Catheter Positions in Congenital Cardiac Malformations

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SUMMARY
Biplane cineangiocardiograms were examined from a population of patients with diverse forms of congenital heart disease and examples were selected to illustrate catheter positions which may help define and elucidate the anatomy of simple and complex cardiac lesions. Familiarity with the appearance of these typical and atypical catheter positions may be of considerable aid in the course of hemodynamic study and in the evaluation of cineangiocardiograms.

The editors suggest that each figure be evaluated as an unknown before reading the caption.

CARDIAC MALFORMATIONS present diagnostic challenges to both pediatric cardiologists and radiologists. Often during a hemodynamic study the position of the cardiac catheter may serve to clarify a diagnosis. The purpose of the present report is to demonstrate the radiographic appearance of commonly encountered cardiac catheter positions in congenital heart disease, and to discuss differential diagnostic possibilities. The presentation is divided in order to describe: 1) venous catheter positions and 2) retrograde arterial catheter positions. Biplane cineangiocardiograms were reviewed from case material collected at the University Hospital between 1969 and 1973. Verification of catheter position was determined at the time of hemodynamic study by pressure tracings, oxygen saturation data and biplane fluoroscopy, and after the procedure by reviewing the cineangiocardiograms.

Venous Catheterizations
Cannulation of the central venous circulation may be achieved from below the diaphragm (saphenous, femoral, or umbilical veins), or above the diaphragm (brachial or axillary veins). The normal position of the inferior vena cava is to the right of the vertebral column. The right atrium, normally the next structure traversed by the catheter, has its posterior-inferior border at the level of the diaphragm. Increased curvature of the catheter tip is obtained by hooking the catheter against the right atrial wall. This allows the catheter to be directed antero-medially across the tricuspid valve into the right ventricle and then into the main pulmonary artery. Figure 1A illustrates the placement of a catheter in the main pulmonary artery by this technique (solid line). Verification of the catheter's position can be obtained by pressure recordings or contrast injection. A roughly similar appearance may be seen with a catheter placed in: 1) an anomalous left superior vena cava which drains the jugular and axillary veins through the coronary sinus, 2) the ascending aorta in L-transposition, or 3) the left...
atrial appendage after the catheter has traversed a patent foramen ovale or atrial septal defect. The presence of an anomalous left superior vena cava is suggested by persistence of a venous pressure tracing and the passage of the catheter toward the left shoulder beyond the cardiac silhouette. This may be verified by contrast injection. Since pressures in the pulmonary artery may be elevated to systemic levels, the aortic location of the catheter may be confirmed by its passage around the aortic arch and into the abdominal aorta (below the diaphragm) or into a carotid or subclavian artery. Passage of the catheter through a ventricular septal defect into the aorta can be distinguished from the more inferior passage into the descending aorta via the main pulmonary artery and a patent ductus arteriosus, since the latter course is approximately two vertebral bodies caudad and to the left of the normal aortic arch in position. Catheter placement in the left atrial appendage is most easily distinguished from a position in the main pulmonary artery by its course, which is usually one vertebral body cephalad, and by oxygen saturation determination and/or contrast injection. In figure 1A, the catheter course illustrated by dotted lines demonstrates the routine approach from the superior vena cava...
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cava to the main pulmonary artery by brachial or axillary venous catheterization. Note that in the lateral view (fig. 1B), the catheter enters the heart posteriorly, and is looped anteriorly across the tricuspid valve through the right ventricle into the main pulmonary artery.

Anomalies of central venous drainage are not infrequently encountered in the pediatric age group. These variations of venous anatomy can result in confusion during the cardiac catheterization. Figure 2 depicts the passage of a catheter into the right atrium via azygous continuation of the inferior vena cava, in which the venous drainage is directed first into the superior vena cava. The catheter passes posteriorly behind the cardiac silhouette and enters the superior vena cava. Although during frontal fluoroscopy the

Figure 4

The catheter was passed through a hemiazygous continuation of the inferior vena cava and superior vena cava and lies posterior in location in the lateral projection (arrows in B). The catheter was then turned inferiorly into the coronary sinus draining the left-sided superior and inferior vena cavae. Entering the right atrium from the coronary sinus, the catheter has been looped across the tricuspid valve into the right ventricle. Note the anterior position of the catheter tip on the lateral projection (B).

Figure 5

A catheter (solid line) was passed into the left atrium from the right atrium through a patent foramen ovale. An inferior passage of a catheter across the atrial septum is shown by the dotted line. Such a catheter course might be seen in a patient with an ostium primum atrial septal defect. (The tip of this catheter is in the left ventricle.)

Figure 6

A catheter was placed in the left atrium from the right atrium through a patent foramen ovale. The catheter has been turned anteriorly (B) across the mitral valve from the left atrium into the left ventricle.
catheter tip may appear to be in the right atrium, its movement remains restricted and it can be advanced only in a cephalad direction into the superior vena cava unless turned inferiorly toward the right atrium at the azygous-superior vena cava junction.

Figure 3 illustrates the course of a catheter entering the right heart through a left-sided inferior vena cava. This may be confused with a catheter placed in the descending aorta unless the pressure tracing is examined. The left-sided inferior vena cava often drains into either the right or left side of what is frequently the common atrial chamber. A third anomaly of central venous drainage is illustrated in figure 4A and B. This figure depicts hemiazygous continuation of the inferior vena cava with passage of a catheter through the left superior vena cava and coronary sinus into the right atrium and right ventricle. Note that the catheter in the hemiazygous system is posterior in position (fig. 4B).

Figure 7

A catheter was advanced across an atrial septal defect into the left atrium and its tip wedged in a left lower lobe pulmonary vein. On the frontal projection (A), this catheter position is similar to a catheter placed in the left ventricle. Note, however, that on the lateral projection (B) the catheter tip is posterior in position and extends beyond the posterior heart border.

Figure 8

A) The catheter has been positioned in a right upper lobe pulmonary vein. B) Contrast opacification demonstrates anomalous drainage of this vessel into the right atrium. C) The catheter has been placed in an anomalous right upper lobe pulmonary vein which is seen, on opacification, to drain into the superior vena cava. Visualization of the vein with contrast material is essential to distinguish these catheter passages from a catheter passage across an atrial septal defect into a normally draining vein.

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In the pediatric age group, the left heart is commonly entered during venous catheterization. The atrial septum may be traversed through a patent foramen ovale or atrial septal defect. The presence of a patent foramen ovale rather than an atrial septal defect is suggested by a significant pressure difference across the atrial septum. Figure 5 (solid line) illustrates the passage of a catheter into the left atrium through a patent interatrial communication (foramen ovale).

In contrast to the superior interatrial catheter passage across the foramen ovale or secundum atrial septal defect, a catheter crossing the atrial septum more caudally is seen in patients with any form of endocardial cushion defect (fig. 5; dotted line). In the simplest form of this entity, the catheter passes across an ostium primum atrial septal defect. However, in more complete atrioventricular canal defects the catheter may be passed directly from the right atrium to the left ventricle.

Figure 6 demonstrates a catheter which has been further advanced across a secundum atrial septal defect into the left ventricle. The lateral projection

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**Figure 9**

This is the typical appearance of a catheter passed from the right atrium across the tricuspid valve into the right ventricle.

**Figure 10**

A catheter (solid lines) was passed from the right atrium through the right ventricle and directed to the right and posteriorly across a ventricular septal defect into the left ventricle and subsequently the ascending aorta. The catheter’s position was verified by the typical pulse contour. The passage of a catheter from the right ventricle across a ventricular septal defect into the left ventricle and ascending aorta may also be accomplished from the arm (dotted lines).
(fig. 6B) illustrates the passage of the catheter anteriorly across the mitral valve into the left ventricle. This position is confirmed by appropriate pressure recordings or contrast opacification. A similar catheter course in the frontal projection may be seen when the left lower pulmonary vein is catheterized (fig. 7). Although the pulmonary venous catheter may not be advanced beyond the cardiac silhouette on the AP projection, it is posterior to the heart border on the lateral projection. Furthermore, pressure tracings easily distinguish left ventricle from pulmonary vein.

When pulmonary veins are catheterized, assessment of their mode of drainage is most accurate when based on indicator dilution curves and/or contrast opacification. It is not possible to be as certain of the mode of drainage based on catheter course alone.

Right upper lobe pulmonary vein catheterization is shown in figure 8A. The course of the catheter through the heart to the right upper lobe pulmonary vein is similar to that seen in the catheterization of a normal right atrium. However, the catheter tip has been advanced beyond the cardiac silhouette revealing its extracardiac location. In figure 8B, the opacified vein is shown to drain directly into the right atrium indicating anomalous pulmonary venous return. Drainage of an anomalous vein into the

Figure 11
A catheter was passed from the right atrium and ventricle across an anteriorly placed aortic valve to the ascending aorta in this patient with D-transposition of the great vessels. Note that the catheter passes around a left-sided aortic arch and there is the characteristic long anterior sweep of the ascending aorta on the lateral projection (B).

Figure 12
A) This is the typical appearance of the catheter passage through the right heart (right atrium, right ventricle, and pulmonary artery) into the descending aorta via a patent ductus arteriosus. Note that the catheter has been passed below the diaphragm (arrow). B) The passage of a catheter into a left lower lobe pulmonary artery during right heart catheterization is illustrated. Although this position mimics the passage of a catheter through a patent ductus arteriosus into the descending aorta, the inability to advance the catheter below the diaphragm differentiates this situation.

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superior vena cava can lead to an identical catheterization and must be proven by contrast injection (fig. 8C). A similar catheter course may also be seen if the catheter has crossed the atrial septum and lies in a normally draining pulmonary vein. Again, contrast opacification of the vessel is necessary to evaluate the mode of drainage.

Passage of a catheter across the tricuspid valve to right ventricle is shown in figure 9. Note the anterior position of the catheter tip in the right ventricle on the lateral projection in figure 9B. This is indistinguishable by position alone from a catheter passage into the anterior aspect of a single ventricle.

