# Atrial Defibrillation Using Heart Wires in a Canine Model

F. REDLING
Klinik für Herz- und Thoraxchirurgie, University of Halle-Wittenberg, Halle, Germany

L. GELLER, B. MERKELY
Semmelweis Medical University, Budapest, Hungary

T. BIEBERLE, M. SCHALDACH
Department of Biomedical Engineering, University of Erlangen-Nuremberg, Erlangen, Germany

H. R. ZERKOWSKI
Universitätsklinik für Herz- und Thoraxchirurgie, University of Basel, Basel, Switzerland

**Summary**

*Atrial fibrillation (AF) is encountered in up to 64% of patients after open heart surgery. In order to avoid high energy external defibrillation as well as a drug treatment which compromises the hemodynamics, our goal is to apply low energy shocks via custom designed heart wires. In a first step, the method was investigated in a canine model. Five mongel dogs (weight 27.2 ± 3.9 kg) were anesthetized with 30 mg/kg of pentobarbitol sodium and ventilated with room air. After opening the chest using a lateral sternotomy technique, two-finger defibrillation heart wires (electrode length 35 mm each) were sutured to three different positions at the right and left atrium respectively. Atrial signals were recorded via bipolar screw-in electrodes, R-waves for triggering the shocks were monitored via bipolar heart wires. AF was induced using an approach modified from Kempler et al. by applying 4.5 V dc to the atria while administering subsequent boli of 0.025 mg of isproterenol. R-wave triggered shocks were delivered after 3 min of sustained AF using a step-up protocol. Each configuration was tested 3 times. AF was converted reliably to sinus rhythm in all but one dog who developed severe hemodynamic and rhythmologic problems (MABP < 40 mmHg, dilatation of ventricles, spontaneous VF). Differences in atrial defibrillation thresholds (ADFT) between the investigated electrode positions were not statistically significant. The mean ADFTs were 2.01 ± 1.44 J, 12.96 ± 7.39 J, 1.27 ± 1.17 J, 2.47 ±2 .79 J, and 1.01 ± 0.56 J in the five dogs, respectively. The heart wires were pulled out without causing visible damage the myocardium in all cases. The results of these investigations show that low energy atrial defibrillation using heart wires is a feasible approach from both a surgical and a rhythmological point of view. In a following clinical study, the relevance of the method as a standard option for AF treatment after open heart surgery will be investigated.*

**Key Words**

Atrial fibrillation, atrial defibrillation, heart wires, atrial defibrillation threshold

## Introduction

Atrial arrhythmias are the most common rhythm disturbances encountered after open heart surgical procedures. The prevalence reported in literature varies from 23 to 64% [3][6][8] and depends on the type of the procedure, concomitant heart disease, history of atrial fibrillation or ischemia, medication, age, and gender. The study of Yousif and coworkers with 100 consecutive patients revealed that the arrhythmias occur predominantly in the critical early postoperative period (63%) and are often preceded by a compromised hemodynamic situation (37.5%). On the other hand, 74% of their patients were in sinus rhythm at the time of hospital discharge. However, the postoperative atrial fibrillation (AF) may have severe clinical consequences including congestive heart failure, hemodynamic impairment, and increased risk of thromboem-

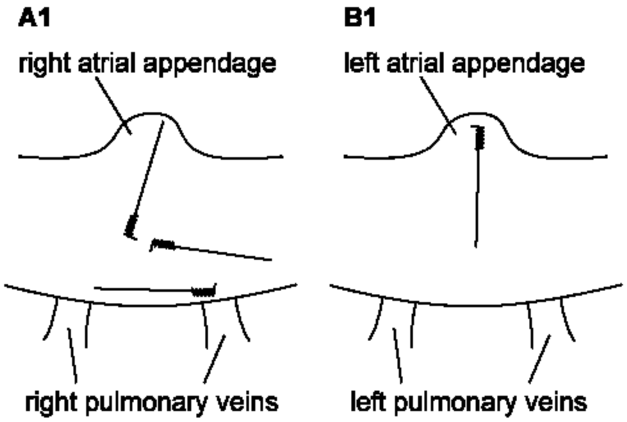


*Figure 1. Electrode configurations A1 and B1 in right and left lateral views, respectively.*

