Arrhythmia Database for Algorithm Testing: Surface Leads Plus Intracardiac Leads for Validation

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Abstract: Ann Arbor Electrogram Libraries (AAEL) is a database of over 500 electrocardiographic recordings made during clinical electrophysiology studies over a period of 15 years. These data are used by university researchers and cardiac device research and development laboratories to develop and test arrhythmia detection algorithms. The AAEL library is in use by all major implantable cardioverter defibrillator manufacturers as well as several Automated External Defibrillator developers. In 1996, the USFDA Center for Devices and Radiological Health licensed a portion of Volumes I for proposed device testing. The data consist of 7 channels of signals: surface leads I, III, V1, an intra-atrial high right atrium (bipolar), an intra-atrial high right atrium (unipolar), an intraventricular right ventricular apex (bipolar), and intraventricular right ventricular apex (unipolar) from the distal catheter electrode. Data were recorded under careful engineering quality control continuously (30 min – 1.5 hr) on FM magnetic tape at a tape speed of 3.75 in/s after signal amplification at a filter setting of 1-500 Hz. Amplifier gain and filter settings were held constant during the entire recording procedure and a 1 mV calibration signal was entered as a reference at the time of recording. All patient recordings contain a baseline sinus rhythm, and subsequently induced ventricular tachycardia and/or ventricular fibrillation, or less frequently, supraventricular tachycardia, atrial tachycardia, and/or atrial fibrillation. Data are typically made available in digitized format (1,000 Hz); digital or FM recordings are also available. AAEL recordings are the only widespread intracardiac test files in the industry. **Key words:** Arrythmia database, intracardiac leads, implantable defibrillators.

The industry standard Ann Arbor Electrogram Libraries has provided benchmark wideband unipolar and bipolar intracardiac electrograms of cardiac arrhythmias for scientific investigation for over 15 years. These recordings allow scientists and implantable cardioverter defibrillator (ICD) developers alike to utilize identical data for testing and device design. Each recording consists of surface electrocardiograms (ECGs) and intracardiac bipolar and unipolar electrograms of diverse cardiac arrhythmias. All recordings were made during routine cardiac electrophysiology studies at the Michigan Heart & Vascular Institute. Each recording has been annotated and reviewed by a cardiac electrophysi-

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ologist and an electrical engineer to ensure an accurate interpretation of each arrhythmia and consistent quality with regard to recording of the electrograms. Patient demographics and antiarrhythmic agents, when used, are included in the annotation of each recording.

Methods and Materials

Data Acquisition

Surface leads and electrograms were recorded during routine clinical studies in the cardiac electrophysiology laboratory. Patients were studied in a supine position and in a fasting, postabsorptive state. After sedation with 1 to 3 mg of intravenous medazolam and administration of 1% lidocaine for local anesthetic, one 8 French, and two 6 French side-arm sheaths (Cordis Corp, Miami, FL) were positioned in the right femoral vein using the Seldinger technique. Each patient received 50 units/kg of heparin intravenously as a bolus. Three 6 French quadrapolar electrode catheters (USCI Division, C.R. Bard Inc, Billerica, MA) with an interelectrode distance of 1 cm were introduced and advanced under flouroscopic guidance. Each electrode catheter had 3 platinum ring electrodes that were cylinders 2 mm in diameter and 2 mm in length. The platinum tip electrode of each catheter consisted of a half-sphere 2 mm in diameter attached to a cylinder 2 mm in diameter and 1 mm in length. The resulting surface area of each ring and tip electrode was 12.6 mm^2. One electrode catheter was positioned in the high right atrium or right atrial appendage. Two electrode catheters were positioned in the right ventricular apex for right ventricular apex pacing and recording, respectively. Unipolar electrograms were recorded using the distal right ventricular apex electrode as the exploring electrode with a heparinized 0.9-mm guidewire (Cordis Corp) inserted into the 8 French venous sidearm sheath serving as the indifferent electrode. The guidewire was positioned in the right femoral vein extending into the right iliac and distal 5 cm of the inferior vena cava. At the end of each procedure, the guidewire and sheath were carefully examined and the absence of thrombus formation was confirmed. In addition to intracardiac atrial and ventricular electrograms, 2 or 3 electrocardiographic surface leads (V1, I, III) were also recorded continuously during the study. Sustained monomorphic ventricular tachycardia and sustained ventricular fibrillation were induced by programmed ventricular stimulation or alternating current.

