TRANSSEPTAL LEFT HEART CATHETERIZATION

A REVIEW OF 135 CASES PERFORMED BY THE BROCKENBROUGH TECHNIQUE

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The rapid advances in cardiac surgery in recent years have acted as a stimulus to the development of methods by which circulatory dynamics can be accurately studied. Several procedures of left heart catheterization have contributed to the assessment of the nature and degree of most lesions of the left side of the heart. In 1960 Morrow and his co-workers[1] reviewed the methods in use up to that time. Left atrial catheterization has been achieved by various means, including the transbronchial[2] and percutaneous suprasternal[3] or posterior[4] approaches, but the transseptal route is now regarded as the safest and most convenient. The transseptal approach was apparently described first by Manfredi in 1956,[5] but it was following the publications of Cope[6] and Ross[7] that the technique gained wide acceptance.[8-18]

The purpose of this paper is to describe our experience with 135 consecutive left heart catheterizations which have been attempted by the transseptal technique of Brockenbrough and Braunwald.[19] Although early reports suggested that it was a safe method,[8,9,11,14] it has subsequently become apparent that it carries significant mortality and morbidity rates.[12,16-18,20,21] These depend to a degree upon the skill and experience of the operator, but even in experienced hands the procedure is not without danger. We therefore wish to emphasize the complications encountered in our own and in other published series.

METHOD AND MATERIAL

The method used was the modification of transseptal catheterization described by Brockenbrough and Braunwald.[19] In this procedure, a teflon catheter is introduced percutaneously over a guide wire into the right femoral vein or by cut-down into the right saphenous vein, and is advanced into the right atrium. The long transseptal needle is introduced into the catheter and made to pierce the interatrial septum in the region of the fossa ovalis. The catheter is advanced into the left atrium over the needle, which is then withdrawn. The left ventricle can usually be entered easily, but in cases of difficulty, anterior rotation of the catheter tip by means of the reintroduced needle may be helpful, or the guide wire may be used. Left-sided intracardiac pressures are measured and cine-angiocardiograms performed.

We have found that the correct positioning of the catheter for engagement of the needle on the fossa ovalis is usually easily achieved if the catheter tip (directed posteriorly and to the patient's left) is moved downwards along the septum from a position high in the right atrium. This was noted independently of the similar observation of Bloomfield and Sinclair-Smith[22] that the flick of the catheter tip downwards past the limbus of the fossa ovalis serves as a useful anatomical guide.

A total of 135 patients were submitted to the procedure, of which 71 were females and 64 males. The age range was from 1 to 62 years. The diagnoses are analysed in Table I. In nearly 60% of cases catheterization was undertaken for the pre-operative assessment of mitral valve disease. In the isolated aortic valve disease group (9%) the stenosis was tight enough to preclude retrograde ventricular catheterization and the valve gradient was therefore established by a combination of the retrograde and transseptal techniques. Congenital heart lesions accounted for 22% of the total, and nearly half of these were cases of ventricular septal defect. The remainder of the congenital lesions comprised a variety of diagnoses including 4 cases of coarctation of the aorta. The miscellaneous group consisted of 1 case of idiopathic left ventricular aneurysm, 1 of severe idiopathic pulmonary hypertension and 1 of ischaemic heart disease (in which it had been thought advisable to exclude the presence of a left atrial myxoma). Three subjects with normal hearts were catheterized to exclude the possibility of a small atrial septal defect.

TABLE I. DIAGNOSIS IN 135 CASES SUBMITTED TO TRANSSEPTAL LEFT HEART CATHETERIZATION

	No.	%
Chronic rheumatic endocarditis	79	59
Mitral valve disease	47	
Mitral and aortic valve disease	30	
Isolated organic tricuspid valve disease	1	
Mitral, aortic and tricuspid stenosis	1	
Isolated aortic valve disease	12	9
Congenital heart disease	30	22
Ventricular septal defect	14	
Coarctation of the aorta	4	
Others	12	
Cardiomyopathy	8	6
Obstructive	7	
Other	1	
Miscellaneous	3	2
Normal heart	3	2

RESULTS

Failures

In the 135 consecutive cases, failure to enter the left atrium occurred in 9 (7%). With our increasing experience the success rate rose and in the latter half of the series the left atrium was entered in all but 2 instances. Reasons for the failures are summarized in Table II. One patient with

TABLE II. FAILURE OF TRANSSEPTAL LEFT HEART CATHETERIZATION IN 135 ATTEMPTED CASES

No of cases failed		*Reason for failure*
LA entry	*LV entry*	
2		Arrhythmia supervened
2		Thick left atrial wall
1		Left atrial atresia
1		Giant right atrium
3		Unexplained non-engagement of septum
	6	Tight mitral stenosis
	1	Catheter too short for patient
9 (7%)	7 (6%)	

a thick left atrial wall had severe mitral valve disease with atrial fibrillation and was presumed to have organized thrombus obstructing the passage of the needle. A giant right atrium, although not rare and capable of considerably distorting septal anatomy, caused serious difficulty in perforation of the septum in only 1 instance. Failure of the catheter to pass from left atrium to left ventricle occurred in 7 cases (6%). In 6 of these very tight mitral stenosis was present, while in the remaining patient, a man of over 6 ft. 3 in. in height, the catheter was too short to reach the left ventricle.

