Defares and colleagues. Fishman subsequently suggested that his findings of increased pulmonary vascular resistance, pulmonary artery pressure and cardiac output reflect vasoconstriction in the unilateral hypoxic lung. The introduction of isotope lung scanning provided a new tool for the study of hypoxic effects on lung perfusion, and indicated a 42 percent reduction in blood flow to the lung ventilated with 100 percent nitrogen as compared to the contralateral lung ventilated with 100 percent oxygen. This report describes a patient with marked diminution or totally absent pulmonary capillary blood flow in the left lung as estimated by macroaggregated 131I-albumin scan. This may be attributed to hypoxia caused by subtotal obstruction of the mainstem bronchus secondary to an intraluminal neoplasm without associated atelectasis, emphysema or consolidation of the lung parenchyma itself. Since the main pulmonary arteries were unremarkable on inspection at the time of surgery, there probably was quantitatively insufficient blood flow to the lung capillaries to be detected by scintiscan. Alternatively, one may speculate on a pre-capillary pulmonary arteriovenous shunt mechanism arising in response to hypoxia.

Although the abnormal physiology in our case has not been explored by studies such as pulmonary angiogram, bronchospirometry, measurements of physiologic dead space or determination of shunt values with high oxygen breathing, the observation per se is interesting in that the radiologically normal lung and patent pulmonary artery by direct visualization had, curiously enough, absent perfusion isotopically for some reason not yet clear. Several experimental observations suggest that the effect of hypoxia on pulmonary circulation is mediated via the autonomic nervous system (vasomotor reflexes). Although the alveolar hypoxia in this case is not of severe degree, one may still presume in the absence of other data that even slight degree of hypoxia is possibly causing sufficient reflex vasospasm. Arterial gas studies may show only slight variation even in the presence of unilateral hypoxia because the contralateral normal lung takes up the compensatory function as well as the bronchial circulation produces small amounts of CO₂. The exact mechanism of pulmonary hyperperfusion in this case is still speculative. However, animal studies with artificial bronchial obstruction are underway. This report may also stimulate other investigators to search for the cause.

**References**


**A Method of Epicardial Pacing without Thoracotomy: Treatment of Heart Block in Patients with Tricuspid Valve Prosthesis**

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A subcostal transdiaphragmatic approach to implant permanent epicardial pacing electrodes eliminates the increased morbidity of another thoracotomy in patients with a tricuspid prothetic valve and heart block. This procedure is particularly suitable for patients who have developed infection or pacemaker failure due to electrode breakage after transthoracic implantation. The operative technique and a case report is presented. Several alternative methods of cardiac pacing in patients with tricuspid prostheses are discussed.

A subcostal, transdiaphragmatic approach for pacemaker electrode implantation on the undersurface of the right ventricle allows epicardial pacing without

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formal thoracotomy. This method of treatment is particularly helpful in a group of patients with prosthetic tricuspid valve, complicated with complete heart block, where the initial attempt of transthoracic epicardial pacing has failed. Surprisingly, the use of this technique has been reported only once in the English literature and possibly it remains unknown to many surgeons. This article emphasizes the value of this method of pacing in a selected group of patients with tricuspid valve prostheses. The technique of the operation and a case report is presented below.

**Case Report**

The patient, a 29-year-old man, was referred to the St. Francis Hospital, Roslyn, for the treatment of cyanotic congenital heart disease with increasing disability. The cardiac catheterization and cineangiographic studies confirmed the clinical diagnosis of Ebstein’s anomaly. The patient underwent open heart surgery on March 26, 1968 for tricuspid valve replacement with a disc valve prosthesis, closure of the atrial septal defect, and plication of the atrialized right ventricle. He developed complete heart block from the procedure and was treated with a P wave synchronous, epicardial pacemaker implanted during the operation. The immediate postoperative course was uneventful and he did well for the next six months. However, in October of 1968, he developed a swelling over the pocket for the pacemaker generator on the left pectoral area following minor trauma. The patient was on anticoagulant therapy which possibly contributed in forming a subcutaneous hematoma secondary to injury. The swelling increased gradually and finally broke through the skin. The wound subsequently became infected although the pacemaker continued to function. He was readmitted to the hospital and on December 18, 1968 a fixed rate, epicardial pacemaker was implanted by the subcostal, transdiaphragmatic route.

Technique of electrode implantation (Fig 1) is as follows:

A 10 cm long left subcostal incision was made and the left rectus abdominis muscle and the rectus sheaths were incised along the line of the skin incision. The xiphoid process was excised and extraperitoneal dissection was continued to expose the undersurface of the diaphragm. The diaphragm, along with the attached pericardium, was incised to expose the inferior surface of the right ventricle. An adequate surface area of the right ventricle was dissected free from the parietal pericardium. The regular pacing electrode spurs were shortened to prevent penetration into the right ventricular cavity. The electrodes were secured in place with silk sutures and the new pacemaker generator was positioned subcutaneously over the left lower quadrant of the abdomen below the belt line. The wounds in the diaphragm and abdominal wall were closed with interrupted silk sutures.

