Early and Late Results with the Mustard Operation in Infancy

Louis P. Egloff, M.D., Michael D. Freed, M.D., MacDonald Dick, M.D., William I. Norwood, M.D., and Aldo R. Castaneda, M.D.

ABSTRACT Eighty-one patients, ranging in age from 36 hours to 24 months and in weight from 2.5 to 12 kg had a Mustard operation for d-transposition of the great arteries (d-TGA) (20 with complex d-TGA) using either deep hypothermic circulatory arrest (68 patients) or conventional cardiopulmonary bypass (13 patients). A Dacron patch was used for the intraatrial baffle and pericardium for augmentation of the pulmonary atrium. Ten patients died following operation. Thirty-two patients had cardiac catheterization 1 year after operation. Of 24 patients with D-TGA and intact ventricular septum, 23 had normal pulmonary artery pressures. In 20 patients left ventricular outflow tract gradients decreased from a mean of 32 mm Hg to a mean of 18 mm Hg after operation. Five patients who had d-TGA and ventricular septal defect and systemic pressures in the left ventricle before operation, had a notable decrease in left ventricular pressures after the procedure. Seven patients required reoperation for baffle obstruction. Mortality following Mustard repair was primarily related to the complexity of the lesion, maturity of the infant, and degree of pulmonary vascular changes. Caval obstruction was related to the configuration of the baffle used in the early part of this series.

The arterial "switch" operation and the original Senning [17] operation are both important techniques for surgical treatment of transposition of the great arteries (TGA). Jatene and associates [11] have achieved impressive results with the former method as have Quaegebeur and associates [15] with the latter. At the same time, major improvements in results are being reported for the more widely used Mustard operation [3, 4, 13, 17, 18]. The questions as to which of these methods to use, at what age, and for what type of lesion, should eventually be resolved by evaluating the operative risks and by comparing early and late postoperative results. In this paper we review our experience with the Mustard operation at The Children's Hospital Medical Center in Boston to provide additional data for answering these questions.

Materials and Methods

From January 1, 1973, to November 1, 1977, 81 consecutive infants with TGA (S.D.D.) who were less than 2 years old underwent an atrial baffle (Mustard) operation (Fig 1). There were 59 boys (73%) and 22 girls (27%). The infants ranged from 36 hours to 24 months old (mean, 9.2 months) and weighed between 2.5 and 12 kg (mean, 6.7 kg). Sixteen of the 81 infants (20%) underwent operation within the first 3 months of life, 6 (7%) within the first month.

The patients were categorized into four groups. Group 1 included 61 patients (75.4%) with d-TGA and an intact ventricular septum (IVS) or a small ventricular septal defect (VSD). Group 2 had 2 patients (2.5%) with d-TGA, IVS, and significant left ventricular outflow tract obstruction (LVOTO) (left ventricular pressure > 100 mm Hg). Group 3 included 13 patients (16%) with d-TGA, a large VSD, and left ventricular pressure near or at systemic level. Group 4 consisted of 5 patients (6%) with d-TGA, VSD, and LVOTO with a pressure difference greater than 50 mm Hg between the left ventricle and pulmonary artery.

Before the Mustard operation was done, a total of 98 procedures were performed on these
infants. The procedures included 73 Rashkind balloon atrial septotomies, 14 Blalock-Hanlon operations, 1 Edwards procedure, 4 pulmonary artery bandings, 4 ligations of the patent ductus arteriosus, and 2 coarctation repairs.