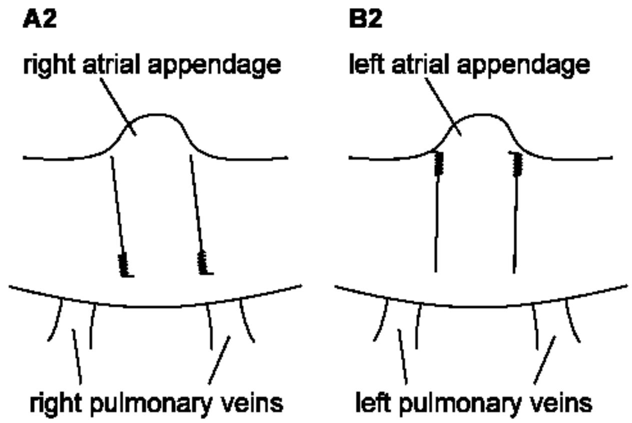


*Figure 2. Electrode configurations A2 and B2 in right and left lateral views, respectively.*

bolic stroke.

Standard therapeutic options for arrhythmia management extend on ventricular rate control and restoration or maintenance of sinus rhythm by correction of electrolyte abnormalities, antiarrhythmic medication, pharmacological or electrical cardioversion, and atrial antitachycardic pacing. All these methods are associated with either limited efficacy and applicability or significant side effects. Recently, internal electrical cardioversion by use of intracardiac catheters has been developed as a very effective alternative [1][4][7]. In the setting of postsurgical atrial fibrillation, however, a different approach seems to be obvious: the use of epicardial wire electrodes. The use of wire electrodes for temporary pacing in the postoperative period has become a routine procedure since its first use in the sixties. The extension to defibrillation has been reported in experimental and clinical settings recently [2][6]. We investigated the feasibility of a new two-fingered wire electrode for atrial defibrillation in an open-heart canine model.

## Methods

*Operative technique*

The study was designed according to the guidelines of the Helsinki protocol of Good Laboratory Praxis. The investigations were performed in 5 adult mongrel dogs weighing 27.2 ± 3.9 kg. General anesthesia was induced by means of i. v. pentobarbital sodium at a dose of 30 mg per kg body weight (Nembutal, Abott Laboratories, North Chicago, IL, U. S. A.). The dogs were ventilated with room air (RO 15, model III, Russia). After accomplishment of a clam shell sternotomy and creation of a pericardial cradle, the epicardial defibrillation heart wires were sutured to the atria as depicted in Figure 1, Figure 2, and Figure 3. In three of the dogs, a coronary artery bypass graft (CABG) was simulated by suturing veins that were left from human CABG operations to the left ventricular anterior wall. At the end of the procedure, the heart wires were removed by gentle pulling, and the myocardium was visually investigated.

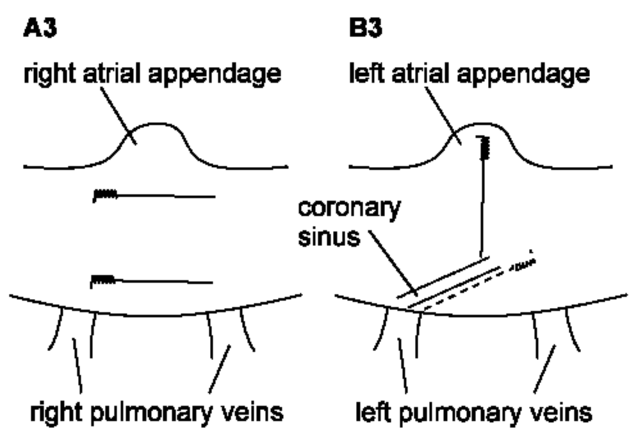


*Figure 3. Electrode configurations A3 and B3 in right and left lateral views, respectively.*

