Thrombo-Embolic Complications of Ventriculo-Atrial Shunts
Angiocardiographic and Pathologic Correlations*

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There have been several recent reports outlining the numerous complications of the Spitz-Holter or Pudenz-Heyer ventriculo-atrial shunt procedure for hydrocephalus. Notable among these is the necropsy-based report of Emery and Hilton, on the cardiac and pulmonary complications in 15 patients. All but 1 of their patients had multiple pulmonary emboli; 5 cases had thrombosis around the distal end of the catheter, 6 had thrombus formation on the wall of the right atrium (partly occluding the tricuspid valve in 2 cases), and 2 had massive pulmonary thrombosis. Similar complications have been noted by others.

After finding a large, unsuspected intracardiac thrombus on the atrial end of the shunt tubing at the autopsy on one of our patients, we felt that angiocardiology would be of value in identifying similar thrombi in patients treated with the Spitz-Holter valve. This paper is the report of the results of angiocardiology performed on 11 children, 10 asymptomatic, of a series of 26 with hydrocephalus. Seven of the 26, including 2 evaluated by angiocardiology, were studied at necropsy. These combined studies uncovered thrombo-embolic lesions in 11 children (42 per cent).

Angiocardiological Evaluation—Clinical Material

Of the 11 children studied by angiocardiology, 6 had myelomeningocele, 1 had a meningocele, and two had communicating hydrocephalus of undetermined etiology; in 1 the process followed bilateral subdural hematoma, and 1 was associated with an encephalocele. The Holter valve shunt tube had been in place for periods of time ranging from 4 to 28 months. The 1 patient with symptoms prior to study had clinical evidence of intermittent obstruction of the tricuspid valve. The other patients were studied in the course of their readmission to the hospital for the evaluation of an enlarging head, or because on palpation the valve did not appear to be working properly, or for revision of a distal catheter which was too high in the superior vena cava as visualized by the chest x-ray. Three asymptomatic patients were called in for the sole purpose of doing the angiocardiogram.

Angiocardiological Evaluation—Results

The angiocardiological data is summarized in Table 1.

Superior Vena Cava Obstruction (2 patients). In one this was complete and in the other partial. Each had developed marked venous collaterals (Fig. 1).

Thrombi in the Superior Vena Cava (4 patients). In 1 of these a laminated thrombus 5 cm. long was present in the superior vena cava (Figs. 2 and 3).

Thrombi in the Right Atrium (2 patients). In one a long pendulous thrombus could be visualized on the angiocardiogram swinging in and out of the tricuspid valve orifice. This patient had symptoms of intermittent pulmonary blood flow obstruction, i.e., tetrad spells (Fig. 4).

<table>
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<th>TABLE 1</th>
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<td>Lesions visualized in 11 angiocardiograms on 11 patients</td>
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<table>
<thead>
<tr>
<th>Number of patients with lesions</th>
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<tr>
<td>Superior vena cava obstruction</td>
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<td>Thrombi in superior vena cava</td>
<td>4</td>
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<td>Thrombi in right atrium</td>
<td>2</td>
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<td>Thrombi in lung fields</td>
<td>2</td>
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<td>Evidence of pulmonary hypertension</td>
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Fig. 1. Angiocardiogram following injection into right median basilic vein. The superior vena cava (SVC) is completely obstructed (arrow). Collateral flow is via vertebral veins and the azygous vein (AZ).

Thrombi in the Lung Fields (2 patients). One child had marked pulmonary hypertension (70/44 mm. Hg), an enlarged pulmonary artery and the typical “pruned tree” appearance of pulmonary hypertension (Fig. 5). This child currently has intractable right heart failure. Another patient showed no contrast filling of the right lower pulmonary artery indicating occlusion of this vessel. (Fig. 6). Pulmonary artery pressures were normal in 6 other patients.

The patient with intermittent obstruction of the tricuspid valve due to the atrial thrombus underwent cardiotomy with removal of the thrombus. This stopped the attacks, but the patient subsequently died from unrelated complications.

Thoracotomy was also performed on a patient with a superior vena cava thrombus. This proved to be a sessile clot 2.0x0.8 cm. rather firmly attached to the wall of the vessel.