Conventional cardiopulmonary bypass was used in 13 patients while surface cooling in combination with core cooling followed by circulatory arrest and core rewarming was used in 54. More recently, surface cooling has been eliminated and 14 patients were repaired using circulatory arrest with core cooling (20°C) and rewarming on cardiopulmonary bypass. Mean circulatory arrest time was 59 minutes (40 to 81 minutes). In patients undergoing deep hypothermic circulatory arrest, with or without surface cooling, a single venous cannula is inserted through the right atrial appendage. Following intracardiac repair, venous return for cardiopulmonary bypass is maintained through the same cannulation site (after repair, the functional left atrium). Venous return proved adequate in all patients. The atriotomy is carried from the atrioventricular groove transversely across the atrium and through the crista terminalis, and extends posteriorly between the right superior and inferior pulmonary veins to facilitate placement of the baffle and to prepare for enlarging the pulmonary atrium (Fig 2). The atrial septum is completely excised. The remaining raw areas are not reendothelialized. The intraatrial baffle was fashioned from pericardium in 6 patients and from double-stretch Dacron in the remaining 75 patients. In the first 12 patients, the baffle was tailored to a butterfly shape (Fig 3). Because of excessive problems with caval obstructions, the configuration of the patch was changed to a modified pantaloon shape (modified from Brom).* The baffle size is estimated after excision of the atrial septum, and during placement the baffle is continually trimmed to conform to the size and configuration of the atria. The baffle is inserted with a continuous suture, starting between the orifices of the left pulmonary veins and extending on both sides to a midpoint between the superior vena cava and right superior pulmonary vein and the inferior vena cava and right inferior pulmonary vein. The second suture line begins at the remaining atrial septum, between the mitral and tricuspid valve, and is carried around the inferior and superior vena cava to meet the previous suture line. The coronary sinus is not incised but is left to drain into the functional left atrium. Finally, a quadrangular segment of pericardium is sutured into the atriotomy to enlarge the newly formed left atrium. All VSDs are closed through the right atrium after the septal and anterior leaflets of the tricuspid valve are retracted. By preference,

Fig 2. Technique used for placement of intraatrial baffle and enlargement of pulmonary atrium. (A) The solid to broken line indicates the atriotomy line. (B) The atrial septum is completely excised. (C, D) The intraatrial baffle is inserted using two lines of continuous suture. (E) A quadrangular piece of pericardium is sutured into the atriotomy to increase the size of the left atrium.

a pericardial patch is used to avoid possible adherence of valve leaflets to the Dacron material. Resection of LVOTO, necessary in 7 children in Groups 2 and 4, was accomplished through the pulmonary artery and valve [1]. All infants were intubated and artificially ventilated for a minimum of twenty-four hours after operation. Postoperative assessment included continuous monitoring of arterial blood pressure, central venous (superior vena cava) and right and left atrial pressures, and electrocardiograms.

Fig 3. Configuration of intraatrial baffle; butterfly shape (left) and modified pantaloon shape (right).

Results
Hospital Mortality
Ten patients, 5 with d-TGA and IVS (Group 1) and 5 with complex d-TGA (Groups 2, 3, 4) died following the procedure (Tables 1, 2).

In Group 1, a 13-month-old girl and a 22-month-old boy, died in low cardiac output. Both had systemic pressures in the pulmonary artery before operation. Postmortem examina-
Table 1. Mortality in Group 1 Patients

<table>
<thead>
<tr>
<th>Age (mo)</th>
<th>No. of Patients</th>
<th>Hospital Mortality</th>
<th>Late Mortality</th>
</tr>
</thead>
<tbody>
<tr>
<td>0–1</td>
<td>5</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>1–2</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2–3</td>
<td>6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3–6</td>
<td>7</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>6–12</td>
<td>23</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>12–24</td>
<td>19</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>61</td>
<td>5 (8.0%)</td>
<td>2</td>
</tr>
</tbody>
</table>

Table 2. Mortality in Groups 2, 3, and 4 Patients

<table>
<thead>
<tr>
<th>Group</th>
<th>Age (mo)</th>
<th>No. of Patients</th>
<th>Hospital Mortality</th>
<th>Late Mortality</th>
</tr>
</thead>
<tbody>
<tr>
<td>2a</td>
<td>8</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>24</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3b</td>
<td>0–1</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1–2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2–3</td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>3–6</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>6–12</td>
<td>4</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>12–24</td>
<td>4</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>4c</td>
<td>3–6</td>
<td>2</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>6–12</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>12–24</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>20</td>
<td>5 (25%)</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

*Group 2 patients had an intact ventricular septum and left ventricular outflow tract obstruction.
*Group 3 patients had a large ventricular septal defect. The 3 deaths represent 23% of the patients in this group.
*Group 4 patients had a ventricular septal defect and left ventricular outflow tract obstruction. The 2 deaths represent 40% of the patients in this group.

