Factors Related to Pleural Effusions After Fontan Procedure in the Era of Fenestration

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Background—Significant pleural effusions after the Fontan operation prolong hospital stay, may increase the risk of infection, and may necessitate a pleurodesis procedure.

Methods and Results—From February 1991 to April 2000, 98 consecutive patients under the age of 18 years underwent the fenestrated Fontan procedure at Children’s Hospital of Wisconsin. Ninety-four patients who survived at least 30 days after surgery were retrospectively evaluated for the following factors: age, ventricular morphology (right single ventricle, left single ventricle [RV/LV]), fenestration open (FO) or closed (FC) at end of operation, intracardiac Fontan (IF) or extracardiac Fontan (EF), days with chest tube output per day >5, 10, and/or 20 mL · kg−1 · d−1 (CTO5, CTO10, and CTO20, respectively), need for pleurodesis, length of hospital stay (LOS), operation during winter respiratory viral season of November through March (ReVS+, ReVS−), and pre-Fontan mean pulmonary artery pressure (PAP) and pulmonary vascular resistance (PVR). In univariate analysis, the ReVS+ patients had prolonged LOS, greater chest tube output, and more pleurodesis (P<0.05), and PAP was related to CTO5 and CTO10 but not to CTO20 or LOS. No significant differences were found in LOS, CTO5, CTO10, CTO20, and need for pleurodesis between patients in RV/LV, FO/FC, IF/EF, or PVR groups. Patients <4 years of age had more instances of CTO20 (P<0.05). When we used ordinary least squares regression analysis with age, FO or FC, RV or LV, PAP, and ReVS+ or ReVS− to predict each of CTO5, CTO10, CTO20, and LOS, only ReVS+ or ReVS− and age were statistically significant in all models.

Conclusions—Use of the Fontan procedure during the respiratory viral season appeared to be related to significant, prolonged pleural effusions and longer hospitalizations. (Circulation. 2001;104[suppl I]:I-148-I-151.)

Key Words: Fontan procedure ♦ heart defects, congenital ♦ risk factors ♦ viruses

The addition of a fenestration to allow right to left shunting after the Fontan operation has been shown to decrease the morbidity and mortality associated with this procedure.1–3 Despite the improvement in operative survival, morbidity associated with the Fontan operation remains significant. One of the contributors to morbidity is postoperative pleural effusion and the concomitant sequelae. Pleural effusions after the Fontan procedure prolong hospital stay, increase the risk of infection, and may necessitate a pleurodesis procedure.3–5 Previous investigators have implicated elevated central venous pressure, thoracic duct injury, absence of a fenestration, postpericardiectomy syndrome, and significant aortopulmonary collaterals as causes of these prolonged pleural effusions.3–6 The purpose of the present study was to evaluate factors related to clinically significant, prolonged pleural effusions after the Fontan procedure in the era of fenestration at Children’s Hospital of Wisconsin (from February 1991 to April 2000). The factors evaluated were age at operation; ventricular morphology, right or left single ventricle (RV, LV); fenestration left open (FO) or closed (FC) at end of operation; intracardiac (IF) or extracardiac (EF) Fontan; number of days with chest tube output >5, 10, or 20 mL · kg−1 · d−1 (CTO5, CTO10, and CTO20, respectively); need for pleurodesis (P+, P−); length of hospital stay (LOS); time of year of operation; preoperative cardiac catheterization data; and postoperative central venous pressure (CVP). The time of year of operation was defined as either during the winter respiratory viral season in Wisconsin (November through March; ReVS+) or not (ReVS−). The most common viruses detected during the winter respiratory viral season are influenza A and B; RSV A and B; parainfluenza 1, 2, and 3; rhinovirus; and adenovirus. Preoperative cardiac catheterization data included pulmonary artery pressure (PAP) greater than or less than the group’s mean of 12 mm Hg and pulmonary vascular resistance (PVR) greater than or less than 2 Wood units.

Patient Population
The patient population included a total of 98 patients; 94 (96%) survived at least 30 days after surgery, and 91 (93%) survived to hospital discharge. Anatomic diagnosis of the patients is shown in Table 1. Eight patients had heterotaxy syndrome.
Table 2 shows continuous variables of the 94 patients, including the mean, SD, and range. Mean age at operation was 4.3 years, and mean weight was 15.3 kg. Mean LOS was 18.2 days, with a range of 5 to 78 days. The total days of chest tube output was a mean of 13.8 days, with the largest percentage of Fontan operations performed during the winter respiratory virus season; 17% of the patients required a pleurodesis between patients in relation to ventricular morphology, FO or FC, IF or EF (Table 5), preoperative PAP was significantly statistically related to longer LOS (P = 0.001) and greater CTO5 (P < 0.001), CTO10 (P = 0.001), and CTO20 (P = 0.003). No statistically significant differences were found in LOS, chest tube drainage, or need for pleurodesis between patients in relation to their age or preoperative mixed venous oxygen saturation, aortic oxygen saturation, PAP within the Glenn circuit, transpulmonary gradient, or PVR.

