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Pacemaker/Defibrillator Evaluation at Los Angeles County Department of Coroner*

ABSTRACT: Pacemakers and implantable cardioverter-defibrillators (ICDs) are implanted medical devices for the treatment of cardiac arrhythmias. These devices are now commonly encountered in the postmortem situation. The Los Angeles County Department of the Coroner uses the services of a cardiac electrophysiology consultant to interrogate pacemakers and ICDs, producing a detailed picture of the cardiac events recorded by the device. We have used this method to evaluate 20 cases where the ICD or pacemaker provided significant information. We report four forensic cases to illustrate the different applications of pacemaker interrogation and its contribution in forensic investigation. This technique was used to establish identification of the decedent, to determine the cause and time of death, and to determine whether device malfunction could have played a role in the death. We conclude that detailed evaluation of the pacemaker or ICD in selected cases may provide essential information to the forensic pathologist.

KEYWORDS: forensic science, forensic pathology, pacemaker

Cardiac pacemakers are commonly used devices for the treatment of patients with symptomatic bradycardias. An implantable cardioverter-defibrillator (ICD) is a device for the treatment of life-threatening ventricular tachycardias. Both ICDs and pacemakers are equipped with telemetric capability for programming and follow-up. Continued technological advancement in these devices affords extensive clinical data that can be correlated with terminal events (1).

Postmortem interrogation and analysis of the device can provide useful information to the forensic pathologist to complement autopsy findings (2). Studies have already emphasized the importance of pacemaker/ICD evaluation (3,4). These four cases illustrate medicolegal applications of the pacemaker and ICD interrogation, which has not been reported in the literature to our knowledge.

Case Reports

From January 1, 2001 to July 30, 2007, a total of 31,733 autopsies have been performed. Twenty of these cases, in whom there was an implanted pacemaker or ICD, and where there was a concern regarding either the device function or the cause of death remained uncertain after the autopsy was performed, were evaluated by the electrophysiology consultant. Their characteristics are presented in Table 1. In four (20%) of these cases, the device interrogation contributed important additional information to the postmortem evaluation. Representative cases are presented below.

Case 1

An elderly black female was found decomposed in her apartment on August 12, 2005. One of the neighbors had called the landlady of the residence to report a foul odor. A locksmith had to come to unlock the front door of the apartment. The decedent was lying supine on her bed. There was no suspicion of foul play. She was last seen alive on August 4, 2005. Her medical history was unknown.

The identification was confirmed through dental X-rays, which were provided by a local hospital, and her age was ascertained to be 71.

The body was bloated with blistering present over the entire body. It weighed 147 pounds and measured 66 inches. There was no external traumatic injury. There was a scar at the upper left chest under which was a palpable implantable device.

The autopsy showed moderate coronary atherosclerosis. A pacemaker evaluation was requested. The device was a Guidant model 1296 implanted in June 2003. There was no evidence of pacemaker device malfunction—particularly, the battery was intact with 40% of battery life remaining by the indicator gauge with an estimated remaining longevity of 4.5 years. The decedent was 100% ventricular paced. Intrinsic "P" and "R" amplitudes, and A and V lead impedances were stable until August 8, 2005. On August 8, 2005 at 09:11 hours by device log time, the device arrhythmia monitor recorded sudden onset ventricular tachycardia, which degenerated into ventricular fibrillation and most likely represented the terminal event in this woman (Fig. 1). This was consistent with the autopsy findings of underlying coronary

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TABLE 1—*Pacemaker/ICD evaluation (2001–2007).*

