Transseptal Catheterization of the Left Heart

Observation in 200 Cases

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In many cases the catheterization of the right heart is not sufficient for an exact diagnosis; this concerns especially acquired valve disease of the left heart and complex congenital malformations. Additional examinations, above all the catheterization of the left heart are indicated. Several methods are reported:

1. Retrograde catheterization of the left ventricle from a peripheral artery.
2. Transbronchial puncture of the left atrium.
3. Percutaneous puncture of the left atrium.
4. Direct transthoracic puncture of the left ventricle.

The fact, that there are many different methods, shows, that each one of them is not completely satisfactory. There may be technical difficulties involved, and the examination can be dangerous or painful for the patient.

The introduction of the transseptal catheterization of the left heart by Cope\textsuperscript{1} and by Ross, Braunwald and Morrow\textsuperscript{2,3} meant great progress. Bevegard, Jonsson, Karlöf\textsuperscript{4}, Steinhart and Endrys\textsuperscript{5}, Brockenbrough et al.,\textsuperscript{6} Gorlin et al.,\textsuperscript{7} Bette et al.\textsuperscript{8} and other authors recommended modifications of the technic. The method is technically simple and does not mean serious molestation to the patient. Investigations of the left atrium and ventricle by probing, pressure registrations, blood sampling and injection of indicator dye or contrast material are possible. The measurements can be taken over longer periods of time in adults as well as in children, at rest or during exercise. Catheterization of the right heart may be performed simultaneously. Intracardial ECG and PCG of the left side can be taken (Beuren and Apitz)\textsuperscript{4}. None of the prior methods offers such advantages.

Technic

We perform the catheterization of the right and of the left heart almost exclusively via the right femoral vein. The catheter is introduced by percutaneous...
puncture. This procedure offers, compared to a veinsectio of the saphenous vein, the following advantages:

1. Surgical preparation of the vessel is omitted.
2. The risk of wound infection is decreased.
3. Even in infants catheters with wide diameter can be placed for cardioangiography.

Under local anaesthesia, the femoral vein, which is situated medial to the femoral artery, is punctured close distally of the inguinal ligament. According to the Seldinger-technic a guiding wire, tipped with a spring coil, is then placed into the vein. Next, the opening in the wall of the vessel is dilated by a conical tipped catheter. So it is possible, to introduce not only conical tipped catheters but blunt-tipped Courand-catheters as well.

Right heart catheterization usually is performed first. To pass the catheter into the pulmonary artery, the tip of it has to be turned upward immediately after entering the tricuspid valve. Not much practice is required to learn how to reach the branches of the pulmonary truncus and how to take pulmonary wedge pressures as easily as by the brachial route. A possible disadvantage may be, that an exact probing of the right ventricle is more difficult by the inguinal route. On the other hand the direct probing of the atrial septum is less difficult and defects in this area can be detected more easily. Venous spasms, seen several times in catheterizations via the brachial veins, never occurred, using the inguinal route.

If a left heart catheterization is indicated, we proceed as follows: the tip of the standard catheter is drawn back into the lower part of the right atrium. A flexible tipped guide wire of 200 cm. in length is advanced through the catheter into the lower part of the superior vena cava. Then the standard catheter is withdrawn and replaced by a shorter, conical tipped teflon catheter, which is curved at the end. When this teflon catheter is situated in the right atrium, the guiding wire is withdrawn. Then the transseptal needle (Brockenbrough) is advanced through the catheter, until the tip of it is still 1 cm. inside from the far end of the catheter. This technic seems more simple and less hazardous, than the introduction of the catheter by means of a straight stiff guide probe. We prefer catheters with one terminal opening and not those with additional side holes, because the latter may bend itself being pressed to the atrial septum. Thus the tip of the needle may leave the catheter through one of the side openings.

First the right atrium is investigated. Then the catheter, guided by the transseptal needle inside, is advanced along the posterior atrial wall to the septum. The puncture is performed in the area of the fossa ovalis; its prominent superior edge can be felt in most of the cases. In case of rotation or displacement of the heart sometimes the atrial septum cannot be felt readily; then no puncture should be performed.