Age < 4 or ≥ 4 years was only related to CTO20 (P = 0.034); younger patients had more CTO20. Importantly, age was not statistically significantly related to the timing of the Fontan operation during the winter respiratory viral season. Age of patients undergoing the procedure during ReVS+ was 4.5 years, whereas age during ReVS− was 4.2 years.

### Results

In univariate analysis, statistically significant differences were found in LOS, CTO5, CTO10, CTO20, and P+/P− between patients in the ReVS+ and ReVS− groups (P < 0.05). As seen in the Figure, ReVS+ patients had greater CTO5 (11.8 ± 9.5 versus 8.3 ± 4.9 days; P = 0.024), greater CTO10 (10.1 ± 9.3 versus 6.2 ± 4.0 days; P = 0.007), greater CTO20 (7.6 ± 8.4 versus 4.1 ± 3.5 days; P = 0.006), and prolonged LOS (22.5 ± 17.3 versus 16 ± 11 days; P = 0.03) and required more pleurodesis procedures (9 versus 6; P = 0.018) than ReVS− patients.

Preoperative PAP was significantly statistically related to CTO5 (P = 0.036) and approached significance in relation to CTO10 (P = 0.056) but not to CTO20 or LOS. Postoperative CVP was significantly statistically related to longer LOS (P = 0.001) and greater CTO5 (P < 0.001), CTO10 (P = 0.001), and CTO20 (P = 0.003). No statistically significant differences were found in LOS, chest tube drainage, or need for pleurodesis between patients in relation to ventricular morphology, FO or FC, IF or EF (Table 5), preoperative PAP greater than the mean of 12 mm Hg, or preoperative PVR > 2 Wood units (Table 6).

The status of the fenestration at the end of the operation was at the discretion of the surgeon. As seen in Table 7, no statistically significant differences were found between patients in the FO or FC groups in relation to their age or preoperative mixed venous oxygen saturation, aortic oxygen saturation, PAP within the Glenn circuit, transpulmonary gradient, or PVR.

Age < 4 or ≥ 4 years was only related to CTO20 (P = 0.034); younger patients had more CTO20. Importantly, age was not statistically significantly related to the timing of the Fontan operation during the winter respiratory viral season. Age of patients undergoing the procedure during ReVS+ was 4.5 years, whereas age during ReVS− was 4.2 years.
years ($P=0.55$). With ordinary least squares regression analysis, only respiratory viral season and age were statistically significant in all models when age, FO or FC, ventricular morphology, preoperative PAP, and respiratory viral season were used to predict each of CTO5, CTO10, CTO20, and LOS ($P<0.05$).

**Discussion**

In the present study, we found that performance of the Fontan operation during the winter respiratory viral season in Wisconsin and age $<4$ years were both statistically related to significant, prolonged pleural effusions and LOS. During the winter respiratory viral season, elective surgical procedures are typically delayed for obvious signs of viral upper respiratory tract infection. This is especially important in patients awaiting the Fontan operation. Many patients, however, may have a subclinical infection that may upset the delicate balance required for adequate flow through the Fontan circuit in the early postoperative period. This could raise the CVP, increase the transpulmonary gradient, and result in prolonged pleural effusions and longer hospital stays. We have shown that the mean postoperative CVP is statistically related to prolonged pleural effusions and LOS.

The presence of significant prolonged pleural effusions lasting $>10$ to $14$ days after the Fontan procedure has been reported to occur in $21\%$ to $45\%$ of patients. These persistent pleural effusions contribute to the prolonged LOS some patients encounter after the Fontan operation. Hospital stays of $>2$ to $3$ weeks have been noted in $13\%$ to $45\%$ of patients. Our results for duration of chest tube output $(13.8$ days), percentage of patients with effusions draining $>2$ weeks $(32\%)$, and LOS $(18.2$ days) are consistent with these studies. There are potential morbidity related to persistent pleural effusions, such as the loss of lymphocytes and plasma proteins, as seen in chylothorax. These losses may place the patient at an increased risk of postoperative infection due to reductions in both cell-mediated and humoral immunity. Additional procedures may also be required secondary to the effusions. One such procedure is pleurodesis, which was required in $17\%$ of our patients. The decision to perform a pleurodesis procedure at our institution is based on the following algorithm in patients with prolonged, high-volume chest tube drainage. Initially, a low-fat diet is used. If this is not successful, the patient is given total parenteral nutrition (nothing per the oral route). Once the drainage has ceased, the patient is again placed on a low-fat diet. If significant drainage recurs after refeeding, the patient is considered for pleurodesis.

Several studies have evaluated the contribution of preoperative and intraoperative factors to post-Fontan pleural effusions and LOS. Factors found to be statistically related to reduced pleural effusions and shorter hospitalizations in these studies were creation of a fenestration, partial exclusion of the hepatic veins during completion of the Fontan procedure, and an EF operation. In the present study, neither leaving the fenestration open nor using an EF operation was statistically significantly associated with prolonged pleural effusion, prolonged LOS, or need for pleurodesis. Patients with an FO did not constitute a higher-risk population than those with FC on the basis of their age or preoperative catheterization data.

The majority of studies have found that most preoperative factors are not statistically related to prolonged pleural effusions and longer hospitalizations. The factors evaluated in these studies were age; preoperative oxygen saturation, PAP, or PVR; ventricular end-diastolic pressure; type of Fontan; previous bidirectional Glenn procedure; presence of branch pulmonary artery stenosis; degree of AV valve regurgitation; and decreased ventricular function. We found that when preoperative PAP was evaluated as a continuous variable, there was a significant relation to CTO5 and that PAP approached significance in its relationship to CTO10 but not to CTO20 or LOS. In our patient population, other preoperative

<table>
<thead>
<tr>
<th>Variable</th>
<th>RV</th>
<th>LV</th>
<th>FO</th>
<th>FC</th>
<th>IF</th>
<th>EF</th>
</tr>
</thead>
<tbody>
<tr>
<td>LOS</td>
<td>18.5±14.5</td>
<td>18.0±13.4</td>
<td>19.4±13.9</td>
<td>15.9±13.1</td>
<td>18.0±12.7</td>
<td>18.4±16.4</td>
</tr>
<tr>
<td>CTO5</td>
<td>9.6±8.3</td>
<td>9.4±6.2</td>
<td>10.3±7.7</td>
<td>7.8±4.3</td>
<td>9.1±5.9</td>
<td>9.2±8.7</td>
</tr>
<tr>
<td>CTO10</td>
<td>8.1±8.0</td>
<td>7.2±5.7</td>
<td>8.0±7.0</td>
<td>6.6±5.3</td>
<td>7.1±5.4</td>
<td>7.4±8.2</td>
</tr>
<tr>
<td>CTO20</td>
<td>6.0±7.4</td>
<td>4.9±5.0</td>
<td>5.5±6.3</td>
<td>4.8±4.7</td>
<td>4.8±4.6</td>
<td>5.2±7.2</td>
</tr>
<tr>
<td>P+, %</td>
<td>14</td>
<td>18</td>
<td>20</td>
<td>10</td>
<td>15</td>
<td>27</td>
</tr>
</tbody>
</table>

Data are shown as mean±SD or percentage. No statistically significant differences were noted.
factors, such as RV or LV morphology, PAP greater than or less than the group’s mean of 12 mm Hg, and PVR greater than or less than 2 Wood units, were not statistically significantly associated with prolonged pleural effusion, prolonged LOS, or need for pleurodesis. Patient selection bias, including suitability for attempted Fontan operation and type of Fontan operation performed, may contribute to these findings.

In conclusion, a fenestrated Fontan operation during the winter respiratory viral season in Wisconsin appeared to be associated with prolonged pleural effusions, longer hospitalizations, and an increased need for pleurodesis. We speculate that limiting the number of Fontan procedures done during the winter respiratory viral season in Wisconsin may decrease the morbidity associated with prolonged pleural effusions and LOS. We further speculate that patients who do require a wintertime Fontan may benefit from routine preoperative screening for the detection of subclinical viral infections. A prospective study that includes a screen for clinical or subclinical viral infections at the time of the pre-Fontan evaluation may further define these preliminary findings.

References

### TABLE 7. Comparison of Preoperative Variables and Status of Fenestration

<table>
<thead>
<tr>
<th></th>
<th>Age, y</th>
<th>MVO₂, mm Hg</th>
<th>SaO₂, mm Hg</th>
<th>PAP, mm Hg</th>
<th>TPG, mm Hg</th>
<th>PVR, Wood Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>FO</td>
<td>4.3±2.5</td>
<td>68±7</td>
<td>85±5.0</td>
<td>12±2.2</td>
<td>5±2.0</td>
<td>1.7±1</td>
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<tr>
<td>FC</td>
<td>4.3±1.9</td>
<td>69±8</td>
<td>82±18</td>
<td>12±1.9</td>
<td>5±1.4</td>
<td>1.5±0.5</td>
</tr>
</tbody>
</table>

MVO₂ indicates mixed venous oxygen saturation; SaO₂, systemic oxygen saturation; and TPG, transpulmonary gradient. Data are shown as mean±SD. No statistically significant differences were noted.