

mg/kg in a 4-h period.⁸ An advantage of topical application is that a relatively small dose may be applied to a limited area, and in our cases the total dosage was always less than 0.1 mg/kg.

In addition to its use in revascularization, topical sodium nitroprusside also could be of value in other vascular procedures such as shunts for dialysis, neurosurgical operations involving microvascular surgery, kidney transplantation, and any instance of spasm caused by surgical manipulation.

In summary, sodium nitroprusside has been applied topically to arteries in spasm in the four cases presented. In all of these cases the spasm was relieved and no systemic effects of sodium nitroprusside were observed. We believe that the topical use of sodium nitroprusside for relief of arterial spasm is a safe and effective technique that facilitates operation, is devoid of measurable systemic effect, and requires only the usual standard of care with close observation of vital signs and communication between surgeon and anesthesiologist.

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Transesophageal Pacing for Bradycardia

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Sinus bradycardia during anesthesia is often acute in onset, may produce hypotension, and may lead to more serious dysrhythmias.¹ The response of bradycardia to pharmacologic intervention is unpredictable, and therefore cardiac pacing provides a more precise and effective treatment.

Current preoperative consideration of transvenous cardiac pacing in patients undergoing surgery has focused on conduction defects such as complete heart block.^{2,3} The development of esophageal electrodes for overdrive cardiac pacing as treatment for tachycardias⁴⁻⁶ suggested to us the use of transesophageal pacing for correction

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of unexpected sinus bradycardia in patients undergoing anesthesia. Transesophageal pacing for sinus bradycardia or asystole offers the potential for a quickly established treatment that achieves a predetermined heart rate without need for time-consuming and difficult intravascular procedures. We report here our experience with 37 surgical patients successfully treated by transesophageal pacing for hemodynamically significant bradycardias.

METHODS

The study was conducted in accordance with guidelines of the institutional Joint Committee on Clinical Investigation. The need for traditional intracardiac pacing was not anticipated preoperatively, and none of the 37 patients had preoperative electrocardiographic evidence of atrioventricular conduction disturbance. The mean age \pm SD of the patients was 62 ± 7 years. Thirty-six of the patients underwent coronary artery bypass surgery; 33 patients had triple-vessel coronary artery disease; and 13 patients had a left main coronary artery stenosis of 50% or greater. The one patient not studied with coronary angiography had stable angina and underwent carotid endarterectomy. Thirty-one patients received propranolol chronically, which was continued to the time of surgery. All patients had preoperative

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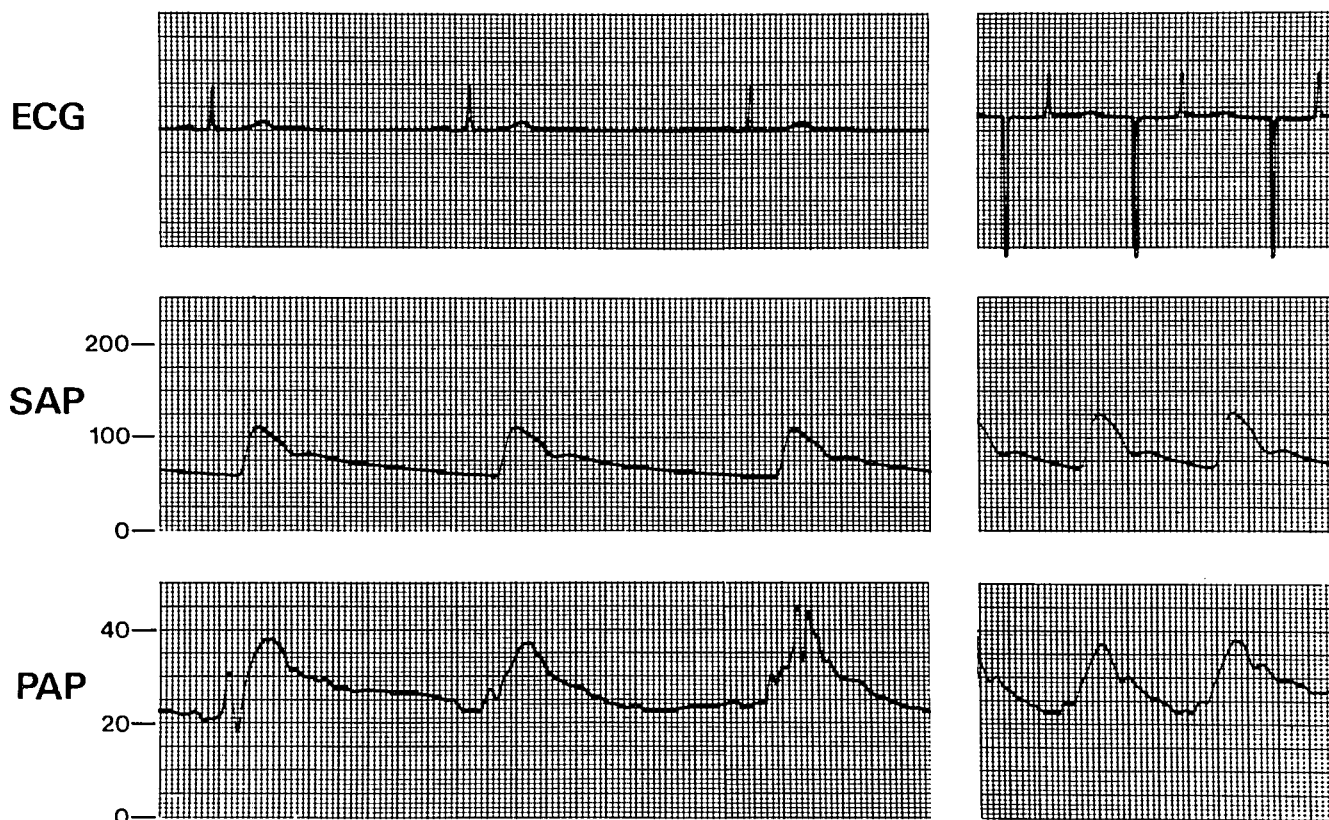