Year	Sex	Age	Cause/Manner of Death	Type of Device	Model	Evaluation
2001	M	52	Ischemic cardiomyopathy Undetermined	ICD	Medtronic Gem II DR 7273	Normal
2003*	F	21	Congenital heart block/asystole Accident	PM	Medtronic Minuet 7108	Depleted battery
2004	M	71	Blunt injuries Accident	ICD	St Jude Medical Epic DR V-236	Normal
2004	F	78	Septic shock Natural	PM	Biotronik Philos DR	Normal
2004	F	86	Cystic encephalomalacia Natural	ICD	Guidant 1198 Insignia	Normal
2004†	M	48	VT/syncope/Blunt head trauma Accident	ICD	St Jude Epic V-197	Normal
2004	M	75	Blunt head trauma Accident	ICD	Medtronic Marquis 7230 CX	Normal
2005	F	5	Congenital heart disease Undetermined	PM	St Jude Medical Affinity DC 5230	Lead failure (Broken pacing wires)
2005	M	28	End stage renal disease Accident	PM	Medtronic EnPulse E2DR01	Normal
2005‡	F	72	VT/Atherosclerotic heart disease Natural	PM	Guidant Model 1296	Normal
2005	M	32	Congenital heart disease Natural	PM	Medtronic KDR 701	Normal
2006	M	75	Atherosclerotic heart disease Natural	PM	Medtronic E1DR01	Normal
2006	M	38	Hypertrophic cardiomyopathy Accident	ICD	St Jude Affinity V-243	Normal
2006	M	82	Atherosclerotic heart disease Natural	PM	St Jude Affinity 5330R	Normal
2006	M	52	Idiopathic cardiomyopathy Accident	PM	Medtronic EnRythm	Normal
2006	M	80	Traumatic injuries Accident	PM	Vitatron T60A1DR	Normal
2006	M	82	Atherosclerotic heart disease Natural	ICD	Guidant 1861	Normal
2007	F	94	Atherosclerotic heart disease Natural	PM	Medtronic Kappa SR701	Normal
2007	F	42	Amyloid cardiomyopathy Undetermined	PM	Guidant 1298 Insignia	Normal
2007	M	78	Pending Pending	PM	St Jude 5386	Normal

VT, ventricular tachycardia.
*Case 3; †case 2; ‡case 1.

atherosclerosis. The pacemaker log (also called "arrhythmia monitor") findings supported a time of death of August 8, 2005 at 09:11 hours. The internal clock of the device (standard computer clock) was used as a time/date stamp.

The cause of death was attributed to ventricular tachycardia secondary to atherosclerotic cardiovascular disease and the manner of death was natural.

Case 2

A 48-year-old man collapsed and reportedly hit the back of his head while coaching a high-school basketball game. The collapse occurred before the game, while the man was talking to another individual. No physical action preceded this. He was transferred to a local hospital. Computed tomography scan of the brain without contrast revealed bilateral mild to moderate subarachnoid hemorrhage along the tentorium and mild to moderate bilateral subdural hematoma, possible epidural hematoma, and cerebral swelling. Craniotomy with subdural hematoma evacuation, left temporal tip lobectomy, and right frontal ventriculostomy were all performed. However, the patient died the next day.

The decedent had a past medical history of thrombocytosis with coagulopathy, renal insufficiency, and atherosclerotic heart disease with an episode of myocardial infarction in 2002. An ICD was implanted at that time. He was on multiple medications, including warfarin sodium (Coumadin®), acetylsalicylic acid (Aspirin), and clopidogrel bisulfate (Plavix®).

The body weighed 189 pounds and measured 68 inches. The external examination of the body showed ecchymosis related to therapeutic intervention; however, no distinct bruises or lacerations were seen. The only external injury identified was a 1×1 inch red abrasion at the occipital scalp. There was a $2 \times 1/4$ inch scar at the upper left chest under which was a palpable ICD.

The autopsy showed severe brain injuries with an estimated 50 cc clotted subdural hemorrhage over bifrontal, left temporoparietal, and occipital regions. There also were diffuse subarachnoid hemorrhage, acute petechial hemorrhages of pons and cerebellum, surgical bone, dural and left temporal defects, cerebral swelling, and frontal lobe softening. The heart weighed 550 g and showed ventricular hypertrophy and dilation. Endocardial fibrosis, especially of the left ventricular lining, was noted. There was evidence of old infarction of the myocardium, which consisted of severe thinning and scarring of the distal anterolateral and anteroseptal myocardium towards the apex. The anterior descending branch of the left coronary artery focally showed up to 60% occlusion.

