CONGENITAL CARDIAC DEFECTS are a major cause of death in the newborn. Fifteen to 20% of infants born with congenital heart disease succumb in the first week of life, to a period when clinical diagnosis is most difficult. Although prognosis is poor, some of these severely distressed infants can be saved if early diagnosis is followed by prompt palliative or curative operation.

Lambert and associates and Rowe have emphasized the necessity of early cardiac catheterization and angiography in the diagnosis of these distressed newborns with congenital heart lesions. Sapin and associates, in 1963, reported the advantages of selective angiography and retrograde aortography using the umbilical vessels in 10 infants with congenital heart disease. These authors suggested that umbilical vessel catheterization and angiography may be an effective and safe diagnostic procedure in the first week of life.

The present study is a further evaluation of this diagnostic technique in a group of 50 infants. With this larger group, more definitive statements can be made regarding the methods, effectiveness, advantages, limitations, and complications of this procedure.

Methods

Cardiac catheterization and angiography, using the umbilical vessels, were attempted in 50 newborn infants. The infants ranged in age from 10 hours to 10 days with a mean of 3.2 days. Their weights ranged from 2,145 to 4,372 g. All of the infants were in poor to critical condition at the time of the procedure.

Indications for study were cyanosis in 23, congestive heart failure in five, and both cyanosis and congestive heart failure in 21. One infant was studied to rule out a vascular ring.

Umbilical Artery Catheterization

Without premedication or anesthesia, the umbilical stump and surrounding abdominal area is cleaned with hexachlorophene and benzalkonium chloride. The area is then draped, and two 000 chromic stay sutures are inserted opposite each other into the edge of the umbilicus for traction during manipulation and for hemostasis. The umbilical cord is then transected just at or above the skin line and the umbilical vessels are identified. The umbilical arteries are next gently probed with fine forceps to exactly delineate the vessel lumina to minimize the possibility of creating a "false passage" during introduction of the catheter. Visible intraluminal blood clots are removed.

A 5F 15-inch-polyvinyl premature feeding tube with a radiopaque liner is attached to a three-way stopcock and is filled with 0.5 N saline. The catheter is then introduced into one of the umbilical arteries and gently advanced until resistance is encountered. This initial resistance is usually overcome by persistent gentle probing in a caudad direction. The catheter is then advanced until easy flow of arterial blood is obtained by suction. The initial blood aspirated may contain a small clot from the tip of the catheter and this is discarded. After flushing, the tube is directed caudally into the internal iliac artery and then cephalad into the abdominal aorta.

A pressure transducer is attached to one of the outlets of the three-way stopcock while the other outlet is used for flushing and withdrawal of blood samples for oximetry.

The catheter can then be guided under fluoroscopic control into the ascending aorta and into the left ventricle. The catheter may also pass through a patent ductus arteriosus into the pulmonary artery and right ventricle. With experience, the soft catheter can frequently be manipulated with continuous pressure monitoring.
without the use of fluoroscopy. Passage of one catheter through a patent ductus arteriosus or into the ascending aorta instead of the neck vessels is often facilitated by passing a second catheter through the other umbilical artery into the aortic arch.

Oxygen saturations, pressures, levocardiograms, and ascending aortograms are obtained exactly as in routine retrograde left-sided catheterizations. Contrast material (Renografin* 1 cc/kg) is injected manually for the angiographic studies.

**Umbilical Vein Catheterization**

If the diagnosis is still incomplete or if further right-sided information is desired, an umbilical vein catheterization is performed. An 8F 15-inch polyvinyl infant feeding tube is inserted into the umbilical vein and the catheter is then filled with radiopaque contrast material. Under fluoroscopic control, the catheter is directed cephalad toward the liver and is often passed from the umbilical vein through the ductus venosus into the inferior vena cava and the heart. Occasionally, the catheter enters the portal sinus and the portal vein or one of the hepatic branches of the umbilical vein. The catheter is then drawn into the umbilical vein, rotated, and manipulated in order to traverse the ductus venosus. If this is still unsuccessful, a test dose of contrast material is injected with the catheter tip in the umbilical vein to ascertain the patency of the ductus venosus. The use of a more rigid catheter such as a Lehman or NIH cardiac catheter may facilitate passage through the ductus venosus.

Right-sided pressures, oxygen saturations, and angiocardiograms are then obtained. The catheter may be passed from the right atrium through a patent foramen ovale into the left atrium for left-sided studies. Following the procedure, the catheters are removed and hemostasis is obtained by placing a purse-string suture around the umbilical vessels.