Fig 4. Mortality among 81 patients having Mustard operation according to age in months. The number of patients and percent relative frequency are shown on the ordinate. The dark portion of the bars corresponds to hospital deaths.

There was no mortality in Group 2.

In Group 3, 3 patients died. A 1-month-old infant had a large conoventricular-type VSD that could not be closed adequately (this patient was seen early in our experience). Therefore a pulmonary artery band was used. The child died four hours after operation. The other 2 patients (7 and 18 months old) died in low cardiac output. Both had systemic pulmonary artery pressure and grade IV pulmonary vascular obstructive disease.

In Group 4, 2 patients died. Postoperative respiratory failure due to massive intrapulmonary shunting occurred in a 16-month-old boy with a VSD and mild pulmonary stenosis (mean pulmonary artery pressure, 50 mm Hg preoperatively). Technical difficulties were encountered in a 5-month-old boy with a VSD, and severe LVOTO that was caused by a posterior deviation of the parietal band. This child died of unrelieved obstruction.

The rate of hospital mortality for the 81 patients in this study was 12% ± 0.04 (SEM). Mortality for patients with simple d-TGA was 8% ± 0.04 and for those with complex d-TGA, 25% ± 0.10 (Fig 4).
Late Mortality

The 2 late deaths of patients in Group 1 occurred 5 and 16 months after operation. A 28-day-old boy had an uneventful immediate postoperative course. However, a reoperation was necessary 2 months after the initial procedure because of progressive severe LVOTO. Three months after the transpulmonary resection of the fibromuscular-type stenosis, the child died of viral pneumonia confirmed at postmortem examination. The other patient, a 4-month-old girl had postoperative superior and inferior vena cava obstruction caused at the narrow central portion of a butterfly-shaped baffle. After reoperation she died in cardiopulmonary failure. The cause of late death in a 17-month-old boy in Group 3 is not known.

Complications

Mild congestive heart failure and transient dysrhythmias were most frequent. Other early postoperative complications included transient seizures (6 patients), chylothorax (3 patients), cortical blindness (1 patient), transient renal failure (1), diaphragmatic paralysis (1), and wound infection (1). The chylothorax resolved spontaneously in all 3 patients. The most serious complication was cortical blindness in a 10-month-old boy with TGA, a large VSD, and previous pulmonary banding. During deep hypothermic circulatory arrest, the intraatrial baffle and the VSD patch were placed within 40 minutes. However, repair of the band site proved difficult. Although there is no direct evidence that the central nervous system lesion was related to hypothermic circulatory arrest, the reconstruction of the pulmonary arteries required an excessive period (81 minutes) of interrupted circulation.

Early (time of hospital discharge) and late postoperative rhythm disturbances are outlined in Table 3. Fifteen patients (18.5%) had dysrhythmias verified by Holter monitoring, at the time of hospital discharge. No late deaths were related to abnormal rhythms. However, 2 patients required cardioversion of atrial flutter after hospital discharge. A 20-month-old boy was in regular sinus rhythm with a few occasional junctional escape beats following Mustard repair. Within a year he was noted to be in atrial flutter, and it was determined he had sick sinus syndrome. A year later he sustained a syncopal episode and a permanent pacemaker was inserted on the assumption that the unconsciousness resulted from a bradydysrhythmia. The other patient, a 19-month-old infant was in junctional rhythm at the time of discharge from the hospital. Two years following Mustard repair, atrial flutter developed, which required cardioversion.

Late Cardiac Catheterization Data

Thirty-one patients were recatheterized at an average interval of 1 year following the Mustard operation: 24 of the survivors of Group 1, 2 of Group 2, and 5 of Group 3. Of Group 1 patients, all but 3 had normal pulmonary artery pressures preoperatively. In 2 of these 3 with normal sinus rhythm and 2 with junctional escape beat in the interim.