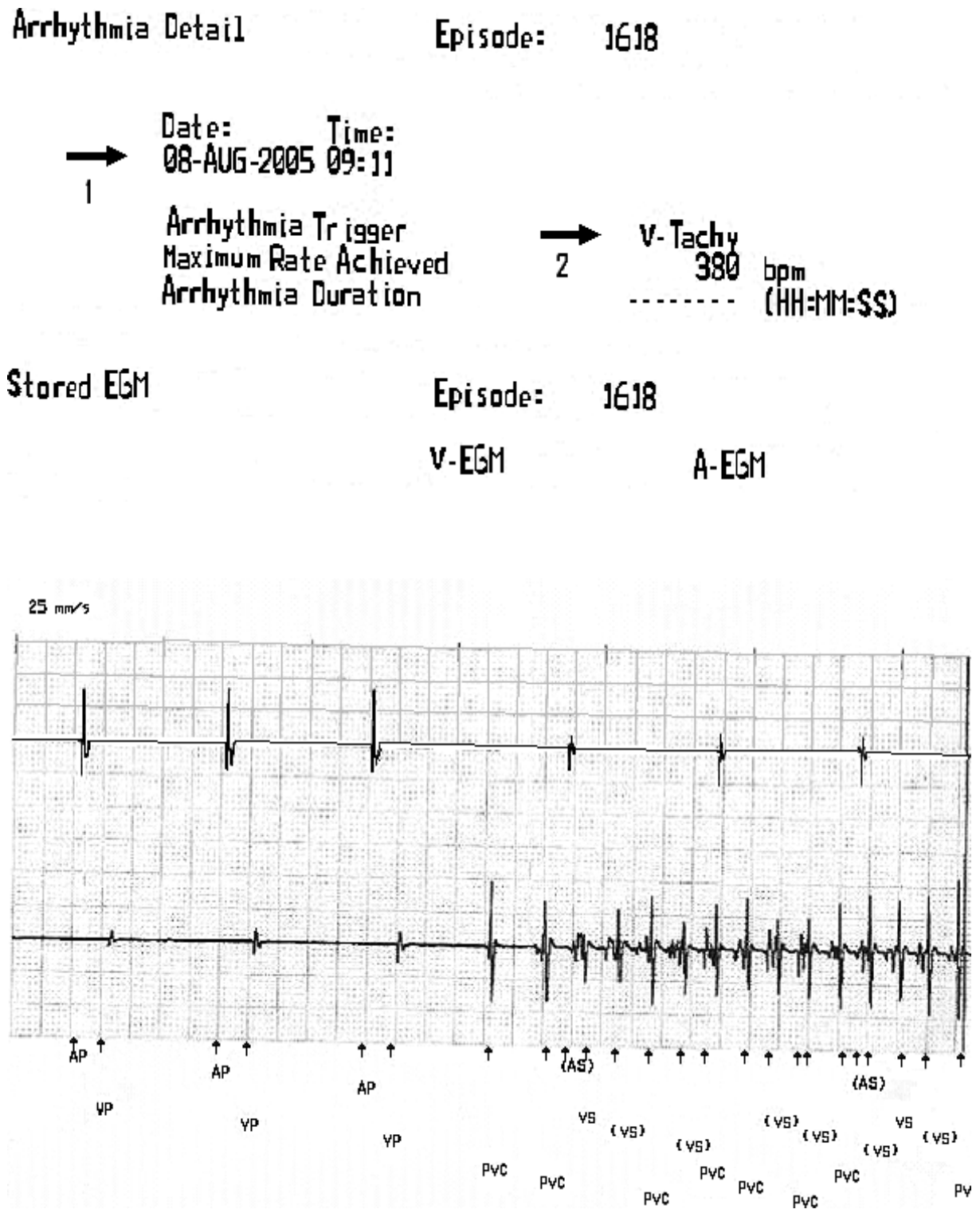


FIG. 1—*Telemetry report of case 1. The first arrow points out the date and time of the final event. The second arrow shows the diagnosis.*