**Results**

Umbilical artery catheterization was attempted in 44 of the 50 infants. The catheter was passed from the umbilical artery into the aortic arch in 41 instances (93%) (table 1). From there the catheter was passed into the ascending aorta in 27 infants. Of 14 in whom the catheter could not be passed from the aortic arch into the ascending aorta, seven had either severe coarctation of the aorta or hypoplastic ascending aorta, while two others had isolated large patent ductus arteriosus.

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with pulmonary hypertension and the catheter preferentially passed from the aorta through the ductus arteriosus into the pulmonary artery and right ventricle. Once the catheter was in the ascending aorta, it was passed through the aortic valve into a ventricle in 20 of 23 attempts. The catheter was passed through a patent ductus arteriosus in eight subjects and in five of these into the right ventricle.

Umbilical vein catheterization was attempted in 41 patients and the catheter was successfully passed into the heart in 23 (table 1). The failures were invariably due to inability to pass the catheter through the ductus venosus.

Angiocardiograms were obtained in 49 of the total group of 50 patients. Injection sites are listed in table 2. Injection into the umbilical vein alone was performed in four patients, but angiocardiograms obtained in this manner are rarely successful and the method is no longer used.

In addition, pressures and oxygen saturations were determined in 25 of the last 26 patients studied. There were no deaths attributed directly to the catheterization or angiocardiographic procedures.

The correct diagnosis was obtained in 37 of the 50 patients (74%) (table 3). On five of the 13 infants who had the nondiagnostic umbilical vessel studies, diagnostic saphenous vein catheterizations were performed immediately afterward; one infant was restudied 2 days later and another 5 weeks later. Two infants had an incomplete diagnosis but, because no major lesion was found, both were treated medically and are now doing well. The remaining four infants subsequently died and postmortem examination revealed inoperable complex cardiac anomalies.

On the basis of the umbilical vessel catheterization and clinical findings, 18 patients were treated medically of whom 10 have died. Of the remaining 19 patients, all of whom were operated on, 13 have died. Of the six surgical survivors who were greatly helped and are alive at present, four have complete transposition of the great vessels with surgically created atrial septal defects, one had resection of a vascular ring, and one had a patent ductus arteriosus ligated.

Autopsy was performed after 22 of the 23 deaths and in each case the presence of the major cardiac defects diagnosed at cardiac catheterization was confirmed.

**Discussion**

Catheterization of the umbilical vein for exchange transfusions in newborn infants

### Table 2

*Sites of Injection for Angiocardiography*

<table>
<thead>
<tr>
<th>Site of Injection</th>
<th>UA cath</th>
<th>UV cath</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aortic arch</td>
<td>8</td>
<td></td>
<td>8</td>
</tr>
<tr>
<td>Ascending aorta</td>
<td>21</td>
<td></td>
<td>21</td>
</tr>
<tr>
<td>Anterior or single ventricle</td>
<td>16</td>
<td>9</td>
<td>25</td>
</tr>
<tr>
<td>Posterior ventricle</td>
<td>8</td>
<td>3</td>
<td>11</td>
</tr>
<tr>
<td>Main pulmonary artery</td>
<td>6</td>
<td></td>
<td>6</td>
</tr>
<tr>
<td>Right atrium</td>
<td>10</td>
<td></td>
<td>10</td>
</tr>
<tr>
<td>Left atrium</td>
<td>8</td>
<td></td>
<td>8</td>
</tr>
<tr>
<td>Umbilical vein</td>
<td>5</td>
<td></td>
<td>5</td>
</tr>
</tbody>
</table>

Abbreviations: UA = Umbilical artery catheter and UV = umbilical vein catheter.