<table>
<thead>
<tr>
<th>Rhythm Disturbance</th>
<th>At Hospital Discharge</th>
<th>1 Year after Operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sinus rhythm</td>
<td>56</td>
<td>58</td>
</tr>
<tr>
<td>Junctional rhythm</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Heart block</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Atrial premature beats</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Ventricular premature beats</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Junctional escape</td>
<td>8</td>
<td>5</td>
</tr>
<tr>
<td>Sick sinus syndrome</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>

While most of the children were in sinus rhythm throughout, postoperative abnormalities on discharge correlated poorly with the findings 1 year later. For example, only 2 of 4 children with sick sinus syndrome at discharge had it 1 year later but it had developed in 3 other children (1 with normal sinus rhythm and 2 with junctional escape beat) in the interim.
left ventricular outflow tract at the time of repair. In the 2 patients with TGA and IVS and (asymmetric) septal hypertrophy (Group 2), preoperative left ventricular pressures measured 160 and 200 mm Hg. In both patients the Mustard repair was accompanied by transpulmonary artery myotomy and partial resection of the hypertrophied septal muscle mass. Although both infants had an uncomplicated postoperative course and continue to do well clinically, systolic left ventricular pressures are still notably elevated at repeat catheterization (90 and 60 mm Hg, respectively). All 5 patients in Group 3, 1 with a pulmonary band, for whom preoperative and postoperative studies were available, had systemic pressures in the left ventricle before repair (Fig 7) that decreased notably after repair. The surviving patients with TGA, VSD, and LVOTO (Group 4) are clinically well but have not yet been recatheterized.

Gradients between both superior vena cava and inferior vena cava and the right atrium are shown in Fig 8. Of the 12 patients with gradients greater than 8 mm Hg, 10 had the butterfly-shaped (narrow-waisted) baffle used at the beginning of this series. The other two had a modified Brom baffle and were operated on within the first month of life. Both had a side-to-side superior vena cava-to-right pulmonary artery anastomosis in order to decompress the superior vena cava at the time of re-
pair [1]. Seven of the 10 patients with butterfly baffles have required reoperation (4 to 24 months after the original operation). To date, we have not seen any patient with obstruction of the pulmonary venous return.

Tricuspid regurgitation was neither a clinical nor a roentgenographically recognizable problem in this series. One patient with a large VSD had a small, hemodynamically insignificant residual shunt.

Comment
Our policy is to treat all patients with d-TGA initially with Rashkind balloon atrial septotomy. After this treatment only those patients in whom oxygen saturation remains below 60% or in whom metabolic acidosis persists are considered candidates for additional emergency procedures. If the Rashkind balloon atrial septotomy is deemed inadequate on the basis of technical difficulties, if residual pressure is measured between left and right atria, if the two-dimensional echocardiogram demonstrates an inadequately sized atrial communication, or if a combination of the last two factors is present, then a Blalock-Hanlon atrial septotomy is advised. On the other hand, if the Rashkind balloon atrial septotomy is considered to be technically adequate and if left and right atrial pressures equalize after the procedure, or if the sectorscan confirms the presence of a large atrial communication, then the Mustard operation is carried out irrespective of the age or weight of the child. By preference, we delay Mustard repair until the child is 6 to 8 months old. In this series of d-TGA and IVS there were 2 deaths in the first month of life but no increased mortality or increased complication rate in those patients 2 to 12 months old compared with those 12 to 24 months old. Although generally in patients with TGA and IVS there is only a remote chance that pulmonary vascular obstruction will occur within the first two years of life [8, 14], the potential is real enough to warrant elective repair before patients are 1 year old as judged by the death of 2 patients with advanced pulmonary vascular obstruction who were 13 and 22 months old.