Twelve-lead ECGs were recorded during spontaneous baseline rhythm and subsequently induced monomorphic ventricular tachycardia and ventricular fibrillation after positioning of the recording electrode catheters in the appropriate chambers. Distal unipolar and bipolar intraventricular electrograms were recorded continuously on FM magnetic tape at a tape speed of 3.75 in. (9.5 cm)/s (Hewlett-Packard Model 3968A, San Diego, CA) after signal amplification at filter settings of 1 to 500 Hz. Amplifier gain and filter settings were held constant during the entire recording procedure, and a 1-mV calibration signal was entered as a reference at the time of recording.

Numbering Convention

Each Ann Arbor Electrogram Libraries (AAEL) recording has been assigned a unique number (such as AAEL001). If a patient's recordings include intentional changes in intracardiac lead positions, the AAEL number is followed by a letter (for example, AAEL 239A, AAEL 239B). These are considered separate subject entities, given the unique characteristics of the recordings.

Arrhythmia Definitions

Single atrial premature depolarizations (APDs) and ventricular premature depolarizations (VPDs) during sinus rhythm have been quantified. Two or more consecutive APDs are referred to as repetitive APDs (RAPDs). Two or more consecutive VPDs are referred to as repetitive VPDs (RVPDs). Any supraventricular tachycardia or ventricular tachycardia having a duration of 6 or more cycles has been annotated separately. Atrial fibrillation is diagnosed if the atrial rate is greater than 330 cycles per minute. Atrial flutter is diagnosed if the atrial rate is 240 to 330 cycles per minute. Supraventricular tachycardia is diagnosed if the atrial rate is between 140 and 240 cycles per minute, and its conduction pattern (1:1, 2:1, 3:1) is reported. Monomorphic ventricular tachycardia (VT) is defined as ventricular tachycardia having a monomorphic configuration and a cycle length of 500 or less milliseconds. Polymorphic ventricular tachycardia (PMVT) is defined as a ventricular tachycardia having a polymorphic configuration and cycle length of 500 or less milliseconds. Ventricular flutter (VFt) is defined as any monomorphic VT with a consistent cycle length of 250 or less milliseconds. Ventricular fibrillation (VFb) is defined as any PMVT with a consistent cycle length of 250 or less milliseconds.

Patient: A259

Statistics
Age: 73
Sex: Male
Diagnosis:
Drugs: None

CH	Lead
1	V1
2	I
3	III
4	HRA-B
5	RVA-B
6	HRA-U
7	RVA-U

	Ventricular Rhythm					Concurrent Atrial Rhythm
Footage	Mode	Arrhythmia	BB-Ax-Plane	Cycle Length	Duration	
272	Sp	SR (APDs)	RBBB	840	97	APDs (6) VPDs (3)
301	I	VT	LBB-S-R	340	22	SR
	Sp	SR	RBBB	690	24	
311	I	VT	LBB-S-L	340	42	SR
	-->P-->	SR	RBBB	700	18	
323	I	VT	LBB-S-L	340	46	SR
	-->P-->	SR	RBBB	730	19	
335		CAL				

HRA-Bi = High Right Atrium - Bipolar; RVA-Bi = Right Ventricular Apex - Bipolar; Un = Unipolar

Sp = Spontaneous; I = Induced; P = Paced; Pa = Pacing (Atrial); CV = Cardioversion; AC = Alternating Curren
CAL = 1 mV Calibration Pulse

SR = Sinus Rhythm; APDs = Atrial Premature Depolarizations; VPDs = Ventricular Premature Depolarizations
VT = Ventricular Tachycardia; VFt = Ventricular Flutter; VFb = Ventricular Fibrillation; AFt = Atrial Flutter;
AFb = Atrial Fibrillation; PM = Polymorphous; IVCD = Intraventricular Conduction Disturbance; N = Normal

BB = Bundle Branch Pattern; Ax = Axis; ? = Unknown

Fig. 1. Patient datasheet containing information from the cardiologist overrreading for patient A259. Patient demographics are given, leads recorded are listed, and footage number (original tape) is annotated with rhythm statistics. The data files are named Axxxyyy, where xxx is the patient number and yyy is the footage location.

