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Effect of Electronic Apex Locators on Cardiac Pacemaker Function

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The purpose of this study was to assess the effects of five electronic apex locators on pacemaker function in vitro. A Biotronik Actros DR+ pacemaker was evaluated at maximum sensitivity on a flat bench top. The pacemaker lead, electronic apex locator, and oscilloscope were connected across a 150-ohm resistor. Pace monitoring was carried out with a Biotronik EPR 1000 programmer and a Tektronix TDS 220 2-channel digital real-time oscilloscope. Four of five electronic apex locators tested did not cause inhibition or interfere with normal pacemaker function. It seems that electronic apex locators can be used safely in patients with pacemakers.

In 1996, there were approximately one million cardiac pacemaker patients in the United States (1). Over 150,000 pacemakers were implanted in 1997 alone, an increase of 24% from 1994 (2). With the aging population, the number of people with pacemakers is increasing every year (3). As a result, dentists are treating more patients with such devices.

Historically, the dental office has been perceived as a potentially dangerous environment for pacemaker patients because of the presence and use of electrical instruments during dental treatment (4–7). In 1974, Woolley et al. (6) showed that dental equipment including pulp testers, desensitizing equipment, and electrosurgical units interfered with a cardiac pacemaker, leading to potentially serious consequences. One year later, Simon et al. (7) found that dental equipment had no effect on 11 of 12 different pacemaker models studied. Both studies were conducted in vivo.

A more recent study by Miller et al. (8) used an in vitro model to assess the effect of various dental instruments on pacemaker function. Two Medtronic pacemakers were used, set to 60 pulses/min, and placed under a Medtronic 9760/90 programmer (Medtronic, Minneapolis, MN, U.S.A.) to create a telemetric connection. Pacemaker and ECG leads were immersed in a 1.5-L saline bath set to 400 to 800 ohms, simulating the resistance of the human body. ECG activity, as well as both atrial and ventricular pacemaker output, were constantly monitored. The results showed that certain instruments interfered with pacemaker activity, whereas other devices had no effect. However, their study did not include the electronic apex locator.

Electronic apex locators (EAL) are widely used in endodontics to determine the root length during root canal treatment. Introduced by Sunada (9) in 1962, the EAL has become an invaluable tool in modern endodontic practice. Although Beach et al. (10) published a case report in 1996 showing the use of an EAL in a pacemaker patient without clinical incident, the dental literature lacks research in this area. Interestingly enough, the instruction manual for many EALs clearly warns against the use of such devices in pacemaker patients (11–13), even though no studies have been published to prove or disprove such practice. The purpose of this study was to assess the effects of electronic apex locators on pacemaker function in vitro.

MATERIALS AND METHODS

Five EALs were tested for pacemaker interference, including the Root ZX (J. Morita Co., Tustin, CA, U.S.A.), Justwo (Toei Electric Co., Kanagawa, Japan), EIE (Analytic Endodontics, Orange, CA, U.S.A.), Neosono (Amadent, Cherry Hill, NJ, U.S.A.), and Bingo-1020 (Dent Corp, White Plains, NY, U.S.A.). A Biotronik Actros DR+ pacemaker (Biotronik, Berlin, Germany) with an atrial lead (model PX45JBP) was set to 60 pulses/min and evaluated at maximum sensitivity (unipolar: AAI mode, 0.1 mV) on a flat bench top. Pace monitoring was carried out with a Biotronik EPR 1000 programmer (Biotronik) and a Tektronix TDS 220 2-channel digital real-time oscilloscope (Tektronix, Inc., Beaverton, OR, U.S.A.).

The study design consisted of directly connecting the pacemaker lead, EAL, and oscilloscope across a 150-ohm resistor (Fig. 1). With the EAL operating, the telemetry wand was held directly over the pacemaker to monitor the pacing pattern for a period of 25 to 30 s. A negative control was conducted with the pacemaker alone. A Dynatech Nevada Medsim 300B ECG simulator (Dynatech Nevada, Inc., Carson City, NV, U.S.A.) connected across the resistor, in place of the EAL, served as a positive control. The control trials were carried out for 10 s. Pacemaker activity was continuously recorded on the ECG printout of the telemetric programmer. These recordings were then examined for pacer inhibition, noise reversion, or inappropriate pacemaker pulses.

