Effects of Cardiac Surgery with Extracorporeal Circulation on Intellectual Function in Children

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SUMMARY
The effect of extracorporeal circulation during open heart surgery on changes in intellectual function was studied in 18 children. A group of patients undergoing such surgery was compared to a control group undergoing cardiac surgery without extracorporeal circulation. The Wechsler Intelligence Scale for Children was used to evaluate the patients. No significant differences were found in either the performance IQs, verbal IQs, or full scale IQs by comparing the postoperative scores to the preoperative scores either within each group or between the groups. Extracorporeal circulation during open heart surgery does not appear to alter intellectual functioning in the pediatric age group.

Additional Indexing Words:
Intelligence quotient  Open heart surgery

NEUROLOGIC dysfunction following cardiac surgery utilizing extracorporeal circulation has been well documented.1-6 This dysfunction is variable and ranges from obvious changes such as complete loss of higher intellectual functions and hemiplegia to more subtle changes in intellect and mild motor and psychological disturbances. Although few studies have been conducted relating the effect of cardiac surgery on children's intellectual functioning, the long term effects of heart surgery on intellectual functioning in adults has been measured by psychological assessment procedures. These studies have produced conflicting results.6,7 Studies of the effects of extracorporeal circulation on aspects of neurologic functioning other than intelligence indicate a significant incidence of signs and symptoms, especially in adults. Gilman8 discovered signs of cerebral involvement in one-third of 35 adult patients. Tufo6 found that about 50% of his adult patients developed signs of cerebral damage immediately following surgery and 15% of the survivors had some manifestations of neurological difficulty. Silverstein and Krieger4 reported three patients with neurological deterioration in a group of 22. Although Silverstein et al.5 reported neurologic complications in six children of 24, the authors related the spuriously high figure to the fact that the study was conducted during the first year of their open heart unit. Kornfeld et al.9 noted that the incidence of delirium associated with open heart surgery was much less than in adults and, in fact, seemed to be absent in children.

A number of mechanisms related to the surgery may be responsible for neurologic changes. Air emboli may originate either in the pump-oxygenator or from air trapped in the left side of the heart. Other materials which may embolize include silicone defoaming material, suture fragments, fibrin clots, Ivalon sponge, Teflon felt or other patch material, fat fragments and calcium fragments from damaged heart valves. Intra- and postoperative hypotension with its associated cerebral hypoxia has also been implicated. Brierley8 and Tufo,6 in pathologic studies of patients who died postoperative, related their CNS lesions to reduced cerebral blood flow.

Although hemodynamic changes rendered by such surgery in children have been studied extensively, there has been no systematic study of possible changes in their intellectual abilities. The purpose of this study is to ascertain whether changes in intellectual abilities do in fact occur in...
Children undergoing open heart surgery with extracorporeal circulation by comparing them to a control group undergoing cardiac surgery not necessitating the use of extracorporeal circulation.

Methods
All children in this study underwent cardiac surgery at University Hospitals of Cleveland between June 1 and July 30, 1972. Testing was offered to 21 patients living within a 50 mile radius of the hospital. One refused presurgical testing. Testing was not offered to one child with obvious mental retardation and significant emotional disturbance. The purpose of the study was explained to the parents of all children and their consent obtained. Group A was composed of 12 patients in whom extracorporeal circulation was used. Eight patients in whom extracorporeal circulation was not used made up group B. One patient in each group refused postoperative testing and was eliminated from his group. Neither patient exhibited obvious change in intellectual functioning. The final sample consisted of 11 patients in group A and seven in group B. In group A the mean age was 9 years, with a range from 7 to 13 years. In group B the mean age was 8 years, with a range from 6 to 14 years. In group A the diagnoses were: interatrial septal defect (five patients), interventricular septal defect (three patients) and Tetralogy of Fallot (three patients). All patients in group A underwent extracorporeal circulation using a Kay-Cross disc oxygenator (Pemca Corp., Cleveland, Ohio) with a screen filter in the arterial line. Flow rates were over 2 liter/min, and the prime was one half whole blood, one half lactated Ringer’s solution.

