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Surgical Correction of the Wolff-Parkinson-White Syndrome in the Closed Heart Using Cryosurgery: A Simplified Approach

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The conventional operation for ablation of accessory atrioventricular (AV) pathways in the Wolff-Parkinson-White syndrome requires an endocardial approach to the AV groove and necessitates the use of cardiopulmonary bypass and induced cardiac arrest. The feasibility of creating transmural atrial fibrosis at the level of the AV anulus in the closed heart in dogs without damaging the vascular contents of the AV fat pad was demonstrated. This was done by dissecting the fat pad from the atrium and applying a cryoprobe to the exposed atrial-anular region after retraction of the fat pad. The technique was then applied to successfully ablate 12 left parietal wall accessory pathways in 11 patients with the Wolff-Parkinson-White syndrome. This simplified approach to any parietal wall accessory pathway does not require cardiopulmonary bypass or induced cardiac arrest and may broaden the indications for this operation.

Surgical interruption of accessory atrioventricular (AV) pathways has become an important therapy in patients with disabling arrhythmias associated with the Wolff-Parkinson-White syndrome (1). The operative procedure generally used was described by Sealy et al. (2) and involves incision of the AV ring on the atrial side of the anular fibrosis using an endocardial approach. This open heart approach necessitates the use of cardiopulmonary bypass and an arrested heart. We examined the feasibility of creating a cryothermic lesion on the epicardial surface of the AV ring after retraction of the fat pad and its vascular contents in a dog model without the use of cardiopulmonary bypass. The purpose of this report is to present the experimental data and early results of operation in 11 patients with incapacitating tachycardia that was poorly controlled by drug therapy.

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Experimental Cryothermic Injury to the Atrioventricular Sulcus

We initially examined the effects of applying a cryoprobe directly to the epicardial surface of the AV fat pad and creating a cryolesion in dogs to explore the feasibility of using this procedure in patients (3). The cryosurgical technique has been described (4). The freezing surface of the cryoprobe is circular (15 mm diameter) and utilizes expanding nitrous oxide as the coolant. The area to be ablated is cooled to −60°C for 2 minutes and allowed to thaw before repeating this procedure. We felt that this technique was inappropriate for patients because of significant cryothermal injury to the vascular contents of the fat pad observed in the dog model. In addition, this method sometimes failed to achieve transmural fibrosis of the anulus and adjacent atrial wall and could theoretically fail to ablate accessory pathways coursing adjacent to the anulus.

Operative procedure. The present technique was devised to protect the vascular contents of the fat pad and also to remove the insulating effect of the fat pad that prevented attaining transmural injury using the epicardial cryosurgical approach. Eight adult dogs of either sex were used in the present study. The dogs were intubated and ventilated using halothane anesthesia. The heart was exposed through a left lateral thoracotomy and the AV sulcus was visualized by retracting the left atrial appendage. The AV fat pad in the

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left lateral region was dissected away from the atrium for approximately 4 cm, dividing atrial vessels when necessary. A segment of the ventricle adjacent to the AV sulcus was then exposed. The fat pad and vascular contents were gently retracted and the cryoprobe positioned against the atrial wall overlapping onto the AV sulcus and adjacent ventricle (Fig. 1). Two overlapping cryolesions (−60°C for 2 minutes) were then applied to the region, and the fat pad was released and allowed to return to its position. After closure of the chest, the animals were allowed to recover. Two of the eight dogs had sham procedures identical to that just described except that cryosurgery was not used.

Pathologic observations. The animals were sacrificed at 2 days, 1 week or 3 to 4 weeks postoperatively. The sham-operated dogs were sacrificed at 1 week. The heart was opened, fixed in formalin and serially sectioned around the left AV groove. The tissues were processed for light microscopy and sections were stained with hematoxylin-eosin, Movat's stain and Mallory's trichrome stain.