Complications

There was 1 death attributable to the procedure. This patient was a 62-year-old woman who had ischaemic heart disease and severe aortic stenosis. The first attempt to perforate her atrial septum resulted in the needle and catheter penetrating the posterior wall of the right atrium. She suffered no apparent ill-effects and the septum was later correctly pierced. During attempts at manipulation of the catheter from the left atrium into the left ventricle, sudden sinus bradycardia, sweating and severe hypotension developed. Two convulsions, presumably caused by cerebral hypoxia, occurred. There was a good response to resuscitative measures, the most effective of which was intravenous adrenalin infusion. The pulse rate returned to normal and the patient's general condition improved remarkably, but it was necessary to continue the adrenalin to maintain a normal blood pressure. Two hours later cardiac standstill suddenly occurred and all resuscitative measures failed. Necropsy revealed tight calcific aortic stenosis and coronary atheroma with generalized myocardial fibrosis and an old myocardial infarction. A puncture wound into the posterior wall of the right atrium was present though no exit wound was noticeable. The atrial septal perforation was on the upper edge of the fossa ovalis. No immediate cause of death was apparent.

A list of complications is shown in Table III. The over-all complication rate was 13%, but excluding the fatal case there were no permanent or serious ill-effects. Transient left pneumothorax developed in 1 of the 3 cases in which there was penetration through the free wall of the right atrium. Perforation of the root of the aorta occurred twice without apparent ill-effect. Supraventricular tachycardia of short duration occurred twice and atrial fibrillation occurred in 3 patients, 1 of which required

TABLE III. COMPLICATIONS OF 135 TRANSSEPTAL LEFT HEART CATHETERIZATIONS

Major Complications	
Death following hypotension	1
Perforation of root of aorta	2
Penetration through posterior wall of right atrium	3
Minor Complications	
Arrhythmias	5
Extravasation of dye	4
Prolonged hypotension	1
Fractured tip of guide wire in right atrium	1
Total	17 (13%)

electrical defibrillation. In 2 of these cases the supraventricular arrhythmia occurred before the left atrium had been entered and the procedure was thus abandoned. Extravasation of radio-opaque dye during angiocardiography took place into the left ventricular wall in 3 cases and into the left atrial wall in 1. One patient developed unexplained hypotension lasting about 6 hours following septal puncture.

Fracture of the tip of a faulty guide wire occurred in the right atrium in 1 patient without apparent ill-effect.

DISCUSSION

The value and advantages of transseptal left heart catheterization have been discussed by Brockenbrough *et al.*[12] By means of a single percutaneous femoral venepuncture access is gained to all chambers of the heart. An accurate assessment of mitral valve disease is achieved by the study of left atrial and left ventricular pressure tracings. These may be recorded simultaneously by means of combined transseptal and retrograde left heart catheterization. The value of this combined technique has been emphasized by Peckham *et al.*[18] Left atrial cine-angiography enables the mobility of mitral valve leaflets to be gauged as well as providing a visual assessment of the degree of stenosis. The angiocardiographic demonstration of mitral regurgitation by left ventricular injection through the comparatively rigid end-hole Brockenbrough catheter is not recommended since extravasation of dye into the myocardium is very liable to occur. This happened in 3 of our cases and we regard left ventricular angiocardiography through a Brockenbrough catheter as a dangerous procedure. Furthermore, it is of limited value as mitral incompetence may occur by a valve leaflet being held open by the catheter.[23]

In the assessment of left ventricular outflow obstruction, transseptal catheterization is of particular value in measuring the aortic valve gradient when the stenosis is too tight to allow for the introduction of a retrograde catheter into the left ventricle. Gradients due to obstructive cardiopathy are notoriously variable[24,25] so that accurate assessment here often depends upon the simultaneous low and high left ventricular pressure recordings made possible by the combined technique. Although early in the series we investigated a number of patients with ventricular septal defect, we now consider that the risk of transseptal catheterization is seldom warranted in this condition. In coarctation of the aorta, however, the procedure is probably the safest method of demonstrating angiographically the site and length of the obstruction.

