Modified Technique of Transseptal Left Heart Catheterization

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Transseptal left heart catheterization was performed in 106 instances in 101 patients using right anterior oblique fluoroscopy to define septal boundaries during interatrial septal puncture, and using a preshaped guide wire to catheterize the left ventricle. By using these two modifications of the classic transseptal technique, the left atrium was entered in 105 instances (99%) and the left ventricle was catheterized in all 87 attempts (100%), including attempts in eight patients with mitral stenosis (valve area $1.29 \pm 0.39 \text{cm}^2$ [mean $\pm$ standard deviation]). No deaths occurred as a direct result of transseptal catheterization; nonfatal complications occurred in 2.8% of patients (hemopericardium in one patient, ventricular fibrillation in one patient and transient vagal reaction in one patient).

The use of the right anterior oblique projection to adequately visualize both the interatrial septum and the intended point of puncture, the use of a pigtail catheter positioned in the ascending aorta to define the relation of the puncture site to the aorta in this projection and the utilization of a flexible preshaped guide wire to catheterize the left ventricle are the major factors contributing toward this improved success rate and low incidence of complications.

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Table 1. Clinical Characteristics: 106 Left Heart Transseptal Catheterizations in 101 Patients

<table>
<thead>
<tr>
<th></th>
<th>AS</th>
<th>MS</th>
<th>IHSS</th>
<th>Normal Function</th>
<th>Regurgitant Lesion Only</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clinical indications</td>
<td>69</td>
<td>25</td>
<td>7</td>
<td>5</td>
<td>—</td>
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<tr>
<td>Dominant anatomic diagnosis</td>
<td>57</td>
<td>21</td>
<td>6</td>
<td>—</td>
<td>13</td>
</tr>
<tr>
<td>Mean gradient* (mm Hg)</td>
<td>55 ± 26</td>
<td>11 ± 7</td>
<td>—</td>
<td>13</td>
<td>9</td>
</tr>
<tr>
<td>Valve area* (cm²)</td>
<td>0.9 ± 0.4</td>
<td>1.8 ± 0.8</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>

*Values are mean ± standard deviation. AS = aortic stenosis; IHSS = idiopathic hypertrophic subaortic stenosis; MS = mitral stenosis.

Transseptal catheterization was performed in 25 patients to evaluate prosthetic valve function. Five of these patients underwent elective transseptal left heart catheterization as part of a research protocol evaluating the Carpentier-Edwards heterograft (23).

The mean left ventricular ejection fraction (calculated in 98 studies in which left ventriculography was performed) was 0.55 ± 0.17.

Transseptal catheterization. The intention of this report is to focus on two modifications of the technique which, we believe, make it a safer, more reliable procedure.

Catheter-needle relation. Before transseptal left heart catheterization, a preliminary assessment of the relation of the distal end of the Brockenbrough catheter to the Brockenbrough curved needle is made. First, the fit of the catheter around the needle in the fully inserted position is evaluated. When the needle is fully advanced into the catheter, the transition from the needle to the distal end of the catheter should be smooth. The use of a needle and a catheter from different manufacturers, or imperfect catheter fabrication, will occasionally result in a rough transition from needle to catheter (Fig. 1). This makes passage of the catheter across the septum difficult after initially successful needle puncture. Second, the distance between the proximal end of the catheter and the metallic arrow on the needle is assessed with the needle tip just inside the distal end of the catheter to ensure adequate retraction of the needle within the catheter during initial catheter manipulation in the right atrium.

Transseptal puncture. The first modification of the classic transseptal technique involves the use of a 40 to 50° right anterior oblique fluoroscopic projection and catheter delineation of the aortic root position to define septal boundaries and the point of interatrial septal puncture. A 7 French pigtail catheter is placed in the ascending aorta and advanced firmly onto the aortic valve. In the 45° right anterior oblique position, a 10 cc hand-held injection of sodium-meglomine diatrizoate (Renografin-76) is then made through the catheter to visualize the aortic root and 2) to ensure that the pigtail catheter is correctly positioned in the posterior noncoronary cusp, thereby serving as a marker of the posterior aspect of the aorta. In this projection, the interatrial septum is viewed en face, with clear visualization of the posterior, superior and inferior aspects of the atria (Fig. 2). The pigtail catheter delineates the aortic valve and posterior wall of the aortic root, allowing the physician to confidently avoid this area. The intended point of puncture is halfway between the posterior boundary of the atra and an imaginary line drawn through the posterior aortic wall, and approximately 1 to 3 cm below an imaginary horizontal line drawn through the aortic valve (as defined by the pigtail) (Fig. 2B).

These relations having been defined and the intended point of septal puncture having been identified, the anteroposterior projection is used 1) to place an 8.5 French Brockenbrough catheter in the high right atrium using a standard 145 cm guide wire, and 2) to gently advance the Brockenbrough needle through the catheter. During this latter maneuver, the distal end of the catheter is constantly observed fluoroscopically to ensure correct position in the

Figure 1. Relation between a Brockenbrough catheter and a Brockenbrough needle from the same manufacturer (above) and from different manufacturers (below). The transition from needle to catheter in the former instance is smooth. In the latter, there is a sudden "step-up" from the needle to the lower lip of the catheter.
high right atrium. With the tip of the needle retracted approximately 1 cm inside the distal end of the catheter, and using anteroposterior fluoroscopy, these two elements are withdrawn into the mid right atrium and simultaneously clockwise rotated so that the metallic arrow on the needle is directed to an approximate 4 o'clock position to point midway between the frontal and sagittal planes. Care is taken to ensure that the catheter does not prolapse across the tricuspid valve. The needle is flushed and the cardiac silhouette is then imaged in an approximate 40 to 50° right anterior oblique projection allowing the broadest perpendicular view of the atrial septum. The transseptal system is further withdrawn until the tip of the catheter is located at the point of intended interatrial septal puncture, approximately 1 to 3 cm below the horizontal plane of the aortic valve, and the Brockenbrough needle is then gently but firmly advanced to the fully inserted position using fluoroscopic guidance and pressure monitoring. More than just light pressure of the catheter against the septum during this maneuver will result in excessive curvature of its distal end and predictable perforation at this site by the needle.

As the needle traverses the septum, the phasic pressure invariably damps, and then in approximately 50% of patients, a phasic left atrial pressure will be seen after full needle insertion. Needle puncture of the interatrial septum is accompanied by a "popping" sensation transmitted through the catheter to the operator's hand and is visualized on fluoroscopy as a sudden straightening of the tensed needle. In the other 50% of patients, incomplete septal perforation results in a damped pressure despite full insertion of the needle into the Brockenbrough catheter. At this point, judgment is required to decide whether to withdraw the needle and repeat the entire procedure, or to continue advancement of the needle and catheter into the left atrium. If there is any doubt about the position of the tip of the catheter at the commencement of septal puncture, the procedure should be repeated. If, however, the operator is confident that the catheter tip is in a favorable position, the needle and catheter are further advanced as a unit. After usually no more than an additional 1 to 2 cm, puncture of the atrial septum by the needle is noted by the tactile "popping" sensation and the sudden appearance of a phasic left atrial pressure. Once left atrial pressure is obtained, the needle and catheter are advanced as a unit approximately 1 to 2 cm, thereby carrying the Brockenbrough catheter itself across the septum. Although a second "popping" sensation may occur because of traversal of the catheter itself across the interatrial septum, this is not often appreciated. Anteroposterior fluoroscopy is then used to visualize the catheter as it is slowly advanced over the needle into the left atrium. During this maneuver, the catheter typically forms a curve with cephalad convexity.
Once the catheter is adequately positioned in the left atrium, the needle is completely removed, the adapter is attached to the hub of the catheter and the catheter is aspirated and flushed.

**Left ventricular catheterization.** The second modification involves the use of a preshaped guide wire to allow anterograde left ventricular catheterization. The soft end of a straight 0.035 inch wide 125 cm long guide wire is bent approximately 10 cm from the tip to form a gentle curve to match the curve of the Brockenbrough catheter in the left atrium. The distal end of the guide wire beyond this curve is then bent to form both a J loop with caudal convexity and anterior angulation to carry the more distal J formation anteriorly and downward through the mitral valve (Fig. 3). With either anterior or right anterior oblique fluoroscopy, the guide wire is advanced beyond the tip of the catheter in the mid left atrium and forward and downward into the mitral valve with the aid of these preformed curves. Left ventricular catheterization is confirmed by guide wire-induced ventricular ectopic beats. The catheter is then advanced over the guide wire and through the mitral valve.

**Results**

**Interatrial septal puncture.** Successful catheterization of the left atrium by the transseptal technique was accomplished in 105 of 106 attempts. Among 69 patients with clinically suspected aortic stenosis, transseptal catheterization was electively performed in 49 patients without an initial attempt at retrograde left ventricular catheterization. In the other 20 patients, transseptal catheterization was performed only after concerted efforts to cross the aortic valve retrogradely with both pigtail and Gensini catheters and guide wires had failed. All patients with clinically suspected dominant mitral stenosis or hypertrophic subaortic stenosis had elective catheterization by the transseptal route. Three patients in this series had two transseptal left heart catheterizations and one patient had three transseptal catheterizations. In the majority of cases, the septum was crossed on the first attempt. The only failure occurred in a 54 year old man with aortic stenosis and regurgitation and an aortic valve area of 1.2 cm². He had an elevated right hemidiaphragm that obscured the en face view of the septum, thereby making clear septal definition, and particularly posterior and inferior septal delineations, difficult. The valve was crossed retrogradely with a Gensini catheter and guide wire.

