

Technical Notes

Use of the Fluid Column in a Cardiac Catheter for Emergency Pacing

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Given the not infrequent need for intracardiac pacemaking during intensive cardiac care, a new type of cardiac pacemaker has been designed and tested [1]. With this pacemaker the heart can be stimulated through the fluid column of any conventional catheter, provided it is filled with a 0.9% NaCl solution. This fluid column pacemaker (FCP) is of the "constant current" type. The FCP was tested in 37 animals, in 30 patients in sinus rhythm, and also in two critical patients. In addition to the pacemaker circuit, a special connector was designed, enabling a fast, effective, and safe contact between patient and pacemaker. The FCP is considered to be ideally suited for use in emergency cardiac pacing in intensive care units and other areas where sudden bradycardias may occur and where intrathoracic catheters are inserted for a variety of reasons.

Key words: emergency pacing, pacemaker, intensive care

INTRODUCTION

In an intensive care unit, many patients have an indwelling catheter in the right side of the heart, usually of the flow-directed balloon type, with the distal tip positioned in the pulmonary artery. Temporary cardiac pacing is used in such patients for a variety of indications [2-4] and is mostly carried out by inserting a transvenous electrode catheter into the right ventricle as introduced by Furman et al [5]. Actual emergency cardiac pacing was carried out in the coronary care unit of the Thoraxcentre in Rotterdam in 4.7% of the patients admitted with a fresh myocardial infarct (70 cases out of 1,483, over a period of 2 years). Prophylactic insertion of a pacemaker catheter in such a unit can therefore be estimated to be necessary two or three times more often or in 10-15% of patients. The hard-wired pacing version of a

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floating balloon catheter is infrequently used for routine prophylactic purposes, because of the higher cost and restricted anticipated need. While a reinsertion of a pacing catheter or the exchange of a hemodynamic monitoring catheter is by itself a relatively simple procedure, it requires special expertise, new materials, and, most importantly, extra time, while the risk of infection is enhanced. The capability of being able to pace the heart immediately, through an existing intracardiac pathway, must be considered to be of great practical advantage, especially in emergency situations.

We have therefore investigated the possibilities of employing the fluid column within a conventional cardiac catheter, when it is filled with a 0.9% NaCl solution, as an electrical conduit for pacing the heart.

MATERIALS AND METHODS

The Pacemaker

The electrical impedance of the fluid column in a cardiac catheter is approximately 0.5–1 megohm, depending on the model and size of the catheter and of the type of fluid in the lumen. In order to overcome this impedance, a pacemaker circuit was designed of the "constant current" type with a pulse width of 1 msec (Fig. 1.). It has a feedback control circuit to maintain the current pulse at the adjusted current level, up to a given maximum, independent of the external load. The pacemaker is battery-powered and has a variable stimulation rate. This rate can be set between 30 and 180 beats per minute. The output of the pacemaker is limited to a certain maximum as shown in Figure 2. In this way, maximally a pulse of 7.5 mA can be provided over an external resistance of 1 megohm. This level has been shown to be more than adequate in our animal studies and patient experience.

The Connector

For use in the coronary care unit and other intensive care areas, a special connector was designed and constructed to provide optimum contact between the external pacemaker and the fluid column in the cardiac catheter (Fig. 3). This connector assembly also serves as an external skin electrode and is fastened to the arm of the patient. Figure 4 shows the connector in its true form. Not only incomplete contact between catheter and pacemaker or the use of a nonconducting fluid will be detected, but also leakage of blood or other fluids, as well as unexpected loosening of the fastening strip. These conditions will lead to a visual and audio alarm while the pacemaker is switched off.

ANIMAL EXPERIMENTS

In the experimental laboratory the FCP was tested in 37 animals, subjected to various other experiments (Table I). All were under general anesthesia and in sinus rhythm. All animals had a floating tip balloon catheter in the pulmonary artery. Satisfactory right ventricular pacing could be initiated in all animals after pullback of the catheter tip into the right ventricle. Current thresholds ranged from 0.2 to 4.3 mA with a mean value of 1.1 mA. In two piglets right ventricular pacing with the FCP and a Swan-Ganz thermodilution balloon catheter* with the tip in the right ventricle

*Swan-Ganz flow-directed thermodilution catheter, model 93A-131-7F, Edwards Laboratories, Santa Ana, California.