One dog was sacrificed at 2 days. A circular 2.0 cm area of fibrinous exudate and congestion was noted on the epicardium of the left lateral AV groove. Transmural acute necrosis of the atrium extending 5 mm superiorly from the mitral valve anulus was present (Fig. 2). The atrial myocardial cells showed intense eosinophilia and other features indicative of coagulative necrosis. This was associated with an early inflammatory response as scattered neutrophils were seen throughout the myocardium. The necrotic muscle was sharply demarcated from adjacent myocardium, and the superior portion of the left ventricle within the area of freezing showed similar changes. There was no evidence of mural thrombus on the atrial or ventricular endocardium. Patchy areas of hemorrhage and fat necrosis were evident in the epicardial fat pad over the AV sulcus. The left circumflex coronary artery was involved by a focal mild acute vasculitis as neutrophils were noted within the tunica media and adventitia. In this dog, the fat pad made inadvertent contact with the cryoprobe during freezing. Approximately one-third of the circumference of the artery, for a length of 6 mm, showed this change. There was no intimal thickening. The coronary sinus showed only a mild degree of hemorrhage within its wall with no evidence of inflammation or necrosis. No abnormalities of myocardium or vessels were seen in tissue outside of the zone of freezing.

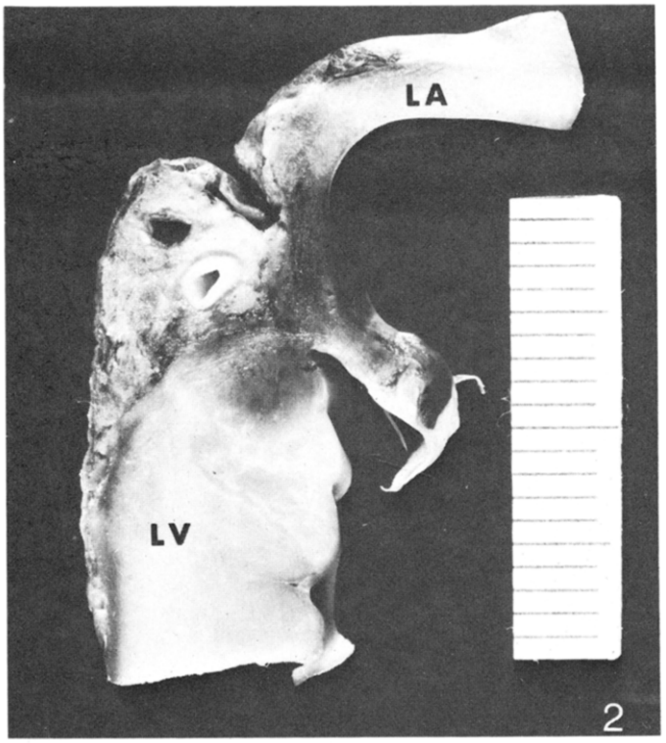
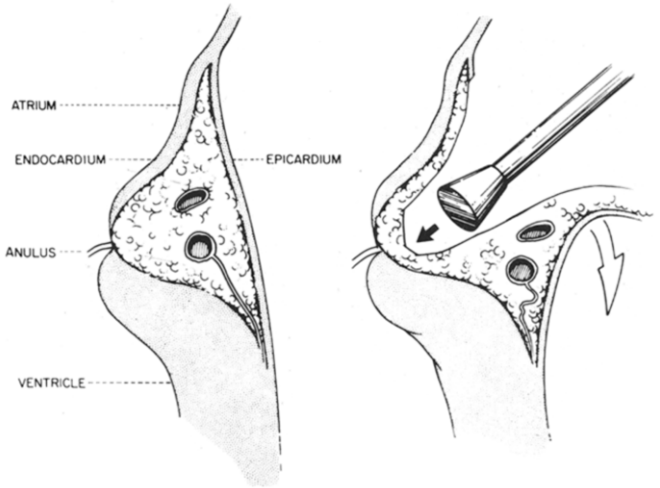


Figure 2. Transverse section through left atrium (LA), mitral valve and left ventricle (LV). Intense congestion and hemorrhage, corresponding to acute necrosis, are evident through the full thickness of atrial wall and in the superior portion of the ventricle. The left circumflex artery and coronary sinus in the epicardial fat pad appear undamaged. (Original magnification × 3.2.)