RESULTS

The negative control showed a normal pacing pattern; the positive control showed pace inhibition (Fig. 2). The Root ZX device caused no interference with pacemaker activity (Fig. 3). Telemetric

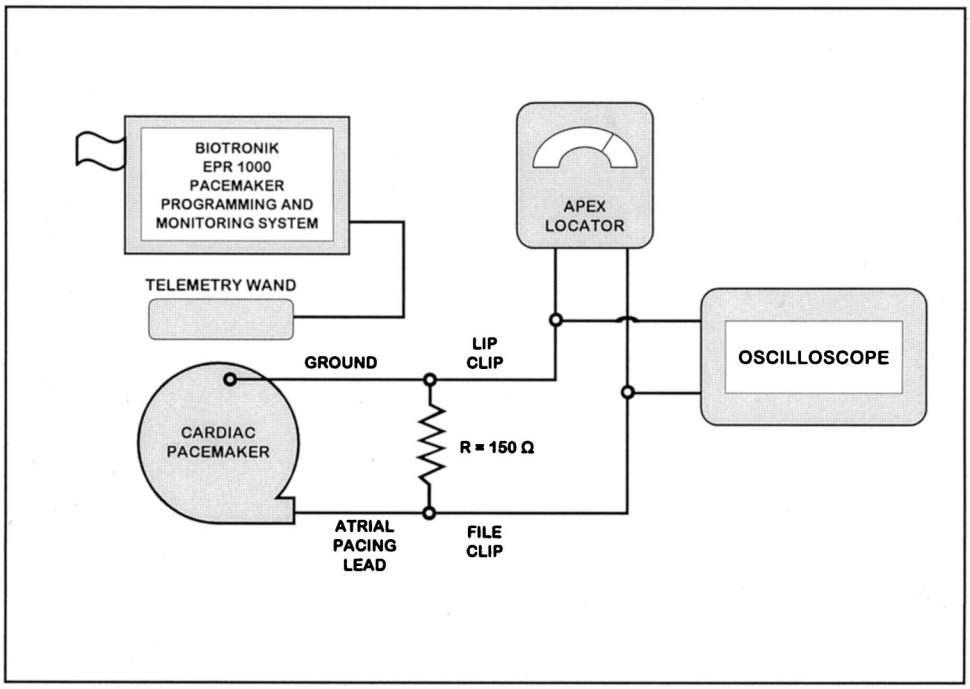

FIG . 1. Protocol used to evaluate the effect of electronic apex locators on cardiac pacemaker function.

recordings for the Justwo and the EIE apex locators both showed the absence of two paced beats within the test period, whereas the Neosono showed that five paced beats were not registered. However, all three devices showed normal pacing on the oscilloscope. The Bingo-1020 device produced an irregular pace recording (Fig. 4) and oscilloscope pattern. All devices, with the exception of the negative control, produced varying degrees of background noise on the telemetric recordings (Figs. 2–4).

DISCUSSION

There have been dramatic improvements in pacemaker technology over the last few decades. Pacemakers manufactured before 1975 used discrete electronic components encapsulated in a clear epoxy case. Electromagnetic interference (EMI) could easily penetrate the pacer and affect the electronic circuits. Modern pacemaker electronics are shielded in a hermetically sealed metal case with capacitors that effectively filter out EMI signals (14, 15). Because newer pacers are less susceptible to interference, results of studies conducted in the past may no longer be applicable.

The setting of the Biotronik pacemaker in the atrial pacing mode provided the greatest sensitivity setting (0.1 mV) of any pacemaker products currently available. Therefore, testing in other modes such as ventricular and dual modes, as well as including other pacemaker models, was deemed unnecessary and omitted from the study.

The selected resistance was determined by a pilot study. Five hundred ohms were used initially, but the EALs displayed no activity. When the devices were connected across 150 ohms, the EAL read-outs approached the "apex" mark, confirming that the EALs were operating properly.

Cardiac pacemaker interference is not a time-dependent phenomenon; a given stimulus either does or does not inhibit normal pacing. Therefore, a testing interval of 25 to 30 s was deemed satisfactory for the purposes of this study.

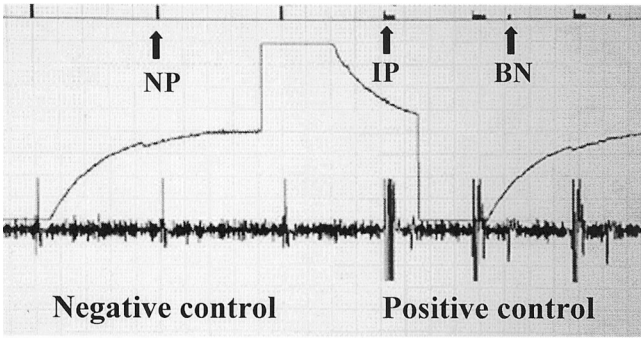

FIG . 2. Representative section of the telemetric programmer ECG readout for the control groups. Note normal pacing (NP) during negative control (left) and both inhibited pacing (IP) and background noise (BN) during positive control (right).