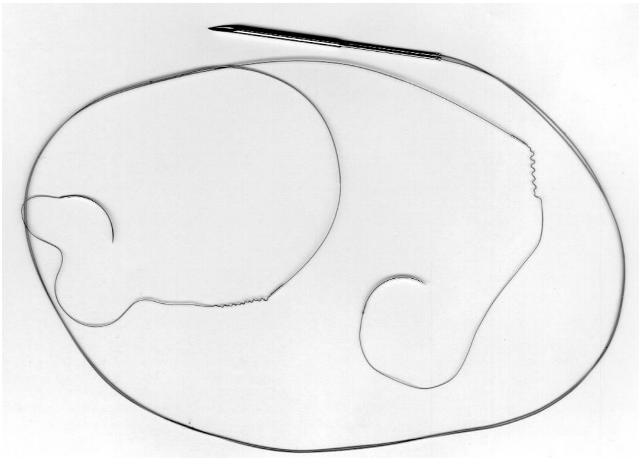

*Figure 4. Photograph of the epicardial two-finger defibrillation wire.*

*Electrodes*
For atrial signal recording, a fractal coated screw-in electrodes was placed at the right atrial appendage (SX 60-BP/2, BIOTRONIK). The ventricular signals were accessed by means of bipolar heart wires at the right ventricular anterior wall (MHW 60-BP, BIOTRONIK). All investigations were executed with open chest.
The defibrillation heart wires were custom designed to fulfill the needs of efficient defibrillation and easy handling (Figure 4). They consist of two polyethylene insulated stainless steel wires with a diameter of 0.25 mm. They are linked to a straight break-off thorax needle of 1 mm of diameter at the proximal end. At a distance of 40 cm the two joint wires are separated. After another 65 mm, a deinsulated portion of 40 mm follows in each of the two wires. At the distal end the wires are connected to a polypropelene fixation element with a myocardium needle at the distal end. The helical shape at its proximal end ensures a stable position of the defibrillation wires. The use of two defibrillation wires with two electrodes each was intended to enable a favorable field distribution across the atria and thus to reduce the defibrillation energy requirements. We investigated three electrode configurations each of which included right and left atrium (Figure 1).

*Defibrillation setup*
Atrial defibrillation was controlled by an external shock analyzer (TMS 1000, BIOTRONIK). Manually activated shock releases were synchronized to the ventricular potential sensed by the shock analyzer from the right ventricular wire electrodes. We used a standard biphasic wave form with a voltage controlled first phase and a short second phase of 2 ms.

*Measurement protocol*
Atrial fibrillation was induced by applying direct current from a 4.5-V-battery to the defibrillation heart wires similar to the method proposed by Kempler and co-workers previously [5]. In order to facilitate arrhythmia induction, isproterenol was administered as i. v. boli (Isuprel, Sanofi, Winthrop, NY, U. S. A.). If stable atrial fibrillation persisted for at least 3 min, defibrillation was attempted using a step-up protocol. It was intended to test all possible combinations of right (A1, A2, A3) versus left atrial (B1, B2, B3) defibrillation heart wires in each dog successively. The sequence of the configuration testing was randomized. Atrial defibrillation threshold was determined three times in each configuration. Atrial and ventricular epicardial signals as well as surface ECG lead III and blood pressure were continuously monitored during defibrillation testing (Figure 5).

## Results

79 sustained episodes of atrial fibrillation were induced by application of direct current in the five investigated dogs. A total number of 335 induction attempts was necessary, i.e. 4.24 attempts per sustained episode. Intravenous administration of isoproterenol was used until induction of sustained AF was easily possible. Therefore, the first induced episodes where the isproterenol level was low usually terminated spontaneously. For example, in the fourth animal, the first sustained AF episode occurred after 45 induction attempts and a infusion of 0.45 mg of isproterenol. For the second sustained episode, 26 attempts and another 0.3 mg were needed, for the third episode 5 attempts and 0.2 mg. The following sustained episodes were induced with a single attempt.
Restoration of sinus rhythm was possible in all 5 dogs and in all investigated configurations. A total number of 397 atrial defibrillation attempts was made. In none of the animals, the investigation of all shock configurations was possible, because of a deterioration of the hemodynamic situation in the course of the investigations. The hemodynamic problems were preceded by induction of ventricular fibrillation with a not appropriately synchronized shock. The incorrect synchro-