The ICD leads were intact, and the tip of the lead appeared to be in proper position in the right ventricle. An ICD evaluation was requested. Consistent with the date and time the decedent fell was a rapid ventricular tachyarrhythmia converted appropriately by an ICD shock within 12 sec (Fig. 2). The device had no evidence of malfunction and appeared to be appropriately programmed.

Death was attributed to the sequelae of blunt head trauma. Contributory factors included atherosclerotic heart disease and thrombocytosis with coagulopathy (on therapy). The injury resulted from fall-associated syncope likely secondary to the episode of ventricular tachycardia, despite the presence of an ICD which successfully terminated the episode. The manner of death was accidental.

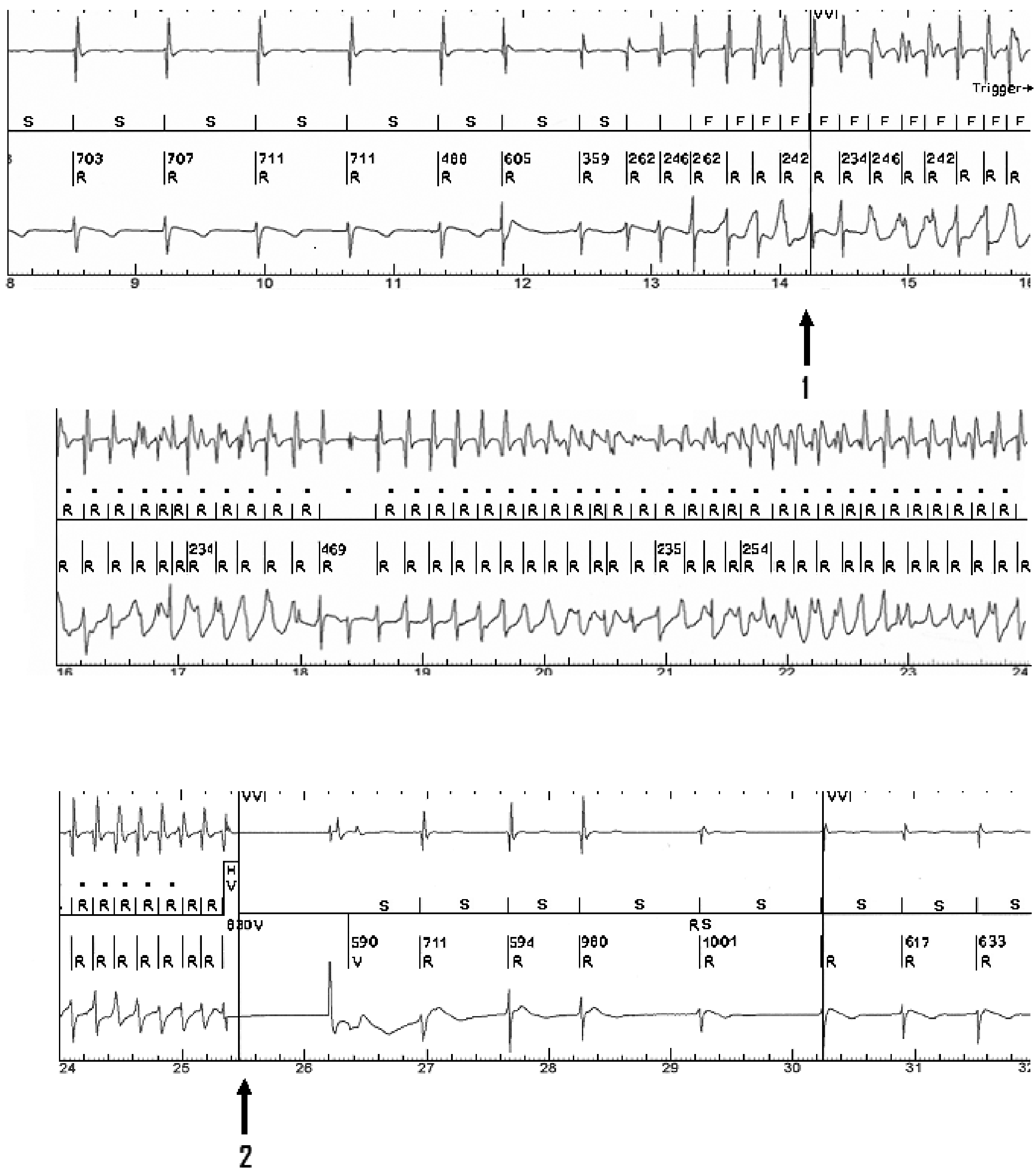


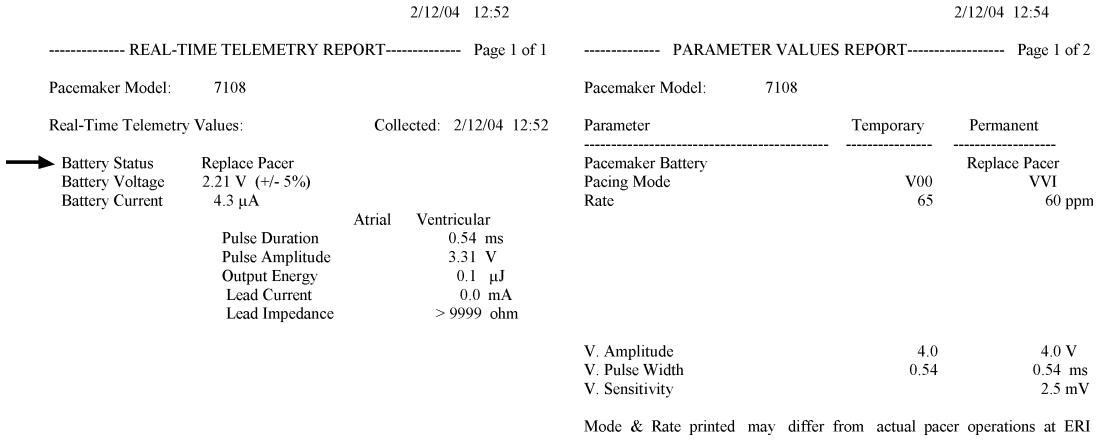
FIG. 2—*Telemetry report of case 2. The first arrow points out the start of the ventricular tachyarrhythmia. The second arrow points out the implanted defibrillator response and the end of the arrhythmia.*

Case 3

A 21-year-old Caucasian female was driving her vehicle in a northbound direction when she reportedly veered from her course of travel and drove across the southbound lane of a two-way avenue. The vehicle then sideswiped a parked car and impacted a tree on a grass parkway. When the paramedics arrived the woman had an initial cardiac rhythm of asystole. She was transported to the hospital where pulses were regained for a brief period of time but the resuscitation was not successful. She was pronounced dead 1 h after her arrival at the emergency room.

The investigation showed that the decedent had a congenital complete heart block with low escape rhythm diagnosed at the age of 10. It was diagnosed when she was taken to the doctor because she had symptoms of dizziness, lightheadedness, and fatigue. She underwent placement of a dual chamber pacemaker. Over the years her pacemaker had been checked only infrequently and sporadically, likely due to inadequate follow-up by the patient. No adjustments had been made in its parameters. She was not on any cardiac medication. A cardiologist checked her pacemaker 17 months prior to her death and wrote in his report that the pacemaker was still functioning adequately and still had 6–9 months of battery life.