**Anterograde transmitral left ventricular catheterization.** Anterograde catheterization of the left ventricle through the mitral valve was attempted in 87 instances and was successful in every case. Attempted anterograde catheterization through an associated stenotic mitral valve, required in eight patients (mean valve area 1.29 ± 0.39 cm²), was achieved in every instance.

Angiography was performed through the Brockenbrough catheter in 77 instances (left atrial angiography in 40 instances and left ventriculography in 37 instances). During our early experience, we preferentially opacified the left ventricle by means of a left atrial injection, but later employed left ventriculography exclusively to better appreciate the presence and severity of associated mitral regurgitation. Artifactual mitral regurgitation resulting from the Brockenbrough catheter lying across this valve is not usually encountered or is otherwise trivial. Adequate positioning of the catheter within the ventricular cavity before left ventriculography was ensured by small hand-held injections of contrast medium. Left ventriculography was performed using 30 to 56 ml of Renografin-76 injected over 3 to 4 seconds. Among the other 29 transseptal catheterizations, left ventriculography was accomplished through a retrogradely...
placed pigtail or Gensini catheter in 24 instances, and was electively not performed in 5 patients with critical aortic stenosis and a low output state.

**Mortality.** One patient died within 24 hours after transseptal catheterization. This was a 64 year old man with critical aortic stenosis (calculated valve area 0.40 cm²) who underwent transseptal catheterization in 1974 at a time when the dangers of a contrast load in patients with severe aortic valve obstruction were not fully appreciated. Within 1 minute after a left atrial angiogram, his blood pressure dropped precipitously. He rapidly became severely hypotensive and developed ventricular fibrillation from which he could not be resuscitated. Review of the cineangiogram revealed that the Brockenbrough catheter was free in the left atrial cavity and that no staining of its wall had occurred. The presumed cause of death was contrast-induced refractory hypotension, a now recognized complication in patients with critical aortic stenosis.

**Morbidity.** Nonfatal complications related to catheterization occurred in three patients (2.8%) (cardiac tamponade in one, ventricular fibrillation in one and vagal reaction in one).

**Signs of cardiac tamponade** developed in one patient, a 70 year old man with severe aortic stenosis (calculated valve area 0.84 cm²), approximately 18 hours after uneventful transseptal catheterization. Interatrial septal puncture was achieved on the first attempt and cardiac perforation was not suspected at any point during the procedure. An emergency pericardiocentesis yielded 350 cc of blood and he was subsequently treated conservatively. He underwent uneventful elective aortic valve replacement 48 hours later.

**One patient developed ventricular fibrillation** while the needle tip was being advanced through the Brockenbrough catheter in the inferior vena cava. It was noted that the end of the catheter had inadvertently crossed the tricuspid valve and was lying in the right ventricle. The catheter was immediately retracted, and the patient underwent electrical cardioversion. Transseptal catheterization was subsequently performed uneventfully.

A **transient vagal reaction** occurred 30 minutes after transseptal catheterization in a 60 year old man with severe aortic stenosis (aortic valve area 0.71 cm²). This was reversed with 0.5 mg of atropine.

**Atrial ectopic beats** were invariably not encountered during interatrial septal puncture. A few patients described momentary nonlocalized chest pain with pressure of the Brockenbrough catheter against the septum or at the time of needle puncture.

**Fifty-four patients underwent cardiac surgery with cardiopulmonary bypass support at a mean time of 15 ± 15 days** (range <1 to 71) after catheterization. No laceration or hematoma was noted on the external surface of the heart or aorta in any patient. The left atrium was opened in 10 patients in whom mitral valve replacement was performed. A puncture site could not be identified on the left side of the interatrial septum in any one of these patients.

**Discussion**

**Previous studies of the classic technique.** Although initial reports of the transseptal catheterization technique were enthusiastic (1,15–17), its use has more recently been tempered by awareness of a significant incidence of morbidity and mortality (17–20). In the Cooperative Study on Cardiac Catheterization (18), a 0.2% mortality rate, a 6% incidence rate of major complications during catheterization involving transseptal punctures and a 3.4% incidence rate of serious complications specifically related to transseptal left heart catheterization were recorded. These data emanate from 16 well established catheterization laboratories, each of which had an active interest in the development of new catheterization techniques and in many of which, methods had been introduced that are now widely used throughout the world (24). The Cooperative Study confirms the 0.4 to 1% mortality (1,19) and 4.5 to 7.9% major complication rates (1,17–20) previously reported from other laboratories. Previous studies also reported a significant failure rate. No data regarding the incidence of successful and failed transseptal catheterization are provided in the Cooperative Study on Cardiac Catheterization (18). However, using the classic technique described by Brockenbrough et al. (16), a 1.3 to 8% failure rate in puncturing the interatrial septum (1,16), and a 5.3 to 67% incidence of failure in entering the left ventricle (1,16,17) have been reported from centers well versed in this technique.