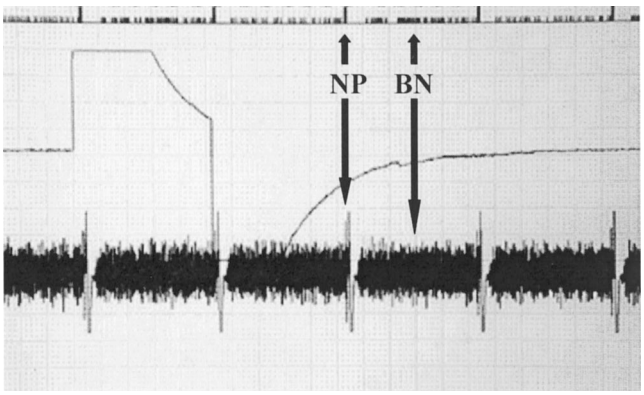

FIG . 3. Representative section of the telemetric programmer ECG readout showing no pacer inhibition during operation of the Root ZX apex locator. A normal pacing pattern (NP) is evident at 1 pulse/s. Note the presence of background noise (BN).

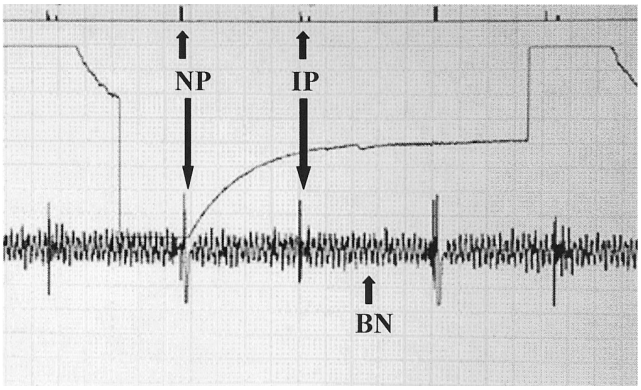

FIG . 4. Representative section of the telemetric programmer ECG readout showing inhibited pacing (IP) during operation of the Bingo-1020 apex locator. Note the presence of isolated normal pulses (NP) and background noise (BN).

The saline bath used by Miller et al. (8) was omitted. Instead, in an attempt to simulate the most rigorous conditions possible, the apex locator was connected directly to the pacemaker. This scenario represents extreme circumstances that do not occur clinically.

Normal oscilloscope patterns indicate uninhibited pacemaker activity. Interestingly, the telemetric recordings for the Justwo, EIE, and Neosono devices failed to register several paces despite such patterns. This phenomenon may be attributed to an electromagnetic effect of the EAL housing on the telemetric wand rather than inhibition of pacemaker function. Although the Bingo-1020 showed interference in this study, the clinical implications are unknown. Some component of the apex locator housing combined with its electronic circuitry may have affected the pacemaker in this case.

Although it is well known that in vitro results cannot be directly transferred to clinical practice, several factors lead the authors to believe that pacemaker interference by EALs is highly unlikely. First, EALs would never be directly connected to the pacemaker leads in a clinical setting. Instead, the circuit produced by EALs is confined to the head region, roughly 10 to 12 inches from the heart, and does not cross the chest. Pinski and Trohman (15) stated that electromagnetic fields decrease with the inverse square of the distance from the source. Second, the titanium or stainless steel case of the pacemaker will serve as an EMI shield, reducing the effects of EMI on the device (14). Third, the body tissues surrounding the pacemaker may serve as insulation, thus further shielding the device from EMI (14). Finally, most EALs operate on a 7 to 9 V battery, resulting in low-level signals. For the reasons stated above, interference with cardiac pacing demonstrated in vitro may not occur in vivo (14).

Manufacturers of EALs continue to warn against the use of their devices in patients with cardiac pacemakers despite the absence of evidence to support such claims (11–13). Although they may possess bench test data similar to those shown above, the lack of clinical data would make it difficult to obtain FDA approval for the devices without such warnings. Human trials are needed to clarify this issue.

In addition to cardiac pacemakers, future research should evaluate the effects of dental devices on implantable defibrillators.

In conclusion, four of five electronic apex locators tested showed no effect on cardiac pacemaker function in vitro. The results of this study suggest that EALs can be used safely in patients with pacemakers. Nevertheless, further studies in humans are required to confirm our findings.

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