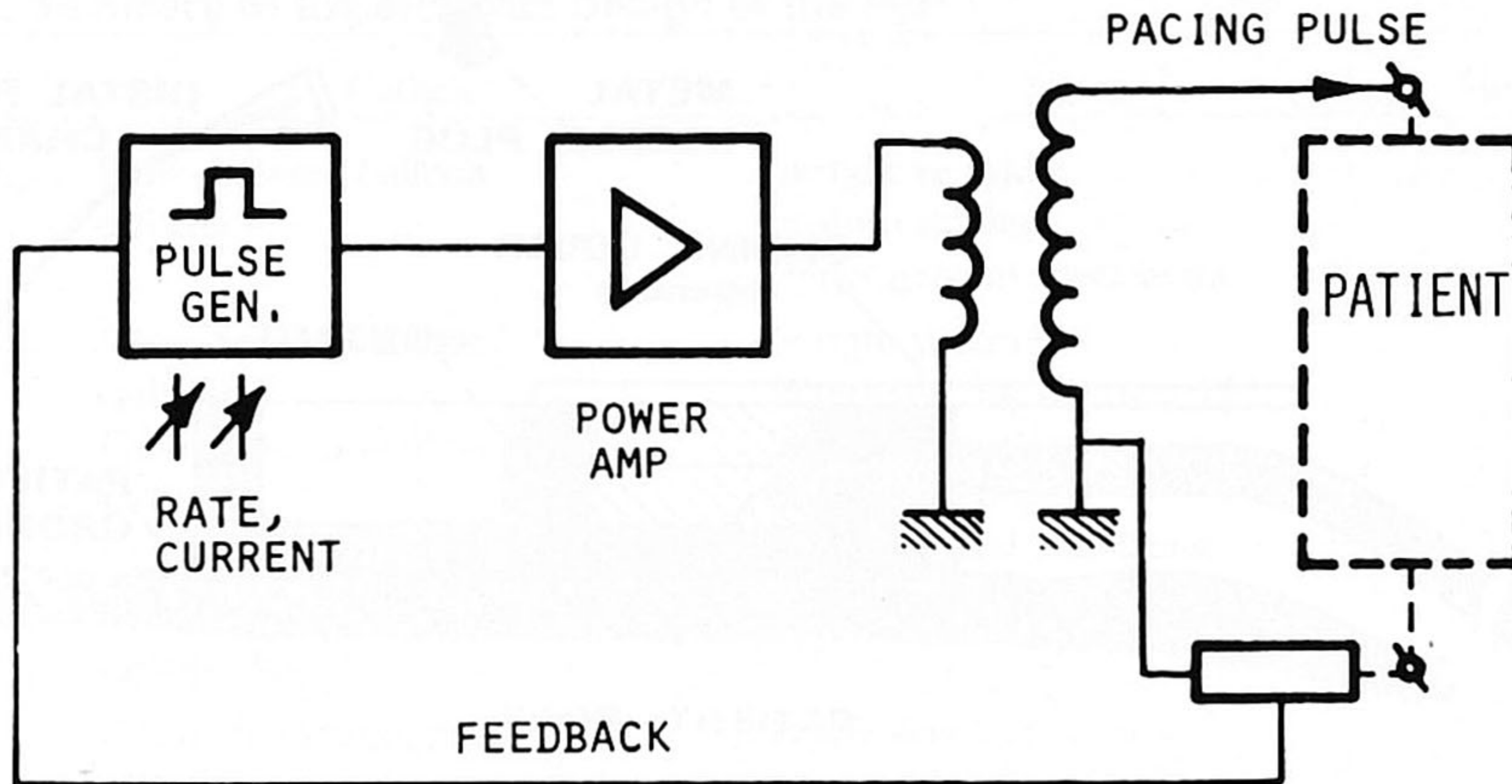


Fig. 1. Block diagram of fluid column pacemaker (FCP). The pulse generator and power amplifier are electrically isolated from the patient. The pacing pulse is sensed and automatically adjusted for voltage, dependent on external load.