Figure 1. The epicardial approach to accessory pathway ablation. **Left,** Representation of the cross-sectional anatomy of the atrioventricular sulcus. **Right,** The fat pad and vascular contents have been dissected away from the atrial surface to the level of the anulus, permitting the application of the cryoprobe to this region.



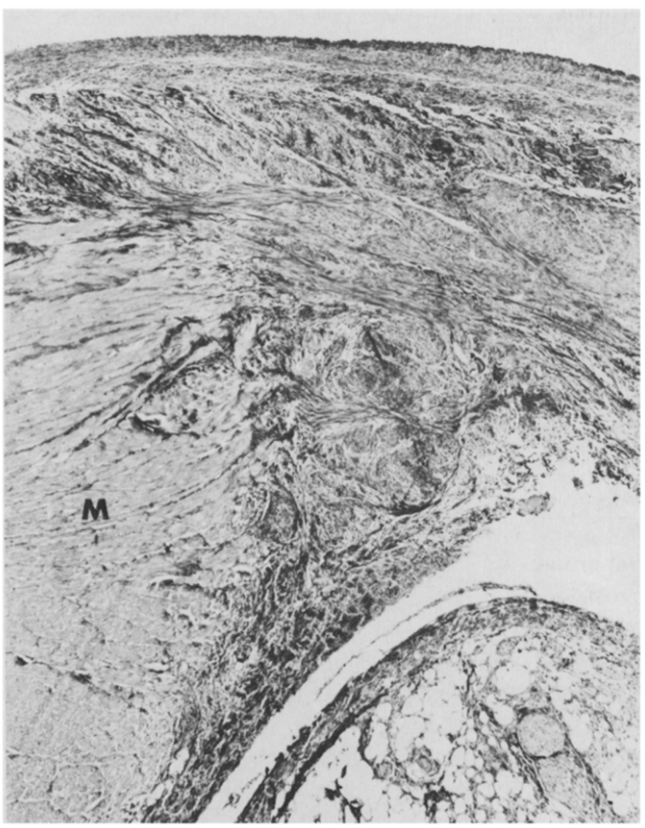
One dog was sacrificed at 1 week. Transmural necrosis of the atrium was again noted. This extended as far as 10 mm above the anulus and was approximately 12 mm in diameter on the endocardial aspect. Necrotic myocardiocytes were surrounded by abundant granulation tissue on both the endocardial and epicardial sides. The superior portion of the left ventricle showed a circumscribed area of central necrosis with a rim of granulation tissue. Patchy foci of granulation tissue were also present in the epicardium. There was no evidence of damage to either the circumflex coronary artery or the coronary sinus.

Four dogs were sacrificed at 3 to 4 weeks. The lower portion of the atrial myocardium within the freezing zone was replaced by a sharply circumscribed fibrous scar (Fig. 3). Only a few chronic inflammatory cells were noted within this area. The scars extended from the anuli superiorly 5 and 6 mm in the two animals, respectively. The atrial endocardium of one of the dogs showed mild fibrous thickening. There was no evidence of any damage to the major vessels. In particular, the left circumflex coronary artery showed no disruption of the internal elastic lamina or intimal thickening and no necrosis of smooth muscle cells or fibrosis in the media. The portions of left ventricular myocardium nearest the mitral valve anulus were fibrotic. There was no indication of aneurysm formation.

