A Multipurpose Catheter for Electrophysiologic and Hemodynamic Monitoring plus Atrial Pacing*

John A. Mantle, M.D., F.C.C.P.; George K. Massing, M.D.; Thomas N. James, M.D.; F.C.C.P.; Richard O. Russell, Jr., M.D., F.C.C.P.; and Charles E. Rackley, M.D., F.C.C.P.

A new multipurpose flow-directed pulmonary arterial catheter has been developed and evaluated in 30 patients with acute cardiopulmonary dysfunction. The catheter permits monitoring of the bipolar atrial electrogram, pulmonary arterial or wedge pressure, central venous pressure, and cardiac output, plus atrial pacing. The standard Swan-Ganz thermistor-equipped catheter was modified to incorporate two ring electrodes on the shaft at 25 and 26 cm from the tip. With the pair of electrodes positioned in the right atrium at the junction with the superior vena cava, stable electrograms of high quality were recorded in all 30 subjects, some for as long as six days. These high-fidelity atrial electrograms permitted rapid and accurate diagnosis of many complex dysrhythmias in these unstable patients. Because of the limited noise in the signal of the electrogram, continuous quantitative measurements of intervals by a computerized system was feasible. Furthermore, the stable intracavitary position of electrodes provided a reliable site for atrial pacing, with pacing thresholds (2 to 12 ma; average, 5 ma) that remained stable for up to four days. Atrial pacing was used to treat sinus bradycardia, atrial tachyarrhythmias, digitalis intoxication, and ventricular dysrhythmias.

The recording of atrial electrograms and pacing of the atrium have been shown to be valuable techniques for the assessment and management of patients with complex cardiac dysrhythmias. Patients undergoing cardiac surgery can have temporary epicardial atrial wires placed for recording and pacing during the postoperative period; however, conventional electrode catheters are difficult to keep in a fixed position within the atrium and, thus, do not permit extended monitoring of the atrial electrogram or continuous pacing of the atrium. This report describes a new multipurpose catheter that has proven suitable for long-term recording of the atrial electrogram and continuous pacing of the atrium, in addition to monitoring of the pulmonary arterial or wedge pressure, central venous pressure and cardiac output determined by the thermal dilution technique.

MATERIALS AND METHODS

Catheter

The standard flow-directed (Swan-Ganz) pulmonary ar-

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Reprint requests: Dr. Mantle, University of Alabama in Birmingham, University Station, Birmingham 35294

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terial thermistor-equipped catheter was modified to incorporate two ring electrodes on the shaft at 25 and 26 cm from the tip of the catheter (constructed by Edwards Laboratories, Santa Ana, Calif.). These distances were selected to permit the electrodes to be positioned high in the right atrium with the tip of the catheter indwelling in the proximal pulmonary artery for a wide range of sizes of cardiac chambers (Fig 1). In addition to the electrodes, the No. 7 French catheter has four lumens, a distal port, a proximal port, a 1.5 ml balloon, and a thermistor.

The electrodes can be used for recording intracavitary electrograms and for pacing the right atrium. In this study, the atrial electrograms were recorded as bipolar intracavitary electrograms. The differences in electrical potential between the two electrodes were recorded as a standard electrocardiographic lead 1 with the electrodes connected to the arm leads. The intracavitary location of the electrodes will determine the type of electrogram that is recorded (Fig 2).

An alternative method is to record the difference in electrical potential between an intracavitary electrode and a surface electrode. Such a unipolar electrogram can be recorded as a lead 1 with one arm lead connected to an intracavitary electrode and the other arm lead connected to a surface electrode. The atrial electrogram recorded by this alternative method has the appearance of a surface electrogram, with a marked accentuation of the atrial component.

The distal port of the multipurpose catheter can be used for monitoring the pulmonary arterial wedge pressures and for withdrawing samples of blood. The proximal port can be used for monitoring the central venous pressure, for injecting the cold indicator for measurements of cardiac output, and for infusing therapeutic agents. The inflated balloon facilitates the rapid convenient passage of the tip of the catheter through the right ventricle into the pulmonary artery and permits the measurement of wedge pressure without advancing the catheter's tip into a small arterial branch. The thermistor senses the temperature of the blood and, when
coupled with a computer, can be used to calculate cardiac output. The external terminals for the electrodes and the thermistor are enclosed within a plastic threaded housing that permits an isolated stable junction with a connecting cable.

Methods

Thirty patients with unstable ischemic heart disease, acute respiratory distress, or primary complex cardiac dysrhythmias were selected for this study. Informed consent was obtained from each of them. Under local anesthesia, a superficial antecubital vein was isolated, the catheter was advanced into the right atrium, the balloon was inflated, and the tip was floated into the pulmonary artery. With the balloon deflated, the position of the pair of electrodes was adjusted to optimize the quality and stability of the intracavitary atrial electrogram and the atrial pacing threshold. The anatomic location of the pair of electrodes was documented by fluoroscopic visualization. The catheter was securely fastened at the site of the cutdown to maintain the position of the catheter during the one-day to six-day monitoring period.