Autopsy Examination

Postmortem examination was performed on 7 children who had had a Holter valve in place for periods of time ranging from 16 days to 9 months. All of these patients had myelomeningoceles and all but 1 had an exposed neural plate (rachischisis).

Two of these cases had angiocardiograms performed prior to death. The roentgen findings were confirmed in one. In the other patient, a 6 mm. filling defect in the superior vena cava was not identified at postmortem examination. However, there was a scarred area in the vena cava where the filling defect

Fig. 2. Brachial angiocardiogram reveals laminations throughout the extent of the superior vena cava (arrows). RA = right atrium. PT = pulmonary trunk.

Fig. 3. Sessile clot in upper superior vena cava (SVC) partially occluding this vessel. PT = pulmonary trunk.
FIG. 4. Selective right atriograms. The arrows identify a large pedunculated thrombus in the right atrium (RA) changing its position during atrial systole (A) and atrial diastole (B). RV = right ventricle and PT = pulmonary trunk.

FIG. 5. Selective right atriogram in a patient with pulmonary hypertension (mean pulmonary artery pressure 54 mm. Hg). The main pulmonary artery and its proximal branches are enlarged. The paucity of contrast media in the peripheral pulmonary vessels produces the “pruned tree” effect characteristic of pulmonary hypertension.
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Fig. 6. Selective right atriogram. A: Pulmonary arterial phase. The pulmonary trunk (PT) and major pulmonary arteries are filled with contrast media. Note the absence of opacification of the right lower lobe vessels indicating vascular obstruction. B: Pulmonary venous phase. The pulmonary veins and left atrium (LA) are now opacified. The right lower lobe remains unopacified.

had been visualized. Histological examination of this region disclosed thickening of the vascular wall with hemosiderin deposits, hemorrhage and an acute inflammatory response outside the wall.

In general the autopsy findings disclosed lesions in three areas; namely around the distal tube, in the heart, and in the lungs.

Involvement of Distal Tube. Three patients had occlusion of the superior vena cava; 1 complete, 2 incomplete. One of the latter cases had had the tube in place 32 days and there was already a thick, fibrinous, translucent sheath surrounding the catheter and independent of the superior vena cava obstruction. Two other cases showed only thickening of the superior vena cava and the inflammatory changes described above. In 2 patients there were no changes around the tube in the superior vena cava, but in these instances the Holter valve had been in place only 16 and 22 days respectively.

Cardiac Involvement. Three patients had a rather large thrombus in the right atrium. In 1 of these 3 the clot extended into the tricuspid valve and produced antemortem symptoms of intermittent obstruction of this valve (Fig. 7). The other 2 with large clots had had the Holter valve inserted only 16 and 22 days prior to death. A 4th patient had had a large thrombus in the right atrium removed surgically. The remaining 3 patients had no cardiac involvement.

Pulmonary Involvement. The most consistent pathological changes occurred in the lungs. Pulmonary alterations were noted in all 7 patients. Five had multiple small vessel thrombo-emboli in various stages of organization (Fig. 8). In 1 of these there was a large embolus in the right pulmonary artery in addition to the small vessel emboli (Fig. 9). Five had areas of acute or

Fig. 7. Pedunculated clot (arrows) attached to the wall of the superior vena cava (S) at its junction with the azygos vein (AZ) and hanging down into the right atrium to the level of the tricuspid valve (TV). This clot produced antemortem symptoms of intermittent obstruction of the tricuspid valve.
FIG. 8. Two photomicrographs from different patients showing pulmonary micro-thrombo-emboli in different stages of organization. Both hematoxylin and eosin. Upper: X300, lower: X440.
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Fig. 9. This autopsy specimen shows a sessile clot (dark arrow) in the lower superior vena cava (SVC), multiple recent emboli in pulmonary arteries (white arrows), and a lung abscess in the apex. There were numerous ante mortem emboli throughout both lung fields.

chronic inflammatory changes including 2 with lung abscesses and 1 with interstitial pneumonia. A 6th patient had diffuse periarteritis, and the 7th had medial hypertrophy of the pulmonary arterioles as may be seen with pulmonary hypertension.