These data are all derived from studies in which transseptal catheterization was performed in the anteroposterior projection. In this view, the tip of the Brockenbrough catheter is withdrawn from the superior vena cava, rotated approximately 45° from the horizontal plane and classically placed over the spine and within the lower half of the right atrial silhouette just before puncture (25,26). This view, however, does not allow appreciation of either left atrial size (which may be critical in determining the exact degree of rotation of the needle from the horizontal plane) or of the relation of the needle to both the posterior atrial wall and the aortic root. Once the atrial septum has been traversed, the left ventricle is classically entered by counterclockwise rotation and further advancing the Brockenbrough catheter through the mitral valve, either with or without a tip occluder (25,26).

**Modifications.** In this report, we describe two modifications of the classic technique of transseptal catheterization, namely, use of the right anterior oblique view to accurately localize the point of intended interatrial septal puncture, and a preshaped guide wire technique to enter the
left ventricle, thereby averting a major risk of serious left atrial or mitral annular trauma by a stiff catheter during attempts to anterogradely cross the mitral valve. Utilization of these two simple modifications has allowed us a 99% success rate in entering the left atrium in 106 instances and a 100% success rate in catheterization of the left ventricle. There was one death unrelated to transseptal puncture and an overall complication rate of 2.8%.

Advantages of right anterior oblique fluoroscopy. The advantage of the right anterior oblique view lies in the en face view of the interatrial septum which it affords. In addition, its anterior limit and, indeed, the exact position of the aortic valve and ascending aorta are defined by a pigtail catheter placed in the noncoronary aortic cusp. The intended point of atrial septal puncture is, therefore, easily localized. This direct view of the boundaries of the intended puncture site obviates the relative contraindications to transseptal catheterization posed by either a very large left or right atrium or by thoracic spinal deformity (20,26). In addition, the angle at which the septum is punctured can be visualized, as can the relation of the Brockenbrough needle to the superior wall of the left atrium after puncture. Finally, when a damped pressure is obtained during needle puncture, as frequently occurs, this projection affords a view of whether the puncture site is anatomically correct, in which case the catheter and needle may be further advanced safely. If needle placement is imperfect, the needle can be retracted and the entire procedure repeated.

It should be noted that the initial withdrawal of the catheter and needle to the mid atrial level and rotation to approximately 45° between the anterior and sagittal planes are achieved under posteroanterior fluoroscopic guidance, thereby ensuring against inadvertent right ventricular or left atrial (via a patent foramen ovale) catheterization.

Anterograde guide wire catheterization of the left ventricle. Of 43 perforations related to transseptal catheterization in the Cooperative Study on Cardiac Catheterization (18), the left atrium was perforated in 8 instances by either the Brockenbrough catheter or a metal stylet. We believe that the rigidity of this catheter contraindicates attempts to ever advance this catheter by itself, including attempts to cross the mitral valve. The Cooperative Study data and the anecdotal experiences by our colleagues of mitral annular perforation have prompted the use of a preshaped guide wire to anterogradely catheterize the left ventricle in our laboratory. We have experienced a 100% success rate with this technique in 87 attempts, including attempts in eight patients with mitral stenosis and a mean valve area of 1.29 ± 0.39 cm². No complications were incurred.

Initial Brockenbrough catheter placement. One patient developed ventricular fibrillation during recommended (24) observation of the needle tip as it was being advanced through the catheter up toward the right atrium. This resulted from inadvertent prolapse of the catheter tip into the right ventricle due to the considerable rotation which it may undergo during passage of the needle. We now initially place the tip of the Brockenbrough catheter in the high right atrium and constantly monitor its distal end fluoroscopically during needle insertion to prevent this complication. We believe that accidental perforation of the catheter in the inferior vena cava by the needle will not occur provided that the operator stops when encountering any resistance to needle advancement. Contrary to the practice of others (20,24), we prefer to initially position the distal end of the Brockenbrough catheter in the high right atrium rather than in the superior vena cava. The confined space of this central vein could potentially lead to serious trauma during rotation of the stiff Brockenbrough catheter within its lumen as the needle is advanced from below.

Conclusion. We have described two modifications of the classic technique of transseptal catheterization, that of utilizing the right anterior oblique projection, which affords an en face view of the interatrial septum, and that of employing a preshaped guide wire for catheterization of the left ventricle. With these two techniques, a success rate of 99% for interatrial septal puncture and 100% for anterograde left ventricular catheterization were obtained. There was no mortality directly resulting from transseptal catheterization and a 2.8% overall incidence of complications.

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References