The external examination of the body showed one $\frac{3}{4} \times \frac{3}{4}$ inch contusion at the right calf and one $\frac{3}{4} \times \frac{1}{8}$ inch contusion at the left knee. The body weighed 228 pounds and measured 67 inches. The



2/12/04 12:52

---------- REAL-TIME TELEMETRY REPORT---------- Page 1 of 1

Pacemaker Model: 7108

Real-Time Telemetry Values: Collected: 2/12/04 12:52

Battery Status	Replace Pacer
Battery Voltage	2.21 V (+/- 5%)
Battery Current	4.3 µA

	Atrial	Ventricular
Pulse Duration		0.54 ms
Pulse Amplitude		3.31 V
Output Energy		0.1 µJ
Lead Current		0.0 mA
Lead Impedance		> 9999 ohm

2/12/04 12:54

---------- PARAMETER VALUES REPORT---------- Page 1 of 2

Pacemaker Model: 7108

Parameter	Temporary	Permanent
Pacemaker Battery		Replace Pacer
Pacing Mode	V00	VVI
Rate	65	60 ppm
V. Amplitude	4.0	4.0 V
V. Pulse Width	0.54	0.54 ms
V. Sensitivity		2.5 mV

Mode & Rate printed may differ from actual pacer operations at ERI

FIG. 3—*Telemetry report of case 3. The arrow points out the pacemaker battery status.*

autopsy showed visceral congestion. The heart weighed 310 g and showed left ventricular hypertrophy. There was no evidence of internal injuries. Toxicology was negative. A pacemaker evaluation was requested. The device was a Medtronic Minuet model 7108. The battery status was "Replace pacer" (Fig. 3). The battery voltage represented a severely depleted battery/pulse generator. At this low level the device may have only paced intermittently resulting in pauses that may have caused a syncopal episode and contributed to the patient's traffic accident. The cause of death was attributed to acute cardiac dysfunction due to a congenital heart disease. However, the manner of death was accidental, as pacemaker battery depletion played a role in the decedent's demise.

Case 4

A Caucasian man who appeared to be in his 70s was found down on the street. He was taken to a local hospital where he was pronounced dead. Cause of death at autopsy was found to be atherosclerotic cardiovascular disease. He had severe left anterior descending coronary artery disease. Fingerprints could not be compared because there was no record. He had no teeth; there were only dentures present so identification could not be done by this method. However, during the autopsy a pacemaker was found. The device was a Medtronic pacemaker. The investigator found a local number and the company's computer records showed that the pacemaker was placed in Mr. J.D., when he was 81 years old. The company also indicated the name of the cardiologist who installed the unit. According to his records, the pacemaker serial number and model number matched with the pacemaker taken from the decedent. Hence the decedent was positively identified as Mr. J.D.

Discussion

Pacemaker/ICD evaluation is infrequent given the total number of autopsies in our office. The cases where the pacemaker/ICD was examined did not represent all the cases in which the decedent had a pacemaker/ICD; the device was tested only if the results were likely to contribute to the forensic investigation.

These four cases illustrate the medico-legal applications of pacemaker and ICD evaluation. First, pacemaker/ICD interrogation can be used to establish both the time and cause of death, as in our first case. A literature review revealed several studies in which pacemakers were analyzed postmortem to determine the cause of death (3,4). Recently, Nägele et al. made a postmortem analysis of pacemaker memory in 19 stable patients dying suddenly out of hospital (3). This study revealed that in 90% of the cases, a tachycardia (most likely ventricular tachycardia) was found correlating to the time of death. Suvarna et al. prospectively removed pacemakers from deceased patients over 3 years and studied 69 of them to establish the cause of death (4). The most frequent causes of death in this group were ischemic heart disease (21/69 cases), cerebral vascular disease (11/69 cases), and neoplasia (11/69 cases). The authors concluded that postmortem pacemaker interrogation was pertinent, especially in investigation of fatalities involving traffic accidents and other forms of accidental death to rule out pacemaker dysfunction.