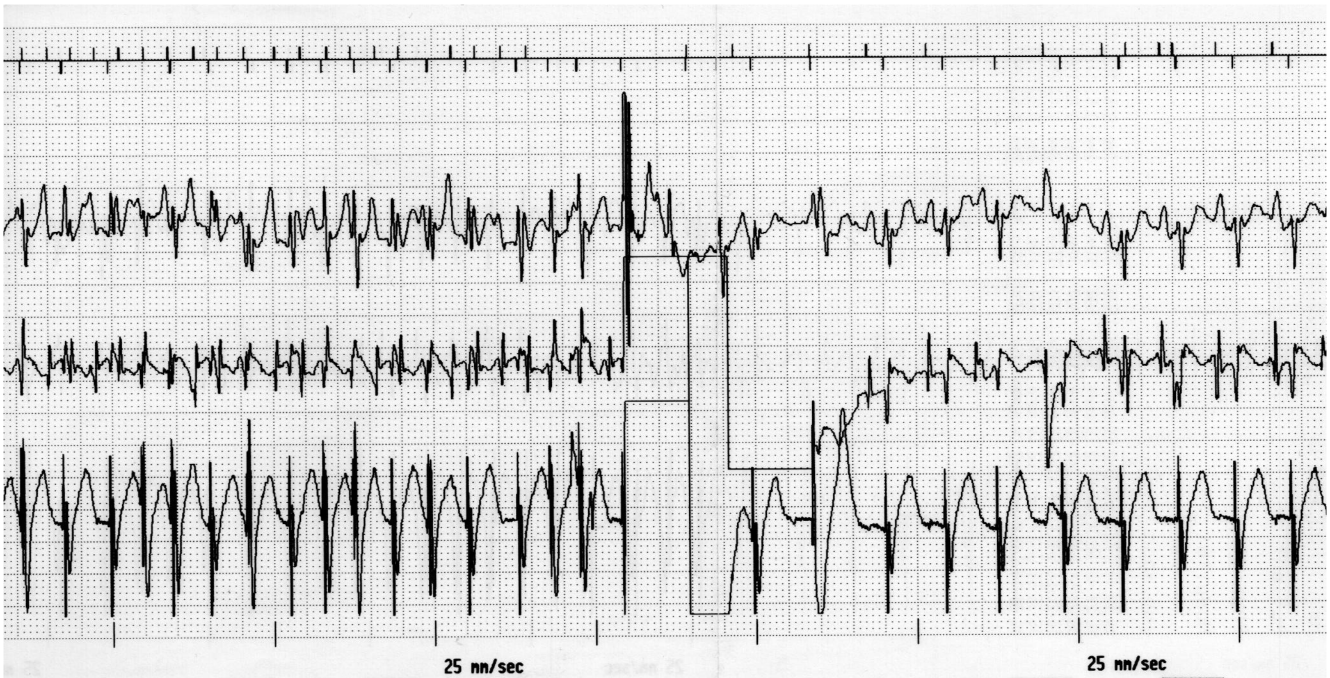


*Figure 5. Atrial defibrillation using a standard bipasic shock of 0.8 J in configuration A2B2. The top panel shows the detection markers for atrial (upper trace) and ventricular channel (lower trace). The following three panels contain the surface ECG lead III as well as epiatrial and epiventricular electrograms, respectively.*

nization was due to a malfunction of the external shock analyzer. The second animal very soon developed severe hemodynamic and rhythmologic problems (MABP < 40 mmHg, dilatation of ventricles, spontaneous VF).