Ann Arbor Electrogram Libraries

Each individual patient has been divided into several data files, containing 1) an example of sinus rhythm, 2) an arrhythmia such as VT, VF, SVT, and 3) calibration pulses. In some cases, there are 2 or more arrhythmia passages for a specific patient. The information from the overreading by the cardiologist is contained in each patient datasheet. Figure 1 shows an exemplary patient datasheet.

The database is most commonly made available in digitized format (1,000 Hz). This digitized format allows the researcher to use AAELVIEW for Windows, a proprietary data display and manipulation software, which allows cutting and pasting of signal files to create custom electrograms. Temporal resolution of the display (samples per division between time hacks) is user selectable, as is display gain on a channel-by-channel basis. AAELVIEW provides the user the capability of cursor-controlled cycle length measurements, amplitude measurements (at the patient level based on the calibrations pulses), and of separating out individual channels for analysis. Data files can be edited by extracting specific passages of interest. Figure 2 is a 7-channel tracing of

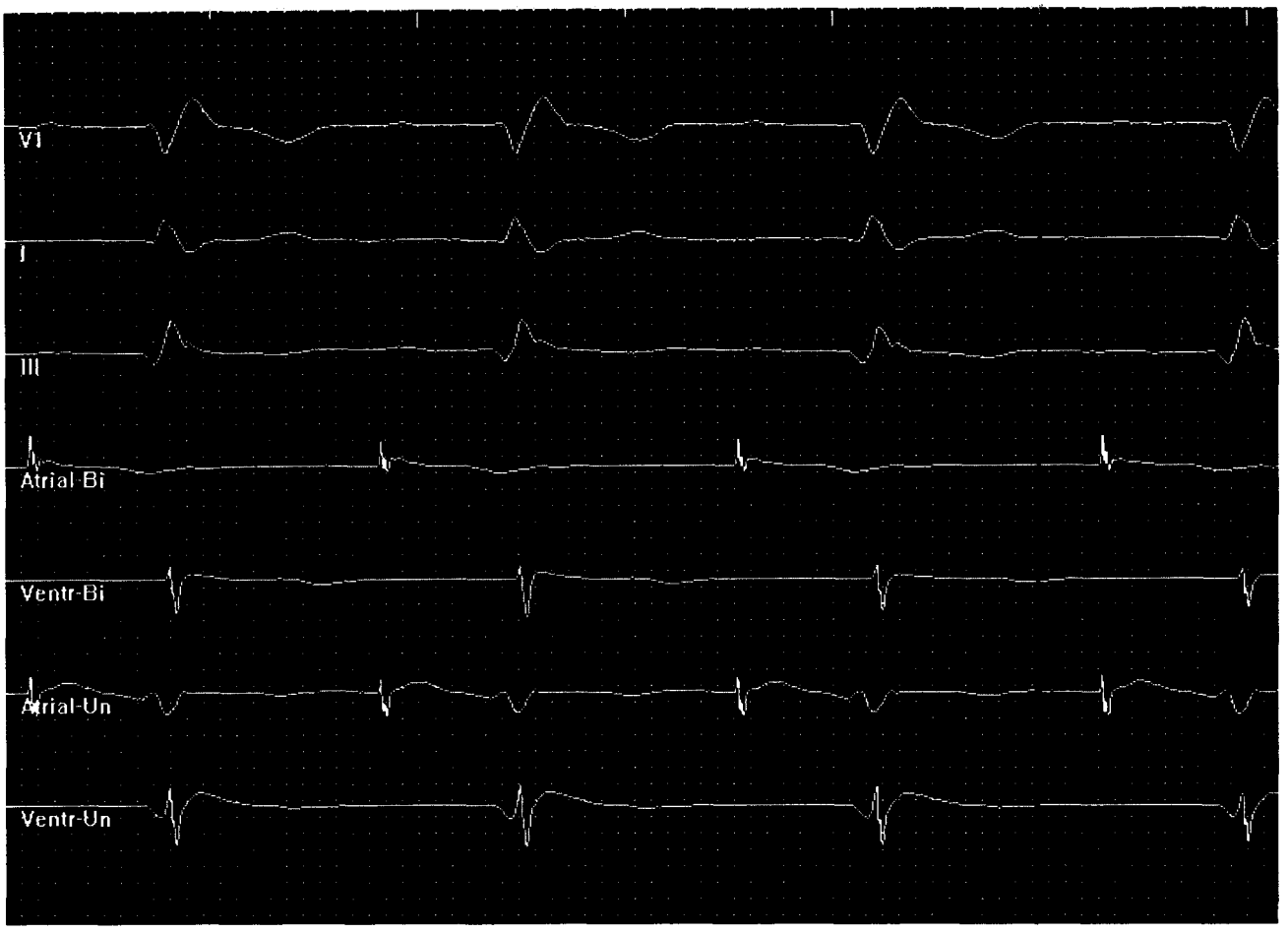

Fig. 2. An example of a passage of sinus rhythm from patient A259. Leads shown are (top to bottom) V1, I, III, high right atrium (HRA) bipolar, right ventricular apex (RVA) bipolar, HRA unipolar, and RVA unipolar.

patient A259 in sinus rhythm and Figure 3 is patient A259 in ventricular tachycardia.