The perforation of the atrial septum does not cause any pain. Complaints indicate a wrong point of puncture, irritation of the coronary sinus or distension of the pericardium. After perforation of the septum oxygenated blood can be withdrawn through the needle. As soon as blood samples and pressure recordings indicate, that the tip of the needle has entered the left atrium, the cathether is advanced to penetrate the septum. The needle is then removed. If the diameter of the tip curvature suits well to the size of the heart, the left ventricle can be entered without difficulties. Otherwise we exchange the catheters as follows: introduction
of the spring coil guide into the left atrium; retraction of the lying catheter and replacement by a fitting one. Since the spring coil guide is kept in the left atrium no repeated puncture is necessary. If cardioangiography is indicated, we use catheters with side holes. In order to avoid contrast material impregnation of the myocardium, one has to be sure that the catheter is floating freely in the ventricular cavity.

**Results**

The investigations have been performed in 200 patients, aged from 2 to 56 years. Included in this number are 39 children. We diagnosed cases of aortic stenosis, combined mitral valve disease, malformations of the aortic arch, ventricular septal defects, tetralogy of Fallot, complex congenital malformations of the heart and endocardial fibroelastosis.

For the first 45 investigations we used a modified Ross-equipment. In one case a puncture was not performed because the septum could not be reached. One child fell ill with pericarditis on the day after the investigation. The examination had been without complications, but we believe, that the pericarditis was caused by the catheterization anyhow. A misplaced puncture we assume as improbable, for cardioangiography had shown evidently the catheter lying in the left atrium. The child recovered completely.

The subsequent 155 examinations were performed by means of the above mentioned technic. In this series 6 adult patients could not be punctured because it was impossible to reach the atrial septum. Four times we did not succeed to pass the catheter through the mitral valve. These were the first attempts with the new technic and lack of experience might have been the cause for the failure. It should be mentioned, that sharp perforation of the septum is rarely necessary in infants; in most of the cases the atrial septum can be passed bluntly with the catheter tip, guided by the needle inside in the area of the fossa ovalis, using little force. Attempts to advance the catheter into the aorta via the left ventricle do not seem appropriate to us; manipulations in the left ventricle with the relatively stiff teflon catheter may result in severe arrhythmias. Especially in aortic stenosis withdrawal pressure measurements do not give a definite information of the anatomical structure of the lesion; this can be achieved however by a selective cardioangiography from the left ventricle. For determination of the pressure gradient of the aortic valve we advance an additional catheter into the proximal aorta via the femoral artery.

Primarily we used catheters with side holes in the above described technic. In a patient with severe aortic valve stenosis and combined tricuspid valve lesion the end of the catheter formed a sharp bend, when pressed towards the
atrial wall, so that the tip of the needle slipped out of a side hole; the projec-
tion on the TV-screen was so unfavorable, that this complication could not be
observed. The extremely thin atrial wall was perforated which resulted in a
cardiac tamponade with lethal outcome. Since that time we principally
prefer catheters with one distal hole only, in order to avoid this complication.
In one case a severe supraventricular tachycardia developed after the perfora-
tion of the atrial septum; it could be brought under control by corresponding
medications. A similar incident with lethal consequence is reported by Porst-
mann et al.\textsuperscript{19)} In accordance to reports by Brockenbrough et al.\textsuperscript{13)} and
Beuren et al.\textsuperscript{14)} we experienced sudden hypotension without bradicardia or
loss of consciousness in 2 patients. The reason for such episodes might be an
irritation of depressor receptors, causing a reflex as described by Douthel and
Kramer.\textsuperscript{15)}

Occasionally one or two premature atrial contractions may be observed
at the time of the transseptal puncture. During the investigation of the left
ventricle sometimes bouts of premature ventricular contractions are seen;
they arrest when the position of the catheter is changed.

Except these complications, we did not see any severe incidents during
transseptal catheterization or selective cardioangiography of the left heart.

Fig. 1 shows the tracing of the systolic pressure gradient in a patient
with severe stenosis of the aortic valve. One catheter had been advanced into
the left ventricle after puncture of the atrial septum; a second catheter had
been introduced into the femoral artery, and the far end of it was brought to
the aortic valve by the retrograde way. The pressure gradient is 130 mm. Hg.
The determination of the filling gradient over the mitral valve is also
possible; one catheter has to be guided into the left atrium by the transseptal

![Fig. 1. Simultaneous left ventricular (L.V.) and aortic (A0) pressures re-
corded by the transseptal technic in a patient with aortic stenosis.](image)
route, the second is guided into the left ventricle through the aortic valve (Fig. 2). This tracing was taken from a female patient suffering from severe combined mitral valve disease. Using this technic, even the degree of insufficiency of aortic and mitral valve lesions can be estimated by means of indicator dye dilution.