The children were given a standardized test of intellectual functioning (the Wechsler Intelligence Scale for Children) within five to thirteen days prior to surgery, and between five to ten weeks after surgery. Tests were administered by three trained research assistants to whom patients were assigned randomly. Each research assistant saw the same child for pre- and postsurgical evaluations. The anonymous test protocols were then scored by a clinical psychologist.

Results
As shown in table 1, the mean preoperative full scale IQ scores of children who underwent cardiac surgery utilizing extracorporeal circulation (group A) were approximately equal to those of children who underwent surgery without extracorporeal circulation (group B). Postoperatively, the mean

Table 1
Comparison of Scores of Wechsler Intelligence Scale for Children (WISC) of Patients Undergoing Cardiac Surgery

<table>
<thead>
<tr>
<th>Lesion</th>
<th>Age (yr-mo)</th>
<th>Preop IQ</th>
<th>Postop IQ</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Full scale</td>
<td>Verbal</td>
</tr>
<tr>
<td>VSD</td>
<td>7–3</td>
<td>93</td>
<td>85</td>
</tr>
<tr>
<td>VSD</td>
<td>7–0</td>
<td>115</td>
<td>114</td>
</tr>
<tr>
<td>VSD</td>
<td>11–0</td>
<td>104</td>
<td>108</td>
</tr>
<tr>
<td>ASD</td>
<td>11–3</td>
<td>110</td>
<td>119</td>
</tr>
<tr>
<td>ASD</td>
<td>13–8</td>
<td>138</td>
<td>138</td>
</tr>
<tr>
<td>ASD</td>
<td>9–6</td>
<td>90</td>
<td>82</td>
</tr>
<tr>
<td>ASD</td>
<td>7–6</td>
<td>108</td>
<td>111</td>
</tr>
<tr>
<td>ASD</td>
<td>11–5</td>
<td>90</td>
<td>89</td>
</tr>
<tr>
<td>TOF</td>
<td>7–9</td>
<td>107</td>
<td>109</td>
</tr>
<tr>
<td>TOF</td>
<td>8–0</td>
<td>123</td>
<td>113</td>
</tr>
<tr>
<td>TOF</td>
<td>8–11</td>
<td>89</td>
<td>95</td>
</tr>
</tbody>
</table>

N = 11
Mean 106.1 105.7 105.8 110.7 107.1 112.1

Group B

<table>
<thead>
<tr>
<th>Lesion</th>
<th>Age (yr-mo)</th>
<th>Preop IQ</th>
<th>Postop IQ</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Full scale</td>
<td>Verbal</td>
</tr>
<tr>
<td>PDA</td>
<td>8–11</td>
<td>101</td>
<td>97</td>
</tr>
<tr>
<td>PDA</td>
<td>7–8</td>
<td>110</td>
<td>103</td>
</tr>
<tr>
<td>PDA</td>
<td>12–0</td>
<td>128</td>
<td>123</td>
</tr>
<tr>
<td>PDA</td>
<td>14–7</td>
<td>94</td>
<td>90</td>
</tr>
<tr>
<td>PDA</td>
<td>6–3</td>
<td>109</td>
<td>108</td>
</tr>
<tr>
<td>PDA</td>
<td>7–11</td>
<td>97</td>
<td>92</td>
</tr>
<tr>
<td>PDA</td>
<td>7–0</td>
<td>114</td>
<td>118</td>
</tr>
</tbody>
</table>

N = 7
Mean 107.6 104.4 109.4 105.7 103.3 108.4

Abbreviations: VSD = interventricular septal defect; ASD = interatrial septal defect; TOF = Tetralogy of Fallot; PDA = patent ductus arteriosus.

Group A: patients undergoing cardiac surgery with extracorporeal circulation.
Group B: patients undergoing cardiac surgery without extracorporeal circulation.

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full scale IQ scores of group A increased relative to preoperative performance. However, this change is not significant ($t < 1$) and may be attributed to practice effects. The postoperative mean full scale IQ scores of group B decreased slightly as compared with preoperative scores. This change also was not significant ($t < 1$). The change in pre- vs postoperative full scale IQ scores was not significantly different between the two groups ($t = 1.43$). Similarly there was no significant difference in the change in verbal or performance IQ scores either within each group (Verbal: Group A, $t = 1$; Group B, $t < 1$. Performance: Group A, $t = 1.08$; Group B, $t < 1$) or between the groups (Verbal, $t = 1.79$; Performance, $t = 1.97$).

Discussion

The results demonstrate that cardiac surgery involving extracorporeal circulation does not have significant deleterious effects on children's intellectual abilities as measured by the Wechsler Intelligence Scale for Children. Although this analysis is statistically valid, one patient in group B (aged 6 years, 3 months) did exhibit a decline in full scale, performance, and verbal scores. This child developed transient chest pain postoperatively which was not angina pectoris. Her preoccupation with this pain might explain the lower score.

It is difficult to ascribe the observed lack of change in intellectual functioning to any one factor. Certainly, recent technical advances in pump oxygenators and closer attention to hemodynamic parameters both intra- and postoperatively have reduced long term effects. These results are consistent with those of Silverstein et al.,5 which is the only similar study of the effect of extracorporeal circulation on children's abilities. However, the results of Silverstein’s study were inconclusive for a number of reasons: psychometric studies were done on only seven of the total series of 24 patients. In addition, the nature of the subjects' heart lesions were not specified, nor were suitable control patients used. In view of this, our investigation may be considered the first well-controlled study of the effects of cardiac surgery involving extracorporeal circulation on children's intellectual abilities. Our findings are also consistent with Linde's6 findings that older children with cyanotic heart lesions have normal intellectual abilities.

This study of children is consistent with the work of Frank et al.7 with adults but is in contrast to Tufo's.6 Frank reported improvement of intellectual abilities in adults after surgery which he explained largely on the basis of practice effects. Tufo6 found that a very high percentage (43%) of the survivors of cardiac surgery showed lowering of certain intellectual functions. This discrepancy is difficult to interpret since different measures of intellectual functioning were used in the two studies. Frank interpreted this discrepancy as a function of sampling characteristics: the higher mortality rate and the more frequent gross CNS damage occurring immediately postoperatively in Tufo's sample would be expected to correlate with a much higher incidence of long term intellectual deficits. Gilberstadt,10 using the Wechsler Adult Intelligence Scale (as did Frank), found signs of intellectual deterioration in a group of 53 patients immediately after open heart surgery. However, the short span between operation and retesting did not allow for an adequate test of the hypothesis of permanent deterioration. Our findings are also consistent with those of Kornfeld2 who noted the absence of postoperative delirium in children.

The factors which account for the apparent higher incidence of neurological complications, intellectual deficits, and behavioral changes following open heart surgery in adults compared with children are still not completely known. Tufo6 noted that in adults cerebral damage was significantly related to increasing age and depression of arterial pressure. Kornfeld et al.,2 demonstrated that surgical stress (as measured by procedure time and bypass time) was comparable in adults and children and thus did not appear to be a factor which could account for the difference in postoperative behavior changes noted. He speculated that the relative neuroanatomic and neurophysiologic immaturity of the brain in children under age 13 may somehow play a role in their differential vulnerability to the effects of open heart surgery. Other factors seen in adults but not in children are calcification of damaged heart valves, a source of emboli, and cerebral atherosclerosis. Future studies relating various parameters to indices of neurologic intellectual and behavioral functioning in children as compared with adults are needed to provide more conclusive understanding of the mechanisms involved in psychologic and neurologic changes associated with cardiac surgery.

References


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6. Tufo HM, Ostfeld AM, Shebilla R: Central nervous system dysfunction following open heart surgery. JAMA 212: 1333, 1970
8. Brierley JB: Cerebral injury following cardiac operations. Lancet 1: 175, 1964
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