Volume I contains recordings from 65 patients divided into 8 sets. The data files found in these directories are named in a format designed to directly correspond to the analog tape patient numbers and delineated segments (ie, footage on the original tape). All files related to patient datasheet AAEL173 are datafile names: A173***.SIG, where *** refers to the original tape footage. (The .SIG extension indicates that the data file is in AAEL's proprietary format with a file header included as a prefix to each file). The header contains 1) the number of channels, 2) the sampling rate, and 3) the patient identifier (ie, AAEL173).

To continue the example, for patient AAEL173, there are three digitized files:

A173670.SIG [Atrial Fibrillation with normal ventricular response starting at 670 ft. on the original analog tape. This particular patient has chronic AFb, so there is no sinus rhythm example]

A173697.SIG [Ventricular tachycardia starting at 697 ft. on the analog tape]

A173702.SIG [Calibration pulses starting at 702 ft. on the analog tape]

The prefix "A173" is the patient number. The next 3 digits correspond to the tape footage on the original analog recording (on the patient data sheet, these numbers can be found under "Footage" on the datasheets)

Sets 1 to 7 contain predominantly ventricular arrhythmias. Set 8 includes nine patients with competing rhythms, ie, simultaneous atrial and ventricular rhythms in the same patient. Volume II contains 52 patients (minimum of three files per patient) divided into 6 sets, and also has predominantly ventricular arrhythmias. Volumes IV (35 patients) and V (41 patients) contain predominantly atrial arrhythmias (atrial fibrillation and