FIG. 1. Response to transesophageal pacing. Panel on left demonstrates sinus bradycardia, heart rate varying from 31 to 35 bpm. Panel on right demonstrates in the same patient esophageal pacing at heart rate of 68 bpm with increase in systemic arterial pressure (SAP), no significant change in pulmonary artery pressure (PAP). Recorder speed 25 mm/s.

sedation including scopolamine. Anesthetic medications included fentanyl in all patients, succinylcholine in 23 patients, pancuronium in 12, and metocurine in two patients.

All patients were monitored with intraarterial and pulmonary artery catheters, as well as ECG monitoring, which included standard and augmented limb leads and V_5 precordial lead. Profound sinus bradycardia, usually associated with significant systemic hypotension, was the indication for pacing.

After onset of the bradyarrhythmia, the bipolar esophageal electrode was introduced orally to a distance of approximately 35 cm from the teeth, and the pacing electrode was positioned to achieve capture as confirmed by the ECG. The pacing generator[§] delivered a 25 mAmp pulse of 20 ms duration. Pacing at a predetermined rate was begun after a 5-s delay for QRS detection.

RESULTS

Prior to beginning transesophageal pacing, the heart rate was less than or equal to 40 bpm in 10 patients

[§] "Pace Aid", Cardiac Resuscitator Corporation, 6024 S.W. Jean Road, Lake Oswego, Oregon 97034.

(including sinus arrest in one patient), 41–50 bpm in 22 patients, and 51–55 bpm in five patients. Atrial pacing was achieved successfully in all 37 patients, including two patients with bradycardia refractory to atropine (0.25, 0.6 mg) and ephedrine (10 mg) iv. A representative tracing of severe bradycardia and the response to transesophageal pacing is shown in figure 1. Twenty-nine patients were paced to heart rate 68 bpm and eight patients to heart rate 78 bpm. Transesophageal pacing was associated with an increase in mean systemic pressure of the 37 patients from 66 ± 11 mmHg ($\bar{x} \pm SD$) to 78 ± 11 mmHg. Of importance for coronary perfusion was immediate increase in diastolic blood pressure of the 37 patients from 49 ± 7 mmHg to 59 ± 8 mmHg during pacing. There was only an inconsequential increase in mean pulmonary artery wedge pressure of 1 ± 2 mmHg.

No dysrhythmias were noted during transesophageal pacing. At the relatively low rates of cardiac pacing employed, there was no ECG evidence of myocardial ischemia. Pacing of the diaphragm occurred transiently in three patients when the esophageal electrode initially was advanced farther than the point at which atrial capture subsequently was achieved. The diaphragmatic response was relieved in each case by withdrawing the

catheter a short distance. It appears that diaphragmatic pacing is an indication that the catheter has been passed farther than necessary for cardiac pacing.

DISCUSSION

Many patients with coronary artery disease and hypertension are treated with a beta-adrenergic blocking drug that usually is continued until the time of anesthesia and surgery.^{7,8} Against this background of beta adrenergic blockade, medications that alone or in combination may produce bradycardia, such as morphine, fentanyl, neostigmine, and succinylcholine are often given as premedication or anesthetic drugs.

The sudden development of sinus bradycardia in this setting, particularly in patients with coronary artery disease or with conditions such as sick sinus syndrome, is important because of the hypotension, sinus arrest, or other dysrhythmia that may develop.¹ The response to pharmacologic treatment of severe bradycardia is unpredictable and may result in no change in the patient's condition or in production of tachyarrhythmias.⁹ The use of an intracardiac pacing electrode requires access to the central venous circulation under aseptic conditions. The procedure for placement of the intracardiac electrode is time consuming and is associated with documented complications.^{10,11}

In contrast to an intracardiac electrode, the esophageal pacing electrode is convenient and can be introduced quickly to permit precise change in heart rate and control of dysrhythmias. Relatively slow rates of pacing at 68 bpm or 78 bpm were chosen in this study because of the extensive coronary artery disease with which the patients presented. At these paced rates, there was satisfactory increase in diastolic blood pressure without increase in pulmonary artery wedge pressure. If desired, rates up to 150 bpm can be obtained with the instrument used in this study.

This technique has been without complication in our experience. Nevertheless, as with any instrumentation of the esophagus, the pacing catheter should not be passed forcefully against resistance. The cuff of the

endotracheal tube may have to be deflated to allow passage of the pacing catheter through the esophagus. These precautions are important, because the most serious potential complication would be perforation or bleeding of the pharynx or esophagus. In our patients, no other catheters (nasogastric tube, esophageal stethoscope) were present in the esophagus at the time of introduction of the pacing electrode. We suggest that the nasogastric tube and esophageal stethoscope be removed prior to passing the pacing electrode.

In summary, transesophageal atrial pacing provides a reliable method for achieving a controlled heart rate in patients with bradycardia and intact atrioventricular conduction who require temporary pacing during anesthesia.

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