Early reports on transseptal catheterization suggested that it was an extremely safe method: in 5 series covering a total of 364 catheterizations not a single complication was mentioned.[5,9,11,14,19] However, in view of the nature of the procedure it is not surprising to find numerous recorded complications.

The death rate is difficult to assess from an analysis of the literature, but in series where deaths have been reported it is approximately 1%. The over-all figure is possibly below this, but it is nevertheless high for a diagnostic procedure. There have been 4 recorded deaths from cardiac tamponade resulting from puncture of the left atrium or aortic root.[15,20,21,26] A fatal coronary embolus arising from the catheter has occurred.[20] Two further deaths have been due to irreversible hypotension follow-

ing catheterization.[12,27] A state of prolonged unexplained hypotension with bradycardia seems to occur frequently enough during left atrial puncture to form a definite syndrome.[13,16,25] It is often associated with aortic stenosis and may last as long as 48 hours.[16]

In the present series we have had experience of it, usually in a minor and transient form, in several cases in which there was manipulation within the left atrium during attempted left ventricular entry. However, its onset may occur simultaneously with atrial septal puncture, or even during engagement of the needle on the atrial septum. This state persisted for 6 hours in one of our patients before recovery took place, and caused death after 2 hours in our fatal case. It is likely that reasons for non-recovery in the latter patient were the presence of tight aortic stenosis, coronary artery disease and a severely ischaemic myocardium. These factors would combine to prevent the restoration of an adequate cardiac output and coronary arterial filling. The mode of production of this syndrome has not been explained, but in view of its rapidity of onset it is probably neurogenic and reflex vagal stimulation is a likely mechanism. Like 'vaso-vagal syncope', it is usually self-limiting, but we have found intravenous atropine, sometimes with the addition of inotropic drugs, useful in treatment.

Puncture of the posterior wall of the right atrium occurs in approximately 1-3% of transseptal catheterizations, but seldom gives rise to untoward effects.[10,15,16,18,29] Puncture of the aortic root without ill-effect has occurred in reported series[15,28,29] and also in 2 unpublished cases known to us.

Other recorded complications include transient atrial fibrillation,[13,16] systemic embolization,[16,18] femoral venous thrombosis,[20] mural left atrial thrombosis,[20] perforation of the catheter by the needle[17,29] and fracture of the guide wire[18] or of the needle tip in the atrial septum.[31] Extravasation of injected dye is a well-known hazard, but the ill-effects, as evidenced by electrocardiographic changes, are nearly always mild and transient.

The fate of the small defect made in the atrial septum by the needle and catheter has been studied by several workers, using ^{85}Kr inhalation to detect any possible residual shunt at atrial level, and also by direct inspection at subsequent operation. Although Ross[7] initially found that 2 of 37 dogs had persistent small defects, there has been much evidence, summarized by Lindeneg and co-workers,[16] indicating that the atrial puncture wound becomes sealed. It was therefore surprising to learn that in our operated cases (usually within a month of catheterization) the surgeon occasionally found ovoid or slit-like defects of the atrial septum up to 0·5 cm. in length.[32] In order to determine the incidence of residual left-to-right shunts at atrial level, we used a hydrogen inhalation technique[33] before transseptal puncture and again at the end of the procedure.[34] Shunts were detected in 3 out of 20 patients investigated in this way, implying non-closure of the puncture wound. It should be noted, however, that these shunts were sought no later than 1 hour after transseptal puncture, and it is possible that, in time, healing would have occurred. In any event, the functional significance of persistent defects is probably nearly always negligible, although one example of a 4 cm. laceration has been reported.[21]

SUMMARY AND CONCLUSION

Experience with 135 consecutive attempted transseptal left heart catheterizations, of which 126 were successful, is described. The advantages of and indications for this technique of catheterization are discussed; its chief use in the present series was in the precise assessment of rheumatic valvular lesions. Reasons for failure to penetrate the atrial septum are analysed. Complications of the procedure included perforation of the aortic root and right atrial wall, arrhythmias, extravasation of dye and, in 1 case, death following unexplained hypotension. The syndrome of bradycardia and prolonged hypotension following left atrial puncture is discussed, with reference to other reported cases. Left-to-right shunts at atrial level were demonstrated by a hydrogen inhalation technique immediately after transseptal puncture in 3 out of 20 patients, but these are thought to be of no haemodynamic importance and may be temporary.

It is concluded that this procedure is a well-established and valuable adjunct to methods for the assessment of left-sided heart lesions, but that in view of its varied and considerable risks it should be applied with great circumspection.

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