### Table 3

*Diagnoses from Successful Umbilical Vessel Catheterizations*

<table>
<thead>
<tr>
<th>Malformation</th>
<th>No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Multiple major cardiac defects</td>
<td>11</td>
</tr>
<tr>
<td>Complete transposition of great vessels</td>
<td>10</td>
</tr>
<tr>
<td>Hypoplastic left heart</td>
<td>6</td>
</tr>
<tr>
<td>Tetralogy of Fallot</td>
<td>3</td>
</tr>
<tr>
<td>Isolated patent ductus arteriosus</td>
<td>11</td>
</tr>
<tr>
<td>Truncus arteriosus</td>
<td>1</td>
</tr>
<tr>
<td>Pulmonary atresia</td>
<td>1</td>
</tr>
<tr>
<td>Vascular ring</td>
<td>1</td>
</tr>
<tr>
<td>Ventricular septal defect</td>
<td>1</td>
</tr>
</tbody>
</table>

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with erythroblastosis was first reported by Diamond and associates in 1946. In 1961, Rudolph and Hirvonen and their associates used the umbilical vein in hemodynamic and angiocardiographic studies in newborn infants without heart disease. James also cannulated the umbilical artery in the delivery room and passed the catheter into the iliac artery. In 1963, Sapin and co-workers, using both the umbilical vein and artery, reported angiocardiographic findings in 10 infants with congenital heart disease. More recently, Emmanuelides and Rein used the umbilical artery approach to obtain abdominal aortograms in a newborn with renal mass and cerebral arteriograms in a newborn with a cerebral lesion (personal communication from G. C. Emmanuelides).

Rowe and Selzer and associates have reviewed the problems and hazards of cardiac catheterization in the newborn. The use of the umbilical vessel approach in experienced hands offers many advantages over the use of the brachial and femoral vessels.

Lack of complications in umbilical vein catheterization has been attested to by the thousands of exchange transfusions that have been performed, the historical references cited herein, and the present study. Umbilical artery catheterization has also been a safe procedure in experienced hands in premature as well as full-term infants even without the use of fluoroscopy.

There were no major complications or morbidity from the catheterization procedure itself in our series. Post-catheterization infection of the umbilical stump did not occur. Portal vein thrombosis and arterial spasm or thrombosis have been reported, but neither was observed in our series. Bleeding when the catheters were removed during, or at the termination of, the procedure was easily controlled by traction on the stay sutures or by external pressure on the umbilical vein or artery.

The danger of arrhythmias and the risks of angiocardiography in hypoxic infants are still present. Injection by hand of contrast material through these soft side-hole catheters has resulted in satisfactory angiocardiograms.

There are several advantages to the umbilical approach. No premedication or local anesthesia is required. The method is fast and simple, and time-consuming cutdown and dissection are not required. The vessels are large and easy to cannulate and following the procedure can be tied off without any ill effects. Two umbilical arteries are usually available. If an indwelling intravenous catheter is necessary following the procedure, the umbilical vein can be used.

Of special significance is the decrease in morbidity following umbilical artery catheterization compared to retrograde studies by direct dissection of an artery. The umbilical artery can be safely ligated at the end of the procedure. The problem of thrombosis due to intimal trauma is also eliminated. The use of a soft polyvinyl catheter precludes puncture of the left ventricle or an artery. Radiation exposure is materially reduced as the soft arterial catheter can often be directed by continuous pressure monitoring without the use of fluoroscopy.

The age of limitation for the umbilical artery procedure was not defined in our study. It was successful in the oldest infant (8 days) in which it was attempted. From an umbilical vein approach, the catheter was passed through the ductus venosus into the heart in 64% of the infants under 6 days of age; the ductus venosus, however, could not be traversed in the small number of patients beyond that age. Although the diagnosis of most of the serious cardiac anomalies which produce difficulty in the first week of life can be made by adequate left-sided studies alone, the saphenous vein can still be used after unsuccessful attempts with umbilical vein catheterization when further studies are necessary. This was done in 14% of our patients.

The umbilical vessel approach has been an effective diagnostic procedure. The correct diagnosis was obtained in 74% of the infants. Another 12% were diagnosed combining the findings of umbilical artery and saphenous vein studies.
The value of the umbilical artery approach deserves special mention. Vlad and associates advocate retrograde arterial catheterizations for left-sided studies and described their findings in a large series of patients. The morbidity in our series is less than that of the femoral or brachial artery approach with no loss of diagnostic accuracy. With experience, the ascending aorta and a nonobstructed ventricle can almost always be entered, as evidenced by the fact that the aorta was entered in 25 of the last 26 attempts. Finally most cardiac diagnoses in the first week of life can be obtained by retrograde left-sided studies alone.

Summary

Cardiac catheterization and angiocardiology through the umbilical artery and vein were performed in the first 10 days of life on 50 infants with serious congenital heart lesions. This procedure has been diagnostically effective and presents minimal risk to the critically ill newborn. The methods, effectiveness, advantages, limitations, and complications of this procedure are discussed.

References


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