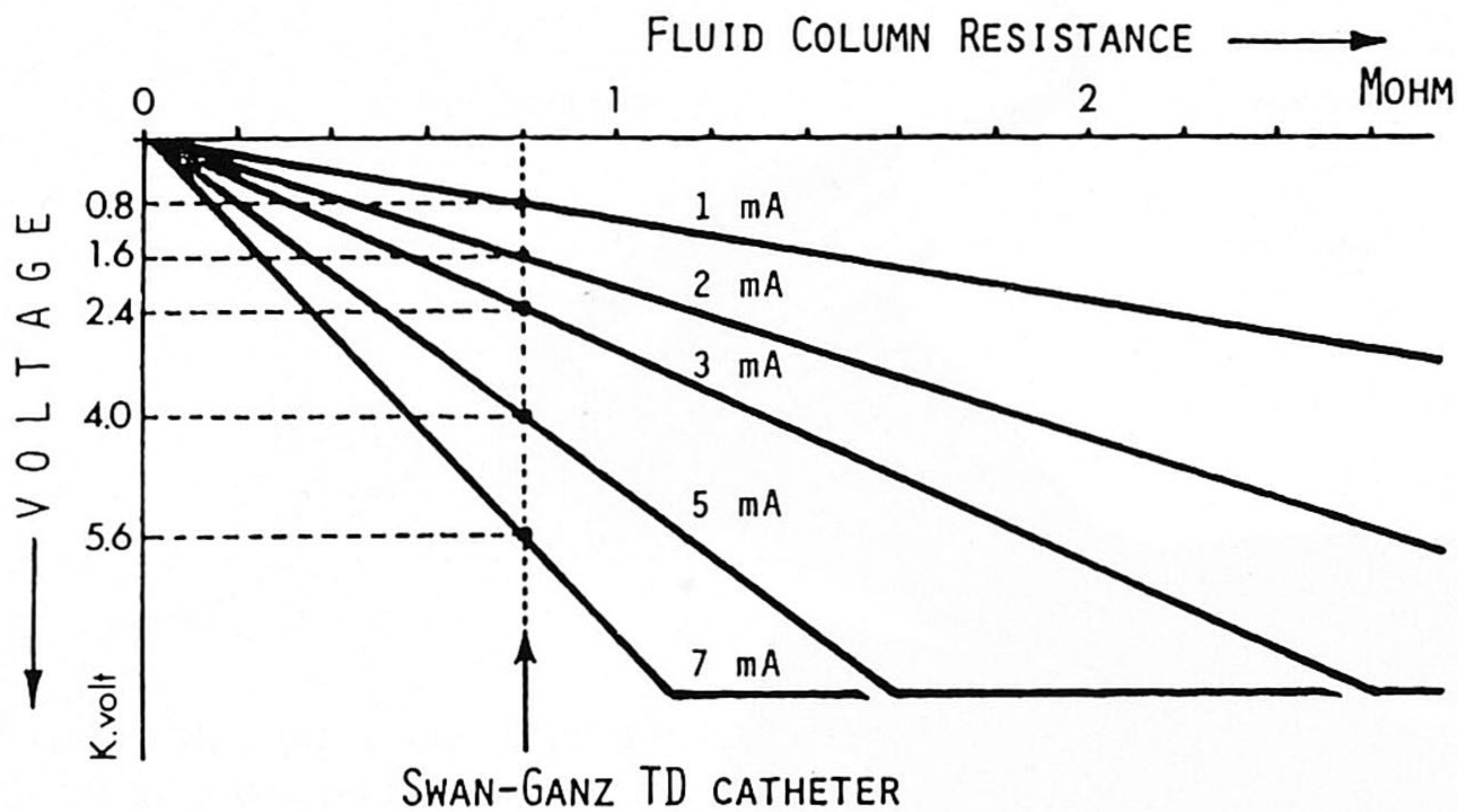


Fig. 2. FCP output characteristics. Output voltage for different current setting, as dependent on fluid column resistance. The resistance of the fluid column of a flow-directed balloon catheter is drawn in to indicate usual operating conditions.

was continued over a period of 12 hrs, with consistent ventricular capture and a mean current of 1.2 mA. Afterwards one of the catheters was seen to contain a 1-cm-long blood clot in its distal end. This did not interfere with pacing.

In five piglets left heart catheters were used—a Sones coronary angiography catheter No 7.5†) in the left ventricle in three, a pigtail ventriculography catheter No. 7‡) in two. Also in these experiments ventricular capture was easily established.

Not all fluids can be used for conducting the pacing pulse as, for instance, 5% glucose does not have a low enough resistance. In all these animals 0.9% NaCl was used to flush the catheters.

†U.S.C.I. International, Box 960, Billerica, Massachusetts 01821, catalog No. 008256.

‡U.S.C.I. International, Box 960, Billerica, Massachusetts 01821, catalog No. 008307.

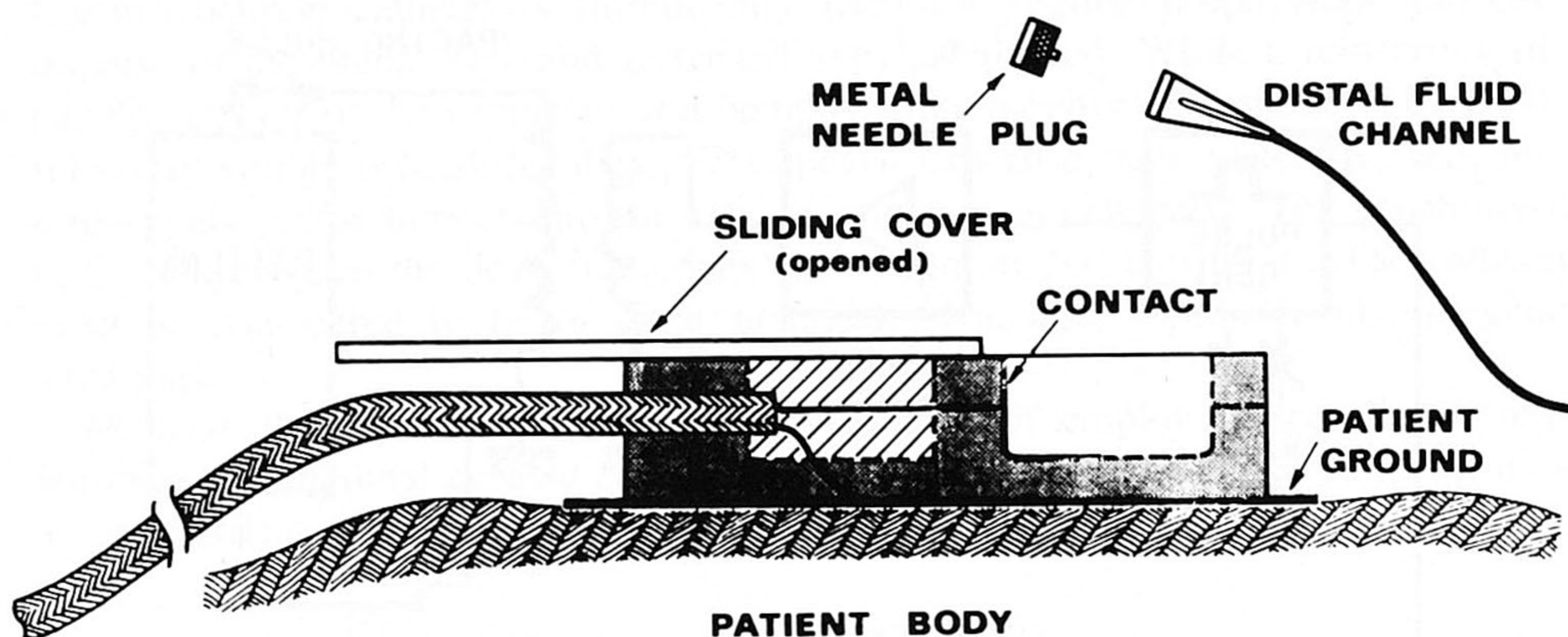


Fig. 3. Diagram of patient connector. The connector provides a skin contact and has a sliding cover on top of a slot for the external end of a cardiac catheter when closed with a metal cap (compare Fig. 4).