The atrial electrograms were continuously displayed, together with the surface electrocardiograms, at the bedside and at the central monitoring station. Strip-chart recordings were obtained on a multichannel write-out at the bedside or on a two-channel write-out at the central monitoring station. An isolation amplifier was used at all times between the intracavitary electrodes and the monitoring and recording equipment to ensure the patient's safety from leakage of electrical current. In addition to the visual monitoring and permanent recordings of the atrial electrogram, a computerized system for bedside monitoring was used to continuously process the data on atrial electrograms and to measure the A-A intervals in selected patients.

In ten patients with normal sinus rhythm, the pacing threshold was determined at the time of catheterization and serially over the next four days or until the catheter was withdrawn. Rapid atrial pacing at rates up to 400 stimuli per minute was performed in the treatment of five patients who had acute atrial tachyarrhythmias. A special device (Medtronic external atrial pacing pulse generator 5320) was used to achieve the rapid pacing rates. Prior to the initiation of rapid atrial pacing, care was taken to ensure that the intracavitary location of the electrodes would not result in ventricular pacing.

Measurements of the pulmonary arterial, pulmonary wedge, and central venous pressures and the cardiac output (by thermodilution) were made as previously described, with the aid of a computerized system for bedside monitoring. The pulmonary wedge pressure was obtained by the technique of balloon inflation.

Results

Stable, high-quality, low-noise bipolar atrial electrograms were recorded in all of the patients for as long as the catheters were left in place (average, three days; range, one hour to six days). The only complication was the development of local phlebitis in some patients after the catheter had been indwelling from three to six days. The electrograms remained stable, despite normal movement, which included sitting in bed and using the bedside commode. In some cases, there were changes in the shape of the atrial electrogram, but the intracavitary recordings remained free of the artifact frequently
observed in the simultaneously recorded surface ECG. The optimal location of the electrodes for recording the atrial electrogram (and pacing) was always high in the right atrium, at the junction with the superior vena cava (Fig 1). When combined atrial and ventricular electrograms were recorded, the electrodes were found by fluoroscopic visualization to be in the region of the tricuspid valve. By slowly withdrawing the catheter while monitoring the electrogram, the electrodes could readily be positioned at a more optimal location (Fig 2). If the electrodes were withdrawn into the superior vena cava, electrograms could no longer be recorded.

The routine monitoring and recording of the bipolar atrial electrograms at both the bedside and the central monitoring station proved to be useful for the documentation and diagnosis of complex dysrhythmias. The example shown in Figure 3 illustrates the recording of a nonconducted atrial beat which was not visible in the surface record. The atrial electrograms were especially valuable in the diagnosis of tachyarrhythmias. The tracings shown in Figure 4 were obtained from an elderly patient with ischemic heart disease who was admitted with a history of palpitations. A wide QRS complex had been documented during sinus rhythm on a prior ECG. The stable rate of 151 beats per minute and the apparent P waves preceding each QRS complex resembled a supraventricular tachycardia, possibly atrial flutter with 2:1 atrioventricular conduction; however, the atrial electrogram clearly documented that there was complete atrioventricular dissociation, with an atrial rate of 98 beats per minute and a ventricular rate of 151 beats per minute.

The example illustrated in Figure 5 demonstrates the use of this catheter for atrial pacing. This patient with dysfuncion of the sinus node was successfully paced via the right atrial intracavitary electrodes throughout the surgical repair of his abdominal aneurysm. With the electrodes positioned at the junction of the right atrium and superior cava, each of the ten patients evaluated while in sinus rhythm could consistently be paced 1:1 until the catheter was withdrawn, from one to five days later. The median threshold was 5 ma (range, 2 to 12 ma). Because of the proximity of the right phrenic nerve to the position of the atrial electrodes, pacing of the right hemidiaphragm occurred in some of the patients when the pacing stimulus was increased above 10 ma.

The serial tracings shown in Figure 6 were obtained in a patient seven days following an acute
anterior myocardial infarction. The increase in heart rate to 127 beats per minute with ST-segment elevation and associated pain in the chest was initially interpreted as a sinus tachycardia; however, the atrial electrogram documented an atrial rate of 254 beats per minute with 2:1 atrioventricular conduction. The atrial tachyarrhythmia was terminated by rapid atrial pacing and then abrupt cessation of pacing. Four of the 30 patients under study developed paroxysmal atrial tachyarrhythmias and were successfully converted to sinus rhythm by rapid atrial pacing via this catheter.