The aorta may be entered from the right heart in

Figure 13
The catheter was passed into a posterior and medially placed pulmonary artery in a patient with L- or corrected transposition of the great vessels. The catheter has traversed the right atrium and morphologic left ventricle on its way to the pulmonary artery. On contrast opacification in the lateral projection (B), the catheter’s position in the main pulmonary artery is demonstrated.

Figure 14
A retrograde catheter was positioned around a normal left-sided aortic arch. The solid white line (B) demonstrates the long anterior sweep of a catheter in D-transposition of the great vessels. The dotted line in B shows the normal posterior location of the aorta on the lateral projection.
lateral view (fig. 10B). A similar passage into the aorta by a catheter introduced from the arm is illustrated by dotted lines. A venous catheter positioned in the aortic arch is shown in figure 11A. On the lateral projection of this illustration (fig. 11B), the aorta is noted to be anterior in position, establishing the diagnosis of D-transposition of the great vessels.

The aorta may also be catheterized from the main pulmonary artery through a patent ductus arteriosus (fig. 12A). In this case, the catheter was advanced below the diaphragm. Figure 12B illustrates a catheter position which resembles the latter placement; however, attempts to advance the catheter resulted in dampening of the arterial pressure tracing and wedging of the catheter tip into a left lower

some patients. Figure 10 illustrates access to the aorta when a saphenous vein catheter (solid lines) is passed across a ventricular septal defect from the right ventricle. The ascending aorta is seen to be in its normal position, medial to the pulmonary artery segment in the frontal projection (fig. 10A), and posterior on the

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**Figure 15**  
*The retrograde passage of the catheter around a right-sided aortic arch is shown.*

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**Figure 16**  
*The retrograde cannulation of the aorta from the arm has been accomplished in this patient with L-transposition of the great vessels. Note that the catheter has passed across a leftward positioned aortic valve. The catheter tip lies within the leftward placed morphologic right ventricle.*

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**Figure 17**  
*A) The retrograde arterial cannulation of a patient with type I tricus arteriosus and a right aortic arch has been accomplished. The catheter has passed into the pulmonary trunk and right lower lobe pulmonary artery. B) Retrograde catheterization of a patient with type I tricus arteriosus in which the catheter could be advanced further across the tricuspid valve into the right ventricle and subsequently across the tricuspid valve into the right airtum.*

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lobe pulmonary artery. In the absence of lateral fluoroscopic views, the passage of the catheter below the diaphragm is the quickest means of verifying its aortic position.

A further example of abnormal great vessel position is shown in figure 13A. Contrast opacification viewed in the lateral projection (fig. 13B) demonstrates that the catheter tip is in a pulmonary artery. However, the catheter is medial and posterior to the normal position, indicating L-transposition of the great vessels.

**Retrograde Arterial Catheterization**

Arterial cannulation may be achieved from the femoral, umbilical or brachial arteries. Retrograde arterial catheterization from the umbilical vessels is easily identified since the catheter proceeds inferiorly from the umbilical artery before entering the descending aorta through the iliac vessels. Often the catheter can be manipulated around the aortic arch. Figure 14 illustrates a catheter placed around a normal left-sided aortic arch (dotted lines). Note the posterior position of the catheter on the lateral projection, figure 14B. The AP catheter position in D-transposition is similar, but the lateral projection demonstrates the long anterior sweep of the transposed aortic arch (fig. 14B, solid line). Figure 15 illustrates retrograde catheterization of a right-sided aortic arch. In L-transposition, the leftward position of the catheter in the proximal aorta in the frontal view (at the left heart border) is diagnostic (fig. 16). A retrograde catheter may enter the pulmonary artery from the descending aorta through a patent ductus arteriosus. In this situation the catheter passage may be differentiated from catheterization of the aortic arch by its more caudal sweep in the lateral view.

Finally, complex retrograde arterial catheter passes may be accomplished from the ascending aorta in patients with coronary arterio-venous fistulas, aortic-pulmonary windows, and truncus arteriosus. In the case of type I truncus arteriosus shown in figure 17, the catheter could be manipulated into the main pulmonary segment and right pulmonary artery (fig. 17A) and from the truncal valve into the right ventricle and further retrograde into the right atrium (fig. 17B).

**Discussion**

A variety of usual and unusual venous and arterial catheter positions have been shown. It is clear that important information concerning the alterations in cardiovascular anatomy that accompany congenital heart lesions may be derived from catheter position alone, although additional data such as hemodynamic determinations, oxygen saturation measurements, indicator-dilution data, and angiography may be required to formulate a complete diagnosis. The use of biplane fluoroscopy and knowledge of catheter position in congenital heart disease contribute to an orderly sequence of maneuvers during cardiac catheterization, reduce the quantity of angiographic contrast material used in the study, and shorten the total procedure time. All of these factors are important in reducing the risk of cardiac catheterization, especially in critically ill infants and children.

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