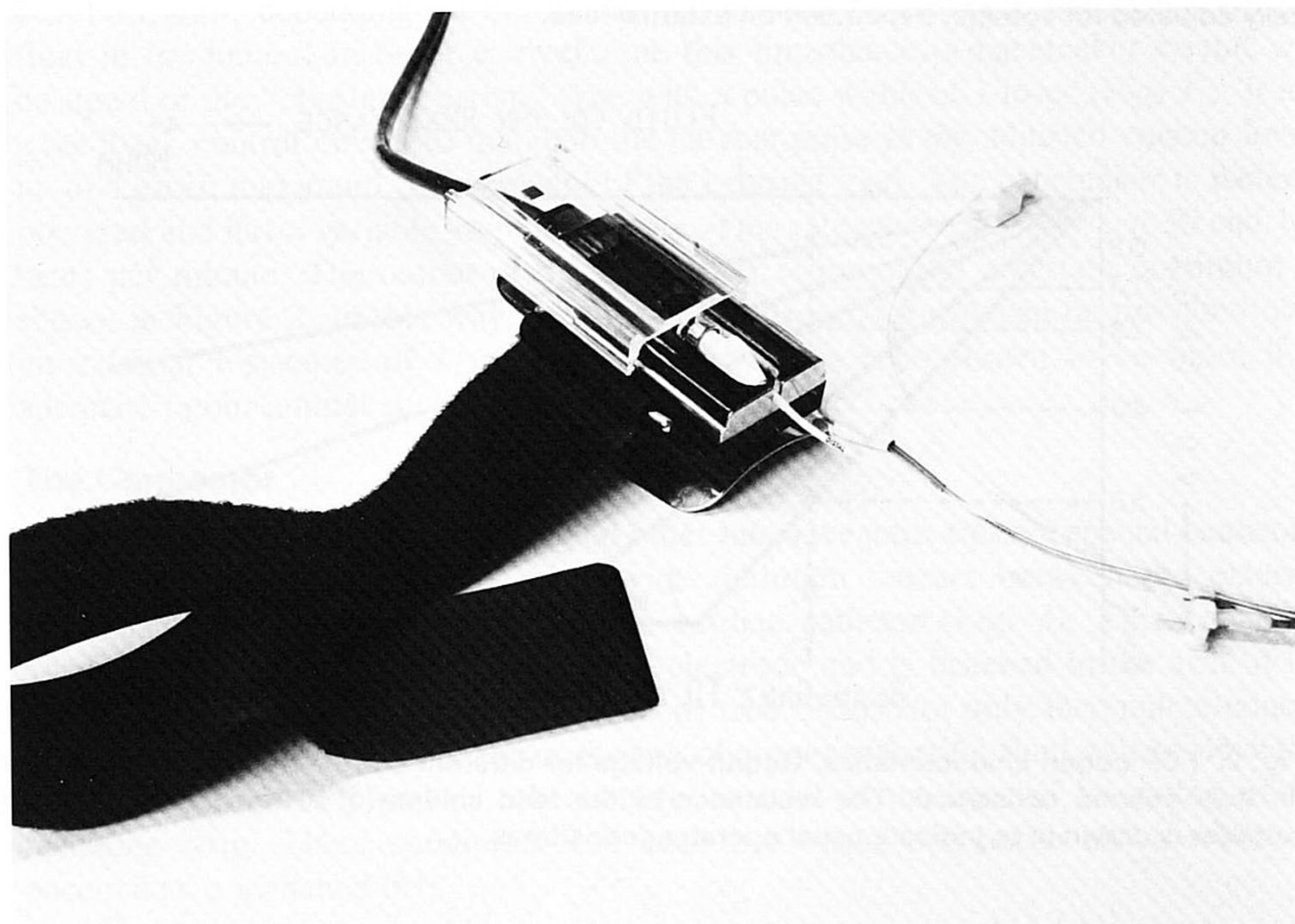


Fig. 4. Picture of connector for contact between patient, catheter, and pacemaker.