Since pulmonary vascular obstruction develops early in patients with d-TGA and VSD [5, 9], our policy is to repeat catheterization when patients are about 3 months old. Should the pulmonary/systemic pressure ratio be greater than 0.75, transatrial closure of the VSD and Mustard operation are recommended at that time. In patients with a pressure ratio of less than 0.75, we delay repair until they are 6 to 8 months old. Of course, if deterioration of the clinical status requires operation before the elective age, Mustard operation and closure of the VSD are done whenever indicated. We do not band the pulmonary artery electively at any age except in those rare instances of infants with TGA and VSD who require an emergency Blalock-Hanlon operation in the first weeks of life. The band is removed within the first year to minimize complications related to the band site. Cortical blindness, the only serious long-term neurological complication in our experience with the use of hypothermic circulatory arrest, occurred in a patient in whom the band had migrated distally resulting in a time-consuming, difficult technical repair.

Thanks to a clearer understanding of the anatomy of the different types of VSDs seen in patients with TGA [2, 19], transatrial closure of these defects has become progressively easier. The only death related to technical problems with closure of a VSD associated with TGA occurred early in our experience.

Mortality following Mustard repair is caused by a variety of factors including the complexity of the lesions, the maturity of the infant, and the degree of pulmonary vascular changes. Mortality within the first month reflects the severity of persistent hypoxemia and the compromised condition of the neonate requiring urgent operation. At the other end of the age spectrum, most deaths were related to pulmonary vascular obstructive disease.

The postoperative hemodynamic studies in patients with TGA and IVS are encouraging. Of the 24 patients who had recatheterizations 1 year after Mustard repair, all but 1 had normal pulmonary artery pressures at rest. Because of the young age of these patients, exercise challenge was not included in these studies. However, we hope to obtain postexercise studies at the 5-year postoperative review. We were reassured that LVOTO gradients less than 60 mm
Hg in patients in whom organic subpulmonary obstruction had been ruled out by angiogram or echocardiogram tended to decrease rather than increase after the Mustard operation. The mechanism (or mechanisms) responsible for these apparently "functional" gradients is not entirely clear, but an exaggerated convexity of the posterior ventricular septum along with systolic anterior displacement of the aortic leaflet of the mitral valve has been implicated as a possible cause. Organic LVOTO, with or without a VSD, on the other hand, can pose great problems to surgical management. Isolated and short segmented forms of fibrous or fibromuscular-type obstructions, aneurysms of the pars membranacea septi, and localized excrescences or remnants of endocardial cushion tissue lend themselves more readily to excision through the pulmonary artery and valve. However, judging the precise extent of the obstruction can be difficult and angiography can be misleading. Death due to inadequate resection of a longer than anticipated fibromuscular tunnel-type obstruction occurred in 1 of our patients in Group 4 with a VSD. In retrospect, this child might have benefited from a palliative shunt, rather than attempted resection, followed later by a Rastelli operation. In patients with a posteriorly displaced parietal band, a relatively common cause of severe subpulmonary stenosis in TGA in association with a large conoseptal-type VSD (malalignment of the conus and septum), extensive resection of the parietal band can lead to difficulties in anchoring the VSD patch. Perhaps the greatest technical difficulty is offered by a diffuse muscular (asymmetrical) septal hypertrophy with or without VSD, which can cause very high left ventricular pressures early in life. Whether the 2 infants in our series with this lesion and residual left ventricular hypertension after myotomy and myectomy will require additional operation remains to be seen.

The incidence of venous inlet obstruction in our experience has been closely related to the configuration of the intraatrial baffle rather than to the baffle material. In the patients requiring reoperation, the obstruction occurred at the waistline of the butterfly-shaped baffle used in the early part of this series. Since changing to the modified pantaloon configuration, reoperations have so far not been necessary. Since the azygos vein system effectively decompresses the superior vena cava, symptoms correlate poorly with the degree of caval obstruction. Follow-up cardiac catheterization or a radionuclide cardiogram, therefore, are the only means of accurately assessing the incidence of venous obstruction. To the best of our knowledge, the report by Clarkson and associates [6] is the only one to include routine catheterization studies after the Mustard operation. Their incidence of significant venous inlet obstruction in children of all ages was 6%, with a higher incidence among infants who were less than 6 months old. With the exception of the 2 neonates, we have not found any relationship between age and caval inflow obstruction. Enlargement of the pulmonary venous atrium with a large pericardial path, we believe, is responsