inhibit or trigger pacing. The most common types are ventricular demand pacemakers, which function by sensing the patient’s QRS complex and fire in the absence of ventricular depolarization, atrial demand pacemakers, which function by sensing the patient’s P-wave and fire in the absence of atrial depolarization, and fully automatic pacemakers.

**Implantable Cardiac Defibrillators**

The implantable cardiac defibrillator (ICD) was developed in the 1960s and works in a similar fashion as the cardiac pacemaker, and is often used in conjunction with the pacemaker. The first ICD was implanted in a patient in 1980. The device functions by delivering an electrical current to the heart in response to a ventricular rhythm that the device perceives as abnormal. It was designed to treat ventricular tachycardia and ventricular fibrillation or sudden cardiac arrest. Early ICDs were quite primitive because they could only shock the heart to slow the heart rate down, had a limited battery, required open heart surgery to implant the device, and had no ability to record the data about the sudden cardiac event if a shock was needed.

The first ICD was quite large and needed to be implanted in the abdominal area. Current ICDs are the size of a pager and can be implanted like a pacemaker. The ICD, like the pacemaker, is a computer-driven device that can store data, provide and record therapies. In addition, the ICD has pacemaker-like abilities and can provide therapy for slow and fast heart rates. The ICD treats a slow heart rate by recognizing that the heart rate is below the parameters the physician has set in the ICD. Once the ICD recognizes that the heart rate is below the acceptable range, it provides pacing to increase the heart rate to the ranges in the ICD. In addition, the ICD can treat a fast heart rate with antitachycardia pacing. This is a painless therapy and sometimes aborts the need to shock the heart if the heart rate is too fast.

The latest generation of implants offers cardiac resynchronization therapy (CRT). These implant devices are used for poor pump or congestive heart failure patients. They are highly advanced devices that provide 100% cardiac pacing to improve pump function along with ICD protection for fast arrhythmias related to the low ejection fraction of the heart.

When combined with the pacemaker, the ICD can function to correct both tachycardia and bradycardia. By facilitating cardiac resynchronization, the implanted ICD can drastically improve the quality of life of the patient via amelioration of symptoms and an overall increase in patient survival.

As the use of pacemakers and implantable defibrillators has significantly increased in recent years, patients that carry these devices are more frequently encountered in a dental practice. Historically, electrosurgery units have been used for a variety of dental procedures. Additionally, dental professionals provide maintenance of their patients’ dentition through the use of cleaning devices. These devices effectively aid in the removal of plaque and hardened calculus from tooth surfaces both above and below the gingival margin. The effect that these devices and techniques may have when used on patients with implantable cardiac devices will be discussed through a review of the current available literature.

**Electrosurgery**

The term “electrosurgery” encompasses three main procedures: electrolysis, electrocautery, and high-frequency electrosurgery. Electrolysis involves the usage
of electrochemical potential, without eliciting any major thermal changes, thus allowing for safer and more precise tissue destruction. This procedure uses energy produced by a direct current generated between a cathode and an anode. When this process is used in human plasma, hypochloric acid and sodium hydroxide are produced at the cathode, while hydrochloric acid and oxygen and chlorine gases are produced at the anode. The result is a large pH gradient within a very localized area. This gradient produces a highly cytotoxic environment, ultimately resulting in a controlled pattern of cellular necrosis. A multitude of different electrosurgical devices exist today (Table 1).

Two common subsets of these devices are half-modulated devices and fully modulated devices. Modulation is a process by which the waveform produced by the unit can be changed via the multiplication of numerous signals. Fully modulated units provide bursts of high voltage, useful for coagulation (Fig 1). Half-modulated units (Fig 2) are capable of blocking a portion of the produced wave through the use of a negative polarity. This creates a blended current, with varying voltage over time (Fig 3).

Electrocautery makes use of a heated metal instrument placed in direct contact with the tissue, allowing the surgeon to desiccate, necrotize, and coagulate the target tissue. There is no electrical current that passes through to the patient, and thus provides minimal risk to implantable cardiac devices. The main risk related to electrocautery involves direct heat conductance if used in proximity of the procedure to the device. Davison and Zamah described the voltage magnitude over a
period of time when using an electrosurgical device to achieve coagulation. They stated that the current is characterized by wave modulation, resulting in bursts of high peaked voltage followed by a rapid decrease in voltage. This modulation creates the thermal changes desired for coagulation (Fig 1).