EXPERIENCE IN PATIENTS

The FCP with its connector was tested in 30 patients after informed consent (Table II). All patients were admitted in our coronary care unit for an acute myocardial infarct. All were in sinus rhythm, and all had a flow directed balloon catheter with the tip in the pulmonary artery. The catheters were filled with 0.9% NaCl solution. Immediately prior to routine removal of the catheter, the tests were carried out. First, the FCP was connected to the distal fluid channel of the balloon catheter. Current was

TABLE I. Summary of Experiments Design of the FCP

Animals	Catheter	Notes	Mean mA
28 piglets	Flow-directed balloon catheter	In right ventricle In sinus rhythm Under general anaesthesia	1.1
2 piglets	Flow-directed balloon catheter	In right ventricle Ventricular pacing over 12 h	1.1
2 dogs	Flow-directed balloon catheter	In right ventricle In sinus rhythm Under general anaesthesia	1.1
3 piglets	Sones coronary angiography catheter No. 7	In left ventricle	0.3
2 piglets	Pigtail ventriculogram catheter	In left ventricle	0.3

TABLE II. Summary of Clinical Trials for the Design of the FCP

Number of patients	Notes	
30	Recent myocardial infarct In sinus rhythm In right ventricle	mean 1.8 mA
1	Emergency patient (35 years old) Anterior wall infarct, shock, IABP, defective multipurpose catheter	0.8 mA
1	Emergency (78-year-old male) Intestinal bleeding, shock, acute Anterior wall infarct, cardiac arrest Electromechanical dissociation	

set to 5 mA with a pulse rate approximately ten beats above the current heartrate. The catheter then was pulled back slowly until ventricular capture was visible on the monitoring oscilloscope. Current then was decreased to assess the threshold. Right ventricular capture could be established in all patients within a few seconds. Mean current threshold was 1.8 mA (range 0.2–4.7 mA). The pull-back trajectory was usually 10–12 cm, depending on the original position of the catheter and possible slack. When ventricular capture was achieved, the catheter could be pulled back over an additional distance of 5–7 cm within the right ventricle without interrupting pacing. The observed thresholds for right atrial and right ventricular pacing were between 1 and 5 mA, as shown in Figure 5.

Finally, during this testing phase, the FCP was used in two emergencies. A 35-year-old male with an acute anterior wall infarct entered in cardiogenic shock and was supported with the intra-aortic balloon pump. When suddenly complete atrio-ventricular block developed, the earlier inserted multipurpose catheter proved to be defective; the patient therefore could not be paced. This catheter was then pulled back with the tip in the right ventricular and effective right ventricular pacing ensued when the FCP was connected, with a current threshold of 1.8 mA. This was continued over