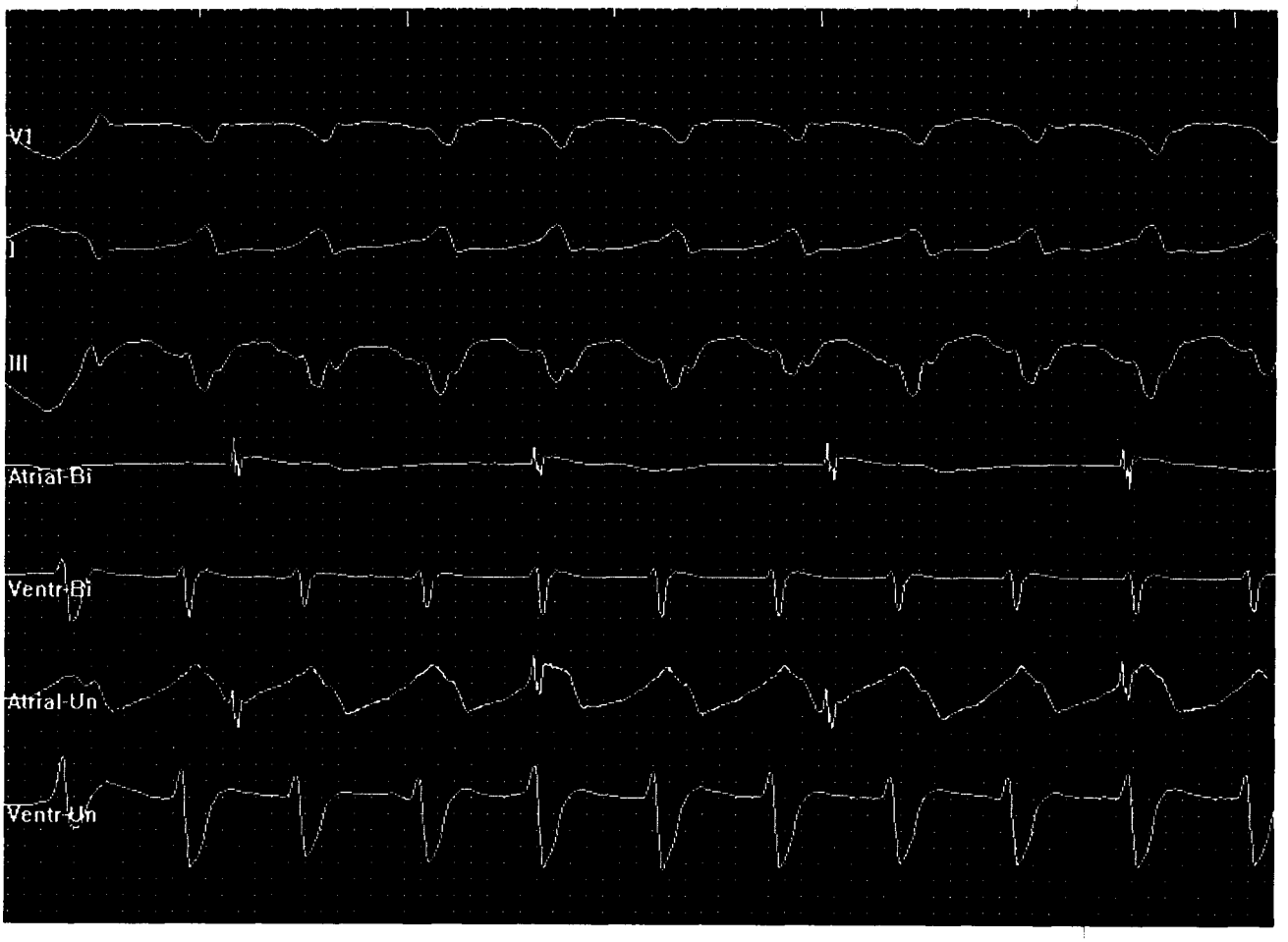

Fig. 3. example of a passage of ventricular tachycardia from patient A259. Leads shown are (top to bottom) V1, I, III, high right atrium (HRA) bipolar, right ventricular apex (RVA) bipolar, HRA unipolar, and RVA unipolar.

flutter). Volume III, which is intended to be a secure database for blinded testing, will be available third quarter, 2003.

Conclusion

The Ann Arbor Electrogram Libraries is a compilation of hundreds of patient recordings acquired during clinical electrophysiology studies spanning more than a decade and a half. This library represents the work of a team of professionals who have dedicated extensive time to the collection, organization, annotation, and preparation of this database for use by authorized licensees.

Publication Requirements

The use of Ann Arbor Electrogram Libraries recordings must be cited and data acquisition procedures should be included in the Methods section of any published paper as follows: [Ann Arbor Electrogram Libraries, Chicago IL, USA]. The number of each Ann Arbor Electrogram Libraries recording used is required to be cited specifically in any tabular listing of results. This requirement is mandated in order to make possible a comparison of the results of any published paper with those of previous as well as future studies that also use the Ann Arbor Electrogram Libraries.