Figure 5 shows an example of the ECG recordings during cardioversion of atrial fibrillation with a 0.8 J shock. The atrial defibrillation threshold values are summarized in Table 1. The mean defibrillation thresholds varied from 0.5 J in configuration A3B1 to 4.6 J

| configuration | animal 1 | animal 2 | animal 3 | animal 4 | animal 5 | mean | SD |
|---|---|---|---|---|---|---|---|
| A1B1 | 2.01 | 12.96 | 3.30 | 2.37 | 0.80 | 4.29 | 4.93 |
| A1B2 | | | 1.13 | 2.10 | 1.37 | 1.53 | 0.41 |
| A1B3 | | | 0.90 | 2.97 | 0.90 | 1.59 | 0.97 |
| A2B1 | | | 0.70 | 5.10 | | 2.90 | 2.20 |
| A2B2 | | | 0.80 | 2.43 | | 1.62 | 0.82 |
| A2B3 | | | 1.27 | 1.15 | 0.95 | 1.12 | 0.13 |
| A3B1 | | | 0.50 | | | 0.50 | |
| A3B2 | | 1.55 | | | | 1.55 | |
| A3B3 | | 4.57 | | | | 4.57 | |
| mean | 2.01 | 12.96 | 1.27 | 2.47 | 1.01 | | |
| SD | 1.44 | 7.39 | 1.17 | 2.79 | 0.56 | | |

*Table 1. Results from atrial defibrillation by means of epimyocardial stainless steel defibrillation wires. Note that energy requirements are subject to big interindividual variations which prevent a statistical analysis of the data.*

in configuration A3B3, the mean value was 2.37 ± 2.73 J. The maximum delivered energy was 30 J. Note however the considerable interindividual variations and the different number of test values underlying these results. These variations prevented a statistical comparison of the different electrode configurations. The shock impedances were in the range of 70 to 100 Ohms.

The defibrillation heart wires were removed by gentle pulling without causing visible damage to the myocardium in all animals. In the three animals, where coronary artery bypasses had been simulated, these bypasses were not affected. In one animal, the wires were removed after having closed the chest. Investigation of the used defibrillation heart wires with an optical microscope did not reveal any damage at the electrodes or at the insulation although a maximum energy of 30 J had been applied.

## Discussion

Our animal results confirm that cardioversion of atrial fibrillation by means of epimyocardial heart wires is a feasible and practicable method. Thus, our experimental study confirms the results of other groups in the sense that the method in general is safe and efficient enough to be applied in the clinical setting [6]. In addition, it shows, that the special approach of our two-finger heart wire is a suitable and time efficient method. Although the data from our pilot feasibility study does not permit any quantitative analysis of the defibrillation threshold, we believe that the values shown in Table 1 are also encouraging with respect to the efficiency of the two-finger defibrillation heart wires. Therefore, we will accomplish the next step of investigating the new heart wires in a clinical study.

## References


[1] Alt E, Schmitt C, et al. Initial experience with intracardiac atrial defibrillation in patients with chronic atrial fibrillation, PACE. 1994; 17: 1067-1078.

[2] Cmolik B, Ortiz J, et al. Successful atrial defibrillation with very-low-energy shocks by means of temporary epicardial wire electrodes. J Thor Cardiovasc Surg. 1996; 111: 392-398.

[3] Creswell LL, Schuessler RB, Rosenbloom M, et al. Hazards of postoperative atrial arrhythmias [see comments]. Ann Thorac Surg. 1993; 56 (3): 539-549.

[4] Keane D, Sulke N, et al. Endocardial cardioversion of atrial flutter and fibrillation. PACE. 1993; 16: 928.

[5] Kempler P, Hayes WJ, Dezern KR, et al. Direct current induction of atrial fibrillation. Am Heart J. 1994; 127 (4 Pt 1): 945-946.

[6] Liebold A, Wahba A, Birnbaum DE. Low-energy cardioversion with epicardial wire electrodes: new treatment of atrial fibrillation after open heart surgery [see comments]. Circulation. 1998; 98 (9): 883-886.

[7] Malinowski K, Revishvili ASh, et al. Internal atrial defibrillation and detection: clinical results. in: Proceedings of Europace '97, Vardas, P. E., ed., pp. 923-928, 1997.

[8] Mathew JP, Parks R, Savino JS, et al. Atrial fibrillation following coronary artery bypass graft surgery: predictors, outcomes, and resource utilization. MultiCenter Study of Perioperative Ischemia Research Group [see comments]. JAMA. 1996; 276 (4): 300-306.

[9] Yousif H, Davies G, Oakley CM. Peri-operative supraventricular arrhythmias in coronary bypass surgery. Int J Cardiol. 1990; 26 (3): 313-318.