The two sham-operated dogs subjected to the procedure without cryosurgery were sacrificed at 1 week. Both dogs demonstrated fibrosis that was transmural near the AV ring. The scar tended to be sharply demarcated from adjacent myocardium, although one of the dogs exhibited patchy atrial fibrosis. The region of fibrosis was considerably smaller and more localized in sham-operated dogs than in their cryosurgical counterparts. No abnormalities were noted in the major coronary arteries.

In summary, the histologic changes subsequent to our cryosurgical lesion evolved from an early state of acute necrosis through organization by granulation tissue, to an end result of a well formed fibrous scar. The lesions were sharply circumscribed. There was no evidence of endocardial thrombus and the coronary arteries were spared. Transmural atrial fibrosis at the level of the anulus was achieved in all dogs. Sham-operated dogs exhibited atrial fibrosis over a smaller area than was seen in the cryosurgically treated dogs, with evidence of patchy fibrosis.

Figure 3. Photomicrograph of left atrium of a dog killed 3 weeks after cryosurgery. A portion of the atrial wall is completely replaced by fibrous tissue. This is sharply demarcated from uninvolved atrial myocardium (M). The endocardium (**top**) is mildly thickened. There is no evidence of thrombus formation (trichrome stain; original magnification × 25, reduced by 11%.)



Ablation of Accessory Pathways in Patients

Clinical features. The operative methods described were then applied to 11 patients referred for surgical treatment of tachycardia associated with the Wolff-Parkinson-White syndrome; 6 were male and 5 were female, with a mean age of 29 years (range 6 to 56). Nine patients had an accessory pathway capable of bidirectional conduction and two had a unidirectional (retrograde conduction only) accessory pathway. The clinical arrhythmias are summarized in Table 1. The arrhythmias were considered life-threatening in four patients with atrial fibrillation and a rapid ventricular response, and one of these patients had developed ventricular fibrillation during atrial fibrillation. All patients had frequently occurring, disabling tachycardia and elected to have surgery rather than undergo further drug therapy. No patient had coexistent heart disease.

The mechanisms of tachycardia and location of accessory pathways were determined at electrophysiologic study using techniques previously described (1). Ten patients had a single accessory pathway at the left lateral AV margin and one patient had two accessory pathways, one in the left lateral and one in the anterolateral AV region.

Operative techniques and results. The location of accessory pathways was verified intraoperatively by epicardial mapping techniques (5). The operative technique employed was similar to the experimental technique with two exceptions. First, the chest was opened through a median sternotomy to allow complete myocardial mapping. Second, all patients were placed on cardiopulmonary bypass as a precautionary measure in this initial series. Delta waves disappeared after dissection and retraction of the fat pad in eight of nine patients with anterograde accessory pathway conduction. In one patient, the delta wave disappeared only after cryosurgery. Because of the possibility that accessory pathways coursing adjacent to the anulus were only contused by this procedure, cryothermal lesions were applied to the anulus as described in dogs to create a transmural scar at this level and ensure the ablation of the accessory pathway. Absence of accessory pathway function was ver-

Table 1. Clinical Characteristics of Surgical Patients

Case	Age (yr) & Sex	Duration of Symptoms (yr)	Clinical Arrhythmia (rate/min)	Drug Trials	Postoperative Follow-Up (mo)
1	29F	25	RT (300), AF (285)*	Metop, pirm	15
2	19M	12	RT (370), AF (210)*	Prop, disop, pirm	14
3	56F	15	RT (260)	Prop, pirm	14
4	19M	4	RT (335), AF (175)	Proc, quin, verap	12
5	17M	12	RT (315)	Prop, quin, verap	12
6	23M	18	RT (335), AF (210)	Prop, verap	12
7	41F	10	RT (380), AF (285)*	Dig, quin, prop, verap	6
8	6F	6	RT (260)	Dig, quin, prop, verap	6
9	25F	20	RT (320)	Disop	2
10	56M	3	RT (380), AF (270)*	Dig, prop, disop, verap, amio	1
11	28M	4	AF (140), RT (240)*, VF	Quin	4