After dressings were applied over the new wound, the old pacemaker generator was removed and the subcutaneous pocket was cleaned and packed with iodoform gauze. The chest wound healed gradually but a small discharging sinus persisted, necessitating removal of the remnants of the electrode wires from the area a few months later. The new pacemaker continued to function well.

**Discussion**

In cases of epicardial pacemaker failure due to various reasons, eg, infection, electrode breakage, et cetera, transvenous pacing usually is the most commonly adopted procedure. However, in the patients with tricuspid valve prosthesis, right ventricular endocardial pacing is not feasible and an alternative method of pacing via transthoracic or other route becomes necessary. A second or third thoracotomy in a patient is always associated with increased morbidity and mortality. Moreover, in the presence of active infection surrounding the electrodes, the manipulation during reoperation may spread the localized infection to the other parts of the chest cavity which will inevitably infect the second pacemaker site. Also, dissemination of the infection through the blood stream is likely following the procedure and may precipitate the life threatening complication of bacterial endocarditis with an infected prosthetic valve. A subcostal transdiaphragmatic approach to implant pacemaker electrodes on the undersurface of the right ventricle appears to be most feasible for permanent pacing in this group of patients.

In the American literature, Parsonnet and co-work-
ers first reported the use of the transdiaphragmatic approach for epicardial pacing in patients who were unsuitable for thoracotomy caused by poor general conditions. None of their patients had a prosthetic tricuspid valve. Therefore, those patients could possibly have been treated with transvenous pacing with equal benefit. Beaulieu and associates very recently reported the experimental studies on transdiaphragmatic implantation of pacemaker electrodes via mediastinoscopy. The operative trauma may be slightly reduced with this technique, but the procedure lacks the convenience of adequate exposure and control over potential intraoperative complications. The proper evaluation of this method must also await its clinical application.

Although not popular in English speaking countries, transdiaphragmatic pacing has been extensively used by many German and French surgeons, in preference to other methods. Some surgeons routinely use this approach except in patients over 70 years of age and in very poor risk patients where transvenous pacings are used. Bruck and Behrends and colleagues reported the use of transdiaphragmatic pacing in 64 patients with good results. The exposure of the heart was wide enough to implant atrial pacemaker electrodes in 42 patients. Carpenter and associates reported their experience with transdiaphragmatic pacing in 32 patients. All these authors found the approach to be safe and technically simple. The operative morbidity and mortality were remarkably low.

Several alternative methods of cardiac pacing are available, which eliminate formal thoracotomy and may be suitable for patients with tricuspid valve prosthesis. Anagnostopoulos and co-workers reported transvenous coronary sinus pacing in two patients with prosthetic tricuspid valves. The total periods of pacing were short, 13 and 15 days respectively. Both the patients subsequently developed infection in the prostheses and died. Also, one of the patients demonstrated an excessively high threshold of stimulation for proper pacing. Considering all these difficulties and the unpredictable results, we think that coronary sinus pacing in complete A-V block, if at all indicated, should be used for very short term pacing as an emergency procedure before implantation of a permanent epicardial pacemaker. Transesophageal pacing, as described by Burack and Furman can also be used as an emergency procedure in patients with tricuspid valve prosthesis and heart block awaiting definitive treatment. Recently, Maramba and his associates have shown that a temporary percutaneous pacing catheter inserted through a prosthetic tricuspid valve did not cause a significant hemodynamic abnormality for several days. Nevertheless, this method could only be used for temporary pacing. Reed and co-workers have described a technique for pacemaker implantation in the myocardium through an extrapleural approach. This procedure can also be used in patients with prosthetic tricuspid valve, except where there is infection over the left chest wall. Nathan and his associates described an approach to the heart through the bed of the sixth costal cartilage for pacing the undersurface of the right ventricle. With this technique the electrodes are implanted on the pericardium and an increased threshold of stimulation was found in several patients due to interposition of fat, scar tissue, or pericardial fluid between the electrode and the right ventricular epicardial surface.

We have found transdiaphragmatic pacing to be a safe and effective procedure. The reports from several European surgeons attest to this finding. Whether the technique is to be routinely used for permanent pacing in unselected patients is beyond the scope of this article. However, in patients with tricuspid valve prosthesis in a particular clinical setting as discussed here, transdiaphragmatic pacing appears to be most feasible. Whether the transdiaphragmatic approach is through a midline epigastric incision as used by European surgeons, or a subcostal incision is a matter of choice. However, it should be remembered that the diaphragmatic incision should be to the left of the midline to gain direct access to the right ventricle and to avoid inadvertent opening of the right pleural cavity. For these reasons, the left subcostal incision may be more helpful.

**References**