High-frequency electrosurgery is the most common form of electrosurgery. This procedure functions by making use of an alternating current that is produced at a high frequency. This current is formed at an electrode tip that can be used to cut, coagulate, or desiccate tissue. The current passes through the patient’s tissue, in contrast to electrocautery. The surgeon has the ability to alter the characteristics of the current produced; higher current and longer current duration results in greater tissue necrosis.

The different forms of high-frequency electrosurgery are electro-fulguration, electro-desiccation, electro-coagulation, and electrotomy (electro-section). Electro-fulguration uses low amperage current with the electrode tip held 1 to 3 mm from the tissue. Electro-desiccation involves a similar process, except the electrode tip is held in contact with the tissue. According to Riordan et al, both of these processes pose a small risk to cardiac devices due to their usage of small currents and minimal tissue damage (Table 2).

Conversely, electrotomy procedures involve the usage of high currents to effectively cut tissue. Due to the high current involved in electrotomy procedures, a ground is used in the form of a dispersive plate, which acts as an indifferent electrode. However, due to the fact that this form of high-frequency electrosurgery produces the greatest magnitude of current, it poses the most considerable threat to the function of implantable cardiac devices and to the patients that present with them. Davison and Zamah also looked at the relationship of voltage over time, but with a focus on current used for electrotomy. A “cutting current” as they describe it is purely non-modulated and produces a pure sine wave when plotted over time (Fig 2). Subsequently, these units are able to produce significantly higher amounts of power and thus allow for the desired cutting action.

As mentioned above, it is possible to achieve a blended current, through which both cutting and coagulation can be achieved (Fig 3). These waves are characteristic of half-modulated electrosurgical units, which are capable of producing varying currents over a unit of time.

**Electrosurgery-related pacemaker complications**

Shapiro et al stated that pacemaker complications during electrosurgery were first reported in 1965, mostly involving the resulting electromagnetic force produced by electrosurgical units. El-Gamal et al examined the result of electrosurgery-induced electromagnetic interference (EMI) on cardiac devices during cutaneous surgery. Surveys were sent to skin surgeons, from which a total of 166 cases were evaluated. Most surgeons took normal precautions, including short surgical bursts < 5 seconds (71% of surveyed cases), use of the lowest clinically reasonable power settings (61%), and avoiding use of surgical devices within close prox-
Cardiac complications noted during these procedures included skipped heartbeats (~5%), reprogramming of the pacemaker (~4%), firing of the ICD (~2%), asystole (~2%), and bradycardia (~1%). Complete depletion of the pacemaker battery was noted in one case, as was an unspecified tachyarrhythmia. This study determined that overall there was a low rate of complications with no significant morbidity or mortality, but the following precautions should still be taken by the surgeon when performing electrosurgery on patients with an implantable cardiac device:\(^{16}\)

- short electrical bursts
- using lowest reasonable power setting
- avoid close proximity of surgical device to cardiac device
- regular maintenance of all electrosurgical devices.

Additionally, O’Donoghue\(^ {17}\) described a case where a patient fitted with a Medtronic 5942 demand pacemaker suffered intermittent asystole during prostatic electrocautery due to suppression of output from the unit.

Miller et al\(^ {1}\) studied the interference of cardiac devices specific to dental electrosurgery. This study involved the usage of a dual-chamber, bipolar unit and a single-chamber, unipolar unit, both of which were produced by Medtronic. Each pacemaker was programmed to their maximum sensitivity, set to a 60 pulse/minute pace, with their leads placed in saline. Pacemaker output and ECG characteristics were continuously observed. Dental devices were operated near the pacemakers and slowly moved away until no interference was monitored. It was noted that both atrial and ventricular pacing were inhibited by the electrosurgical unit, up to a distance of 10 cm.\(^ {1}\)

It is important to note that implantable cardiac devices have been improved markedly since their inception to avoid EMI issues,\(^ {2}\) by making use of more sophisticated circuitry in aims of avoiding issues from exogenous interferences.\(^ {15}\) As a result, current pacemaker units can withstand EMI due to shielding of the internal circuitry. This system protects the pulse generator within a hermetically sealed titanium or stainless steel case. Also, newer pacemaker systems have made increased use of bipolar lead systems, which has also served to decrease the sensitivity of pacemakers to EMI. Filtering systems have also been implemented, enabling the pacemaker to ignore non-cardiac signals.\(^ {18}\) Additionally, cardiac devices have been instilled with the ability to revert to a firing at a default rate upon sensing strong, exogenous EMI.\(^ {2}\)

Yet, despite these advances in device design, cardiac pacemakers have still been shown to behave erratically in response to the current produced by high-frequency electrosurgery.\(^ {2}\) A pacemaker may recognize the current produced during surgery as the patient’s own heart rhythm, and this results in an inhibition of the device. This phenomenon is known as “inhibition by interference”.\(^ {2}\) Furthermore, ventricular fibrillation has been reported in pacemaker patients during electrosurgery, as well as reprogramming or complete deactivation of the pacemaker.\(^ {19}\) The effects of electrosurgery on specific pacemaker models are presented in Table 3.

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### Table 3: Effects of electrosurgery on specific pacemaker models

<table>
<thead>
<tr>
<th>Study</th>
<th>Surgery</th>
<th>Pacemaker</th>
<th>Comments</th>
<th>Complications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Miller et al(^ {1})</td>
<td>In vitro study</td>
<td>Medtronic Thera 7942</td>
<td>Dual-chamber, bipolar</td>
<td>Atrial and ventricular pacing inhibited</td>
</tr>
<tr>
<td>Miller et al(^ {1})</td>
<td>In vitro study</td>
<td>Medtronic Minix 8340</td>
<td>Single-chamber, unipolar</td>
<td>Atrial and ventricular pacing inhibited</td>
</tr>
<tr>
<td>O’Donoghue(^ {17})</td>
<td>Electrocautery</td>
<td>Medtronic 5942</td>
<td>Demand pacemaker</td>
<td>Intermittent asystole: suppression of pacemaker output</td>
</tr>
</tbody>
</table>
Electrosurgery-related complications with ICD

When discussing potential complications regarding cardiac defibrillators, certain variables will determine the devices’ potential sensitivity to EMI.

Most patients who have implanted cardiac devices have been provided with a device identification card by their cardiologist. This card identifies the model number, manufacturer, and medical contacts. This information will assist the dental professional in identifying any contraindications for proceeding with dental hygiene treatment.

If a device uses unipolar leads, the distance between the anode and cathode is great, with the anode covered by a metal casing, and the pulse generator and cathode at the tip of the lead. These systems are more susceptible to EMI-related alterations than bipolar leads, which have both the anode and cathode within the tip of the lead. EMI can result in either over sensing or under sensing of the device. Over sensing occurs when the defibrillator mistakes the EMI as the patient’s own heart rhythm and delivers a compensatory shock; this may result in ventricular tachycardia, fibrillation, or myocardial burns. Under sensing occurs when the defibrillator is deactivated, thus leaving the patient without the therapeutic potential of the device.

The literature suggests that the use of electrosurgery procedures on patients with implantable cardiac devices is generally safe as long as precautions are taken. Cases have been reported where electrosurgery units have interfered with cardiac device functioning, but their occurrences are rare. Increased use of bipolar pacemakers and improved EMI shielding of devices have further decreased the incidence of electrosurgery-related malfunctions, but they are still susceptible. It is therefore important that surgeons are aware of the potential complications and how they can best be avoided.

ULTRASONIC AND CARDIAC DEVICES

A multitude of dental instruments, including ultrasonic and sonic scaling cleaning devices, piezoelectric units, electrosurgery units, and electronic apex locators produce an environmental electromagnetic field. There are conflicting results analyzing the deleterious effect, if any, of these devices interfering with the magnetic field of cardiac pacemakers. Clark et al., as well as Adams et al., pioneered the analysis of dental devices interfering with cardiac pacemakers, and determined that ultrasonic and sonic cleaning devices should not be used in proximity to pacemaker patients due to EMI. The research was corroborated as recently as 1998, in an in-vitro study conducted by Miller et al., which concluded that ultrasonic scalers, ultrasonic baths, and electrosurgery units should be outright avoided in patients with cardiac pacemakers as they cause interference at distances of 37.5 cm. As a result of these studies, many dentists consider pacemakers to be an absolute contraindication to using ultrasonic and electrosurgical devices in clinical practice. However, there have always been conflicting scientific data regarding this topic.

Simon et al. and Dodinot et al. found no effect of EMI from dental devices on cardiac pacemakers or ICDs. These studies seem to be easily dismissed without sound basis. Many ultrasonic scaler device manufacturers recommend avoiding the use of these devices on patients with pacemakers, while the manufacturers of the devices do not hold the same tenet. To further highlight the discrepancy, the Journal of Periodontology published initially in 2000 an article discouraging the use of magneto-strictive ultrasonic devices on patients with cardiac devices; the paper was rescinded in 2007. There was little discussion by Miller et al. as to possible reasons for the absolute discrepancy in results. One reason they surmised was directly related to the Simon et al. experiment being an in-vivo study; they hypothesized that the pacemaker leads were shielded by human tissue, and thus more impermeable to EMI. If correct, this is further reason for new research to be predominantly cited regarding the effect of den-
tal instruments and EMI. As cardiac pacemakers become more sophisticated, and their shielding is improved, this area of research is in need of constant updating to allow dental professionals to offer all patients the best dental care possible. We will attempt to determine if the prevailing thought of being overly cautious with patients having implanted cardiac devices is justified based on current research.

### Ultrasonic

Ultrasonic devices are ubiquitous in dental offices (Table 4). Ultrasonic scalers are used routinely for prophylaxis and other periodontal procedures by dentists, specialists, and dental hygienists, while ultrasonic dental baths are used to prepare instruments for sterilization, with the efficacy of both having been well established. Ultrasonic devices can be further divided into two categories: magnetostrictive and piezoelectric. Magnetostrictive devices operate between 18 kHz and 45 kHz, while piezoelectric devices operate between 25 kHz and 50 kHz. Magnetostrictive devices use a series of metal rods or sheets attached to a scaling tip, which moves in an elliptical movement. Piezoelectric devices function based on dimensional changes of crystals when a current of electricity is passed through them; this allows for a linear movement of the scaling tip. Although these devices may produce varying clinical outcomes, that is not within the purview of this analysis.

<table>
<thead>
<tr>
<th>Device</th>
<th>Method of Action</th>
<th>Manufacturer</th>
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<tbody>
<tr>
<td>Cavitron</td>
<td>Ultrasonic</td>
<td>Dentsply</td>
</tr>
<tr>
<td>BioSonic</td>
<td>Ultrasonic</td>
<td>Coltene</td>
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<td>Integra</td>
<td>Ultrasonic</td>
<td>Parkell</td>
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<tr>
<td>TurboSENSOR</td>
<td>Ultrasonic</td>
<td>Parkell</td>
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<tr>
<td>Titan-S</td>
<td>Sonic</td>
<td>Star Dental</td>
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<tr>
<td>ScaleMaster</td>
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<td>MTI Dental</td>
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<td>SONICflex</td>
<td>Sonic</td>
<td>KaVo</td>
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<td>PIEZOsoft</td>
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<td>miniMaster</td>
<td>Piezoelectric</td>
<td>EMS</td>
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<tr>
<td>ProUltra</td>
<td>Piezoelectric</td>
<td>Dentsply</td>
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</tbody>
</table>

### Ultrasonic-related interferences with ICDs

Recent research which attempted to elucidate the effects of EMI on ICDs during the operation of dental devices was by Brand et al. This in-vitro study tested the use of electrosurgical units, ultrasonic scalers, ultrasonic baths, dental handpieces, and amalgamators on ICDs. The Guidant Vitality 2 EL type VR ICD and its leads were placed in a saline bath to simulate the electrical resistance of the human body. Dental devices were operated continuously, as well as in on-off intervals, within 2.5 cm of the ICD. The only device to cause EMI within 2.5 cm was the ultrasonic dental bath, which began to produce interference at a distance of 12.5 cm. In a later study by the same group, other ultrasonic baths were tested, as well as other ICDs. Only one specific brand of ultrasonic bath cleaners, the Branson 200, produced any sort of interference; however, two ultrasonic bath cleaners analyzed by Miller et al, also immersed in saline solution, produced EMI at distances up to 30 cm. The EMI caused episodes of ventricular noise, which may prohibit the ICDs ability to correct ventricular arrhythmia. Brand et al suggest that there is no reason to exercise caution in patients with ICDs, as ultrasonic baths are often kept in a separate sterilization area, away from patients. If anything, these results should cause more fear for dental professionals and employees of dental offices who may have ICDs.
In contrast to this, another in-vitro study conducted by Roedig et al. found that ultrasonic scalers do cause EMI within close range of pacemaker leads. Even more startling, Roedig et al. found that battery-powered composite curing lights also caused EMI; this device was previously not thought to cause any significant EMI. The researchers found similar results in both pacemakers and dual-chamber ICDs. The ICDs tested were all produced by Medtronics and dental scalers were operated at all power settings. The dental devices were tested in two different manners: first, the device was placed on the ICD and leads and turned on, recording EMI while moving the device away from the ICD; second, the dental device was turned on at a distance of 3 feet from the ICD and moved closer to the ICD until it was resting on the ICD. EMI was recorded at distances greater than 12 cm from the leads of the implantable devices. This study is in stark contrast to Brand et al.’s study, despite using similar materials and methods to record EMI. Reasons for the discrepancies were not offered by the authors in another study. Due to the varying results of in-vitro studies, the severity of the issue at stake, as well as the fact that in-vitro studies cannot be directly correlated to clinical results, further research, particularly in-vivo studies, are indicated.

The latest study, at the time of this analysis, regarding the use of ultrasonics and EMI was conducted by Maiorana et al. This in vivo investigation measured if ultrasonic piezoelectric devices caused any noticeable EMI on patients with cardiac devices by measuring both surface- and intra-cardiac ECGs during dental treatment. The group used a small group of 12 patients that were treated using the miniMaster piezoelectric scaler. Five different ICDs were tested: St. Jude’s Atlas VR, St. Jude’s Current VR, Medtronics Consulta CRT, Medtronics Concerta CRT, and Ela Medical’s Ovatio DR. All patients were treated using an ultrasonic device set to the maximum 8 Watt power setting. All ECGs were evaluated by a cardiologist present at the scene. The researchers found absolutely no adverse effects on ICD function. After dental treatment, all ICDs were tested via manufacturer recommendations to ensure no malfunctions. No effect at all was found from the dental scalers, despite the scaler being set to the maximum possible settings.

Additionally, Maiorana et al. proposed that the results found by Roedig et al. are actually the result of interference between the dental device and telemetry, and that no actual interference occurred between the dental device and the ICD. Additionally, Maiorana et al. proposed several reasons that previous in vitro studies are not of clinical significance today. First, the research group highlights the fact that in-vitro studies cannot be directly translated into clinical outcomes. This is an important point that cannot be understated when treating patients. Furthermore, all of the previously discussed in-vitro studies measured EMI at the closest distance possible, often 10 cm. This distance from dental instrument to ICD lead is never possible in clinical practice, as the device is confined to the region of the head and mouth, at least 25 to 30 cm (10 inches) away from the ICD leads (Fig 4). Finally, ICDs are more heavily shielded than they were when first introduced, and the human skin, bones, teeth, etc also provide a method of shielding between the dental device and the ICD.
A summary of the previously listed studies is presented in Table 5.

**CONCLUSION**

The link between dentistry and general medicine goes beyond understanding the etiology of multifactorial diseases, as it also includes the ability to work with both specialties in providing patients with satisfactory care. The use of dental surgery on patients with implantable cardiac devices is an area where two fields of healthcare must come to a consensus on proper protocols. Currently, the mindset of most dental practitioners is that extreme caution should be taken in caring for patients with ICDs in the dental chair during treatment. However, this view is not corroborated by the current clinical data, and appears to be misguided. While further in-vivo studies are needed to determine the true level of risk, if any, regarding EMI and patients with implantable cardiac devices, the current belief of ICDs being a contraindication for electrosurgery or ultrasonics use is not rooted in scientific results. Using the precautions stated in this analysis, the risk of any deleterious effect on ICD function is minimal.

**REFERENCES**