The recordings in Figure 7 illustrate the management of a patient with digitalis intoxication and heart failure using this catheter. The patient had been receiving digoxin as treatment for severe heart failure when the dysrhythmia occurred. The atrial electrogram demonstrated both atrial fibrillation and atrial tachycardia, with 2:1 atrioventricular conduction. When the therapy with digoxin was withheld, the atrial rate slowed, the atrioventricular conduction improved, the ventricular rate increased, and cardiac performance deteriorated. Rapid atrial pacing was then used to produce second-degree atrioventricular block and thus slow the ventricular rate and improve cardiac performance. When atrial pacing was discontinued on the next day, the spontaneous rhythm was normal sinus rhythm.

In addition to the visual monitoring and conventional recording of the bipolar atrial electrograms for immediate clinical use, representative electrograms were processed by a computerized system for continuous quantitative measurements of intervals and analysis of rhythms. An example of a computer-generated display is shown in Figure 8. The abnormal cyclic variation in this patient's sinus rate has been observed in patients with acute myocardial infarction and is the subject of continuing investigation. The low noise-to-signal ratio and large amplitude of the bipolar atrial electrogram recorded via this catheter permitted reliable continuous computerized processing over extended periods.

Figure 5. A (left), Simultaneous recording of surface ECG, bipolar atrial electrogram (AEG), and pulmonary arterial pressure (PA) during atrial bigeminal dysrhythmia. B (right), Stimulus artifact (S) with 1:1 atrial pacing and 1:1 atrioventricular conduction.

Figure 6. Simultaneous ECG and bipolar atrial electrogram (AEG). A (left), Atrial tachyarrhythmia with 2:1 atrioventricular conduction in patient with recent anterior wall myocardial infarction. AR, Atrial rate; and VR, ventricular rate. B (right), Normal sinus rhythm following cardioversion by rapid atrial pacing. Premature junctional beat demonstrates retrograde conduction to atrium.
Cardiac dysrhythmias are frequent complications of myocardial infarction, acute cardiopulmonary dysfunction, cardiac surgery, digitalis intoxication, and electrolyte imbalance. Prompt identification and accurate diagnosis are essential in the proper management of these disturbances in rhythm. Although the value of recording an atrial electrogram and pacing the atrium for the management of complex cardiac dysrhythmias has been previously reported, the routine clinical application of these techniques in patients that have not had atrial wires placed at the time of cardiac surgery has been limited. Standard pacing catheters with the electrodes mounted near the tip are difficult to position and keep in place within the right atrium; however, the present study demonstrates that a single pair of electrodes mounted on the proximal shaft of a Swan-Ganz pulmonary arterial catheter can be readily positioned within the right atrium for stable pacing.
electrographic monitoring and continuous pacing. As illustrated in Figure 2, the electrodes can be rapidly and conveniently positioned at the optimal recording site at the bedside without fluoroscopic guidance by monitoring the bipolar atrial electrogram. The natural curve of the proximal shaft of the catheter ensures that the electrodes will be held in a stable position adjacent to the atrial wall, independent of the cardiac size. Chatterjee et al. have recently reported the evaluation of a special flow-directed catheter with two pairs of electrodes (atrial and ventricular) mounted on the shaft of the catheter; however, the fixed distance between the atrial and ventricular pairs of electrodes did not accommodate to the various sizes of cardiac chambers that were encountered in their population under study.17

The ability to routinely monitor the atrial electrogram and pace the atrium over a period of several days proved to be valuable for the identification and management of unstable complex cardiac dysrhythmias. The high-quality, low-noise bipolar atrial electrogram recorded via this catheter permitted continuous quantitative computerized monitoring and analysis of the atrial rhythm that have not been possible from the low-amplitude P wave of the surface ECG. Atrial pacing via this catheter was used both intermittently and continuously for extended periods in patients with a broad range of supraventricular and ventricular dysrhythmias. The intracavitary pacing for conversion of atrial tachyarrhythmias was done rapidly, without the discomfort, general anesthesia, and risk associated with external direct-current cardioversion.18-20 The use of temporary atrial pacing in patients with symptomatic sinus bradycardia permitted a more direct control of rate than pharmacologic interventions and a more physiologic approach than right ventricular pacing. The special advantage provided by this catheter was a stable electrode site that could be used for atrial pacing over extended periods of time without the hazard of movement of the catheter or accidental ventricular pacing; however, the position of the electrodes should still be assessed by recording a bipolar electrogram prior to initiating pacing. Fluoroscopic visualization (when available) may also be used to insure a safe intra-atrial location prior to rapid pacing.

In addition to recording atrial electrograms and pacing the atrium, this single multipurpose catheter permitted monitoring of the pulmonary arterial pressure, central venous pressure, and cardiac output. This ability to monitor these various measurements over extended periods of time provided a distinct advantage in the evaluation and management of these patients with combined hemodynamic and rhythmic disturbances.

REFERENCES