Discussion

Important among the recognized complications related to the use of the ventriculo-atrial shunt are:

1. Perforation of the cardiac muscle by the distal end of the tube
2. Embolic behavior of a detached distal end of the tube
3. Occlusion of either the proximal or distal end of the shunt apparatus
4. Bacterial endocarditis
5. Thrombosis of the superior vena cava or thrombus formation within the right auricle
6. Pulmonary embolization with or without pulmonary hypertension
7. Infection in the form of meningitis or septicemia

Past experience with foreign bodies chron-
ically implanted in the cardiovascular system indicates that thrombo-embolic phenomena may occur and create a serious problem.\textsuperscript{12,14} It also appears that chronic trauma, such as might occur in the superior vena cava or right atrium from the shunt tube, may afford a nidus for the implantation of bacteria and the development of thrombus formation.

Although not all reported cases of thrombo-embolic complications have been definitely related to infection, we feel that the presence of infection, and septicemia in particular, is a major factor in the development of the last 4 complications listed above. Five of our 7 autopsied cases, all with myelomeningoceles, had proven septicemia prior to death and the other 2 had pulmonary abscesses at the time of the autopsy. One case of pulmonary abscess did not have a blood culture and in the other only one negative blood culture was obtained. This patient had a myelomeningocele infected with a coagulase positive Staphylococcus aureus organism. In the presence of septicemia, 1 of our patients developed a large atrial mural thrombus only 16 days after the shunt operation was performed.

Of the 6 children with thrombi defined by angiocardiography, 3 had proven septicemia. A 4th had a leaking and infected myelomeningocele subsequent to insertion of the Holter valve shunt. Two others, without septicemia, had thrombi limited to the superior vena cava.

In the series presented by Anderson,\textsuperscript{1} autopsy was obtained in 5 of the 7 children who died with septicemia. All cases had a foreign-body reaction to the intracardiac tube, 3 had auricular mural thrombi, and in 3 the intra-auricular portion of the tube was encased in a fibrous sleeve of variable consistency.

Septicemia was present in 2 of the 3 cases with pulmonary thrombo-emboli reported by Noonan and Ehinke.\textsuperscript{13} One of the 2 also had endocardial and tricuspid valve vegetations.

Although clinical data were not reported, of the 15 autopsy cases with heart and lung complications studied by Emery and Hilton,\textsuperscript{7} at least 7 had evidence of septic emboli.

Three of the 4 cases of thrombo-embolic complications of the Holter valve shunt presented by Talner \textit{et al.}\textsuperscript{18} had infections of various forms: an infected myelomeningocele with the shunt in place; meningitis and septicemia; and an infected myelomeningocele with meningitis and septic emboli.

In a series of 60 valves inserted by McNab,\textsuperscript{11} 8 patients died as a result of a septic clot formation in the superior vena cava or heart.

However, pulmonary embolization can occur in unshunted hydrocephalic patients and without apparent infection. The recent excellent review of the pulmonary vascular changes complicating ventriculovascular shunting for hydrocephalus by Friedman \textit{et al.},\textsuperscript{8} based on 65 autopsies, indicates that 4 of 17 “control” patients (hydrocephalus without ventriculo-atrial shunt) had pulmonary thrombi considered to be present ante mortem. In contrast, 37 (58 per cent) of the patients in whom a shunt had been performed, had pulmonary vascular lesions. Most of the lesions they classified as “recent” were found in children dying within a week of surgery, whereas the “old” lesions were usually found in the patient living a month or more after surgery. They noted a tendency for patients in the shunted group to have bronchopneumonia and meningitis together rather than either type of infection alone; septic pulmonary infarction was found only in patients with previous shunting procedures. The presence of infection did not appear to influence the incidence of the vascular lesions.

Bruce \textit{et al.},\textsuperscript{2} could find no difference in the incidence of bacteremia in cases of hydrocephalus, with or without spina bifida cystica. Their findings in 19 cases of septicemia (6.3 per cent of the total) is contrary to our more limited experience described below.