Valuable aid for exact determination of the position of the catheter tip is given by intracardial electrocardiography. Fig. 3 shows the consecutive tracings of an intracardial atriogram during the withdrawal of the catheter from the left into the right atrium. The electrical impulse reaches left atrium later than the right one, and the intrinsic deflection of the QRS complex is retarded on the left side also. The recordings of the upper part of the atrium show prevailing negative potentials; in the mid position they

Fig. 2. Simultaneous left atrial (L.A.) and left ventricular (L.V.) pressures recorded by the transseptal technic in a patient with mitral regurgitation and stenosis.

Fig. 3. A withdrawal tracing (IEG) from left to right atrium. This illustrates how the polarity of the P wave can be studied on each side of the septum. In this case they are biphasic in the left atrium and negative in the right atrium.
are biphasic and positive potential preponderate in the lower part. In case of anomalies of the heart position the intracardial ECG means valuable help for orientation. For example a catheter tip lying in the coronary sinus reveals a characteristic tracing. This may help to avoid incidents due to a wrong site of transseptal puncture. Also in selective cardioangiography of the left heart the position of the catheter tip can be exactly controlled. In case, that close contact of the catheter with the ventricular wall is not signaled by extrasystoles, increase of the S-T elevation takes place; then the catheter is drawn back until normal intraventricular ECG is observed. In this way impregnations of the myocardium with contrast material can be avoided.

Pressure measurements are insufficient for exact detection of the anatomical deformity of an aortic stenosis. Visualizing of the lesion by means of contrast material is necessary. Fig. 4a and 4b show selective cardioangiography in a female patient suffering from hypertrophic subvalvular stenosis in anteroposterior and lateral view. The catheter is floating freely within the left ventricle after transseptal puncture. Fig. 4a shows the severe narrowing deep in the cavity of the chamber and the protruding ventricular septum.

The aortic valve itself is tender. The moderate reflux of contrast material into the left atrium is caused mainly by the site of the catheter. The pressure tracings of the atrium had not been typical for an effective mitral insufficiency. The systolic pressure gradient over the aortic valve was 120 mm. Hg. Fig. 4b shows the considerable narrowing of the subaortic part of the left ventricle.
In cases of aortic coarctation exact knowledge of length and site of the stenosis is important for the choice of surgical approach. Additional anomalies can be ruled out easily by selective injection of contrast material into the left ventricle. Fig. 5 shows a a.p.-view of an cardioangiogram of a female patient with aortic coarctation and patent ductus. The location of the stenosis is typical. Marked poststenotic dilatation of the aorta can be noticed. The pulmonary artery is filled with contrast material via the patent ductus.

A very rare disease is the isolated congenital mitral valve insufficiency. Fig. 6 shows the a.p.-radiogram of a boy, suffering from congenital mitral

Fig. 5. Selective angiocardiogram in the anteroposterior projection in a patient with coarctation of the aorta and patent ductus arteriosus.

Fig. 6. Left ventricular angiocardiogram in a patient with congenital mitral insufficiency. No filling defects are seen in the left atrium. The opacification of the enlarged left atrium is clearly visible. Elevation of the mean left atrial pressure with prominent v-wave.
valve insufficiency; contrast material is injected into the left ventricle. The catheter is situated in the lateral angle of the mitral valve and should not enlarge the reflux of contrast material into the dilated left atrium in this position. The mitral valve is clearly outlined.

It may be very difficult to distinguish a combined ventricular and atrial septal defect from a partial persistent atrioventricular canal. Here left sided ventriculography may be of great help. In Fig. 7a and 7a the a.p. and lateral radiograms of a boy with a combination of atrial—and ventricular septal defects are shown. Both pictures indicate simultaneous contrast filling of aorta and pulmonary artery. The slight reflux into the left atrium is due to the position of the catheter within the mitral valve. The right atrium is not tinged with contrast material.

![Fig. 7. Transseptal left ventricular angiocardiogram in the anteroposterior projection (left) and in the lateral projection (right) in a patient with a ventricular septal defect. Simultaneous filling of the aorta and pulmonary artery.](image)

**DISCUSSION**

Compared to the methods of direct puncture, the transseptal catheterization by the percutaneous femoral route offers several advantages. Pressure registrations in all 4 cavities of the heart can be taken, as well as intracardial injection of indicator dye, using a single site of percutaneous puncture. For selective cardioangiography small amounts of contrast material are sufficient. The original method of Ross, using a thin polyethylene catheter, which could not be seen by X-ray is generally abandoned. Only some modifications of this technic are still in use.