Another medico-legal application is that the device can be tested to confirm that it was functioning adequately. In our second case, the decedent had a fall, which was associated with cardiac disease-related syncope. The ICD evaluation determined that the defibrillator functioned properly by detecting ventricular fibrillation and delivering a successful rescue shock. However, during the 12 sec needed for the device to deliver effective therapy (in newer ICD devices, this time now averages 6–8 sec), the decedent had syncope and a fall resulting in an ultimately fatal subdural hemorrhage despite the successful defibrillation. In the published studies concerning postmortem pacemaker evaluation, evidence of dysfunction is infrequent. Nägele et al. found no evidence of specific pacemaker-related problems (electronic failure, battery depletion or undersensing) in their study of 19 decedents (3). In 69 cases, Suvarna et al. found that the pacemaker functioned within normal limits (4). Junge et al. described the case of a 66-year-old patient with an ICD wherein the device was deactivated by exposure to a magnetic field just hours before the patient's death (1).

In 1977, Raasch emphasized the role of postmortem pacemaker evaluation to show that pacemaker failure contributed to the death (2). He analyzed 56 pacemakers postmortem. Thirteen of them showed evidence of malfunction. Low voltage and rate slowing were the most common findings (seven cases). The other abnormalities were absence of significant generator output (two cases), infection (two cases), severe fibrosis about lead electrodes (one case), and lead defect (one case). According to a review of pacemaker malfunction in living patients (5), sensing abnormalities are the most common malfunction, occurring in *c.* 3% of patients. Failure to capture occurs in 1–2% of patients; the remaining problems affect another 1%. Failure of output and failure to capture can result from battery depletion (5). The modern pacemaker has a battery life of 5–10 years, depending on use (4), and device and lead

malfunction are very rare compared to 30 years ago. In our third case, the 21-year-old victim had a pacemaker implanted at the age of 10 for complete heart block. When she died, the original battery was still present. Although the pacemaker evaluation took place 5 months after the decedent passed away, the battery drainage was minimal because there was no output to the heart. Given the context of the circumstances of death, it is highly probable that pacemaker battery depletion played a significant role in the decedent's demise.

Finally, pacemakers can be used for identifying decedents. The serial number is registered with the manufacturer and can be tracked back to the implanting physician and the patient, as in our fourth case. This can be useful when no fingerprints or dental records are available for identification (6).

The safe disposal of pacemakers is important. Pacemakers and ICDs should be removed prior to cremation, as they rupture during cremation due to pressure build-up within the sealed device. ICDs should be turned off by using a programmer or by applying a magnet over the device to prevent morticians from getting a shock when cutting the leads to remove a device. Also, the device should be cleaned and disinfected. The pulse generator and the leads should be washed to remove body fluids and debris using a disinfectant solution. However, the device should not be submerged in fluid, to avoid fluids entering the pulse generator's lead ports (7).

Program details are checked by electronic interrogation of the pacemaker unit according to the manufacturer's instructions. Manufacturer's programmers (with correct date and time) download data via telemetry. Biotronik, Sorin, Boston Scientific, Medtronic, and St. Jude Medical each have proprietary programmers to interrogate pacemakers or ICD generators. This provides information about the device functions, events, and whether the battery is depleted.

In California, pacemakers and ICDs are the property of the family. They cannot be reused or refurbished by United States Federal law. After its removal the device should be decontaminated to avoid safety risk and biohazards. Only nuclear-powered pacemakers (now very rarely seen) require a special procedure: after the patient's death, the Nuclear Regulatory Commission should be contacted within 24 h by the owner of the pacemaker license. Then, once removed, the nuclear pacemaker is supposed to be returned to the manufacturer (8).

Manufacturers are also interested in extracting and analyzing data, and there could be a perception of conflict of interest. This is why these devices are evaluated by an independent consultant. After evaluation, the devices are kept as medical evidence until disposition. Postmortem device analysis is a necessary means of quality assurance as it yields valuable information about product reliability (9). It also provides a rich source of information for clinicians and manufacturers.

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