It is now well recognized that “non-pathogenic” bacteria can be the infecting organism in the bacteremia and/or septicemia associated with the ventriculo-atrial shunt. Organisms of this type so far reported include: \textit{Staphylococcus albus}, \textit{Corynebacterium sp.}, \textit{Serratia marcescens}, and \textit{Bacillus subtilis}.\textsuperscript{2} Three of our patients developed a \textit{Staphylococcus albus} septicemia; other organisms causing septicemia in our series were: \textit{Corynebacterium sp.}, \textit{Alkaligenes Fecalis}, \textit{Streptococcus Fecalis}, \textit{Pseudomonas}
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*Staphylococcus aureus.* It was not unusual to isolate different organisms at different times.

In our series of 11 thrombo-embolic complications, 8 had proven sepsis. We feel that it may be significant that all of these infections occurred in children with myelomeningoceles, usually with an exposed neural plate and usually operated upon after the sac had had an opportunity to become infected. This was generally the result of tardy referral to our center. Without debating the merits of operating or not operating on these cases, we feel that if the neurosurgeon does decide to operate under these circumstances, he should expect a high incidence of infection, septicemia, and thrombo-embolic phenomena.

To help prevent the establishment of infection in the primary lesion, it is our policy to operate upon the surgically resectable myelomeningocele as soon after birth as possible. Culture of the myelomeningocele sac contents is obtained after the skin has been cleaned and prepared immediately prior to surgery.

Blood cultures should be obtained periodically and certainly where infection is suspected. The septicemia may be of low grade and the symptoms subtle. Fever, anemia, splenomegaly, and failure to thrive are indications of infection. It may be helpful to pump the valve just prior to obtaining the blood culture. The ventricular fluid as well as the heart blood should be cultured when the shunt is revised. Once septicemia is diagnosed, the appropriate antibiotics should be given in full dosage and the shunt apparatus removed as a complicating foreign body. The question of the long-term prophylactic use of antibiotics and anticoagulation is naturally controversial and there is little available experience to help answer the question.

The thrombo-embolic complications produced symptoms in 8 of our patients. Two had tetrad attacks (episodes of cyanosis and respiratory distress) due to intermittent obstruction of the tricuspid valve and 1 had right sided heart failure as the result of pulmonary hypertension. Clinical evidence of pulmonary hypertension includes accentuation of the pulmonary 2nd heart sound in the 2nd left interspace, the development of an early systolic-ejection-click, and the murmur of pulmonary or tricuspid insufficiency. Periodic chest roentgenograms may reveal evidence of right ventricular hypertrophy, enlargement of the pulmonary artery and alterations in the pulmonary vasculature. The electrocardiogram may also show the pattern of right ventricular hypertrophy.

However, the cardio-pulmonary involvement may be extensive, with no clinical evidence of the abnormality. Angiocardiography is therefore the single most important measure in identifying the presence or absence of thrombo-embolic lesions. Of the 6 children with lesions demonstrated angiographically, only 1 had symptoms at the time of the study. Therefore, we now obtain angiocardiograms on any patient in whom a shunt has been performed if he has evidence of sepsis or is otherwise not doing well. We also do this study routinely prior to revision of the shunt or on the operating table at the time of the revision. The importance of angiocardiography in the continuing evaluation of these patients provides an important argument for the management of this clinical problem in a medical center where the necessary ancillary facilities are available.

**Summary**

Eleven patients treated with the Spitz-Holter ventriculo-atrial shunt for hydrocephalus had angiocardiograms which demonstrated superior vena cava obstruction, thrombi in the superior vena cava, large thrombus formation in the right auricle, or evidence of pulmonary embolization. All but 1 of these patients were asymptomatic at the time of the study.

Autopsy examination of 7 hydrocephalic children with shunts (2 previously examined angiographically) revealed lesions in the superior vena cava in 3, large thrombi in the right atrium in 3, and multiple small pulmonary thrombo-emboli in 5 cases.

We have discussed these cardio-pulmonary complications and emphasized the role of infection and septicemia in their genesis and the value of angiocardiography in their long-term management.
References