*Denotes arrhythmia observed only in laboratory. AF = atrial fibrillation; amio = amiodarone; dig = digoxin; disop = disopyramide; metop = metoprolol; pirm = pirmenol hydrochloride; proc = procainamide; prop = propranolol; quin = quinidine; RT = reciprocating tachycardia; verap = verapamil; VF = ventricular fibrillation. The cycle length of reciprocating tachycardia and the shortest cycle length between preexcited beats during atrial fibrillation are shown in ms. Patients 3 and 8 had unidirectional (retrograde only) accessory pathways. Patient 5 had two accessory pathways, left anterior and left lateral.

ified intraoperatively before closure and at electrophysiologic testing 1 week postoperatively. Patients were discharged from the hospital 7 to 10 days after surgery. No patient has had a recurrence of tachycardia or return of the delta wave during the follow-up period (3.5 to 11 months, mean 7.6).

Discussion

The first surgical correction of the Wolff-Parkinson-White syndrome was performed by Sealy et al. (6) in 1967. Since that time, they have refined the surgical techniques for ablating accessory pathways (1) and their favorable results have been duplicated by others (7–10). The widely used technique of Sealy et al. (2) involves separation of the atrium from the anulus through an endocardial approach and dissecting the atrial and ventricular surfaces free of the AV fat pad. This necessitates the use of cardiopulmonary bypass and is generally performed using aortic cross-clamping and cardioplegia.

Advantages of cryosurgical technique. In 1977, Gallagher et al. (11) were able to use cryosurgery to ablate a left-sided accessory pathway from the epicardial surface. Their patient was unique in that a distinct accessory pathway potential could be recorded from the epicardium below the fat pad, indicating a very superficial location of the accessory pathway as it joined the ventricle. Unfortunately, this situation is uncommon (1) and the specific technique cannot be used in all cases (12). Dissection of the fat pad from the atrial surface enables cryosurgery to be used for all free wall pathways. Ventricular branches of the coronary artery are spared. Some residual fat left on the atrial surface near the anulus diminishes the possibility of inadvertent incision of the atrium. Retraction of the fat pad allows the cryothermal lesion to be applied to the anulus, creating transmural injury in this region to ablate accessory pathways coursing adjacent to the anulus while sparing the vascular contents of the fat pad from cryothermal injury. It is important that the cryoprobe *not* touch the fat pad as evidenced by arterial damage in one dog in which this inadvertently occurred. Cryosurgical lesions produced by this technique heal by fibrosis into a firm, well delineated, nonarrhythmogenic scar (4).

Mechanism of accessory pathway ablation. The mechanism of accessory pathway ablation by this technique is not certain and is probably different in individual subjects depending on the unique course taken by the accessory pathway through the AV region. The accessory pathway may be directly interrupted by dissection of the fat pad from the atrial surface. Indeed, Becker et al. (13) demonstrated that left parietal accessory pathways can course through the fat pad "outside a well formed anulus fibrosis." The accessory pathway may also be injured or destroyed as a result of atrial fibrosis due to interruption of atrial blood vessels by the dissection. Finally, the accessory pathway may be destroyed by cryothermal injury, as was clearly the case in one of our patients. Nonetheless, the technique taken in total ensures the creation of a controlled area of transatrial fibrosis at the level of the AV ring and minimizes the potential for failure.

Clinical application. This simplified closed heart approach is applicable to all patients with right or left parietal wall accessory pathways, a group constituting the majority of patients referred for surgery (1,7–10). The technique is more rapid than the conventional operation in that it does not require atriotomy, cardiopulmonary bypass or induced

cardiac arrest. Morbidity rates in patients undergoing concomitant procedures for organic heart disease may be decreased because of a reduction in cross-clamp time. Although this technique appears promising, long-term follow-up study of a larger number of patients is required to establish its role in the surgical treatment of the Wolff-Parkinson-White syndrome.

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