The catheterization of the left heart by the percutaneous route can be
performed in children as well as in adults. Even in infants of 2 years of age surgical preparation of the vessel is not necessary when catheters of smaller diameters are used.—In rare cases of infants a blunt passage of the atrial septum was not possible. Then we employed a small transseptal needle, as described by Brockenbrough. Generally the femoral vein admits catheters of larger diameter than the brachial veins, an advantage especially for injections of contrast material.

For selective cardioangiography of the left heart, the catheter has to float freely within the cavity of the atrium or the ventricle. Endrys and Steinhart report an injection of contrast material into an retrocardial pulmonary vein, causing a pulmonary edema with paroxysmal tachycardia. To avoid impregnations of the myocardium with contrast material Porstmann et al. describe a method of intravascular closing of the distal opening of the catheter. This technic seems to offer advantages, but we do not have own experience yet.

In 6 patients the atrial septum could not be punctured, because it could not be exactly delimitated with the needle. In cases of displacement of the inferior vena cava, excessive enlargement or abnormal position or rotation of the heart those mischieves may happen. Then, corresponding to the situation, a retrograde probing of the left ventricle from a peripheral artery or a transthoracic puncture of the left chamber can be carried out without changing the supine position of the patient. Shortly Loogen et al. gave a report about this method. In cases with anomalies of position or rotation of the heart Bender et al. recommend the modified technic as described by Bevegard, Jonsson and Karlöf. According to his experience even wrong located punctures are without severe consequences. We have only few experience with this needle and cannot give any conclusive critic. In 4 early investigations we did not succeed to enter the left ventricle. For trespassing the mitral valve it is important to choose a catheter with a curvature diameter, that fits to the individual heart size. The guiding of the catheter tip in an inferior and ventral direction needs some special practice. Since we are able to employ the long guide wire in order to replace a catheter by one of a different curvature diameter, the left ventricle could be entered in all cases.

Complications are reported by several authors and one should not consider the method as unpericulous in spite of its advantages. Brockenbrough et al. did not see severe incidents in 450 transseptal catheterizations. In 2 patients they observed reversible auricular fibrillation and in 2 cases sudden unexplained hypotension. Small amounts of blood within the pericardial space were found at a following surgical operation in some patients; the authors assume that in these cases a perforation of the free atrial wall had
taken place. McIntosh et al.\textsuperscript{20)} reported one case, in which the catheter was pierced by the needle without severe consequences. A similar description is given by Beuren et al.\textsuperscript{14)} They report an incident with lethal consequence in a patient with an extremely high situated small left atrium, in which the puncture was performed to far inferiorly. Adrouny et al.\textsuperscript{21)} describe several severe complications during a series of 191 transseptal catheterizations. In 9 cases the free atrial wall was perforated and one death occurred. In 2 patients a haemopericardium was found at the following surgical operation. One patient died from a coronary embolism; in this case a combination of a wide guiding catheter with a smaller probing catheter was used for the left heart catheterization. The diameter of thrombus corresponded with the width of the guiding catheter. Moreover 2 pulmonary embolism following preparation of saphenous vein are described by the authors.

During the last 145 percutaneous catheterizations we did not see remarkable complications. Blunt passage of the septum is possible in children in almost all cases and eventually also in adults diminishing the risk of the procedure. We believe, that complications, as seen among the first series of 55 investigations can be avoided by the modified technic. Above all the transseptal puncture should not be tried, if orientation in the right atrium is not satisfactory. In none of our cases we saw a thrombophlebitis after percutaneous puncture of the femoral vein. It is also possible to repeat the catheterization, because the vein is not ligated. Introduction of wide catheters causing no venous spasms is often the basis for an effective cardioangiography.

As far as our experience is concerned, the percutaneous transseptal catheterization seems superior to the other methods of left heart catheterization. But the complications described above show that the method is not without risk.

**Summary**

Experiences with 200 transseptal catheterizations of the left heart are reported. The percutaneous insertion of the catheter into the femoral vein offers essential advantages. Investigations of all cavities of the heart may be performed through a single venous intubation. The examination have been carried out in patients with left-sided heart valve disease, especially aortic valve lesions, in complex congenital malformations and endocardial fibroelastosis. Own complications and incidents, as reported by different authors, are discussed. Severe complications can be avoided by use of the modified technic. The percutaneous transseptal catheterization is superior to other methods of left heart catheterization. The advantages and possibilities of the method are demonstrated.
REFERENCES