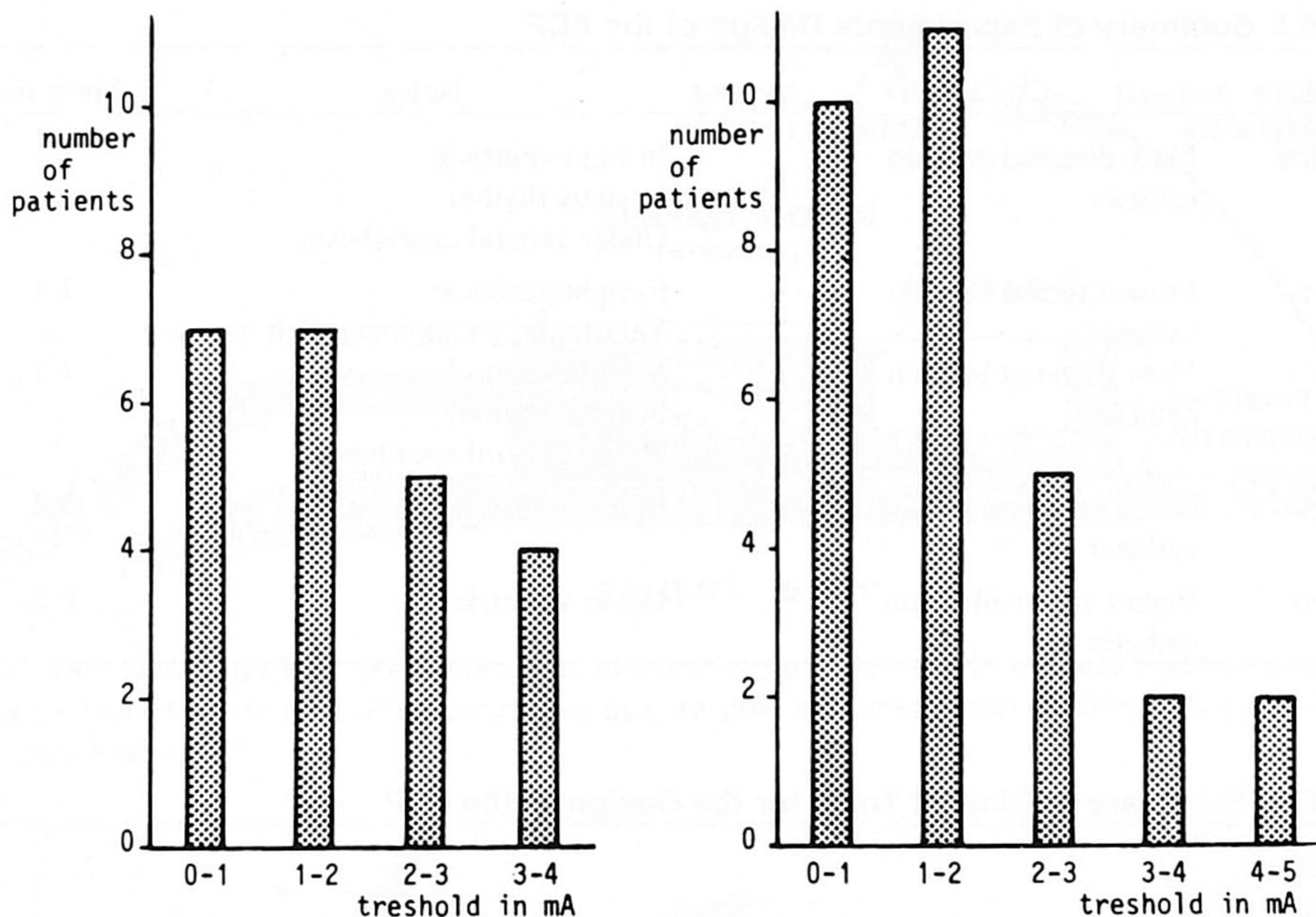


Fig. 5. Current thresholds for right atrial (left) capture in 23 patients and right ventricular capture (right) in 23 patients with the fluid column pacemaker. All patients in sinus rhythm.

a period of approximately 15 min, until another intravenous pacemaker lead was introduced.

The pacemaker was also used in another emergency situation in a 78-year-old male patient in shock due to massive intestinal bleeding after an automobile accident, associated with an acute myocardial infarct and cardiac arrest. The heart could be paced through the fluid column of a balloon catheter, with an adequate electrical response but no cardiac output ensued owing to electromechanical dissociation. Further resuscitation proved impossible.

RESULTS AND DISCUSSION

In all instances, cardiac pacing through the fluid column of a cardiac catheter could be achieved within a few seconds. Current thresholds ranged between 0.3 and 4.5 mA, with a median of 1.8 mA. The FCP operates with a voltage between 1 and 5 kV, depending on fluid column resistance (Fig 2). Accidental contact with one or both electrodes of the functioning pacemaker by the patient or the medical staff proved harmless, as there is only a limited amount of energy involved (maximally 5 kV and 7 mamp over a period of 1 msec, depending on external resistance). The feedback adjustment for differences in external resistance is practically instantaneous.

Furthermore, it was shown that cardiac pacing through the fluid column of a catheter could be easily effected with the catheter tip in the right ventricle, the right atrium, and the left ventricle. The pacemaker was also used unsuccessfully in one critical patient with a defective multipurpose catheter due to an interrupted pacing wire. The patient, with a fresh infarct and on the intra-aortic balloon pump, did not

lend himself easily to a reinsertion of a conventional pacing catheter. With the FCP, he could easily be paced through the fluid column of that catheter.

Because of the emergency character of the potential application, special attention was given to the design of the arm-connector assembly, with sensors monitoring the position of the sliding cover, the connection with the fluid column, and possible leakage of fluid or blood. Until now, this design has proved quite satisfactory in the practical setting of the coronary care unit.

SUMMARY

A new type of pacemaker and connector, specially designed for cardiac pacing through the fluid column of a cardiac catheter, is presented. The design was successfully tested in 37 animals and 30 patients; it was also used in two emergencies. Emphasis is placed on its application in intensive care units and other areas where emergency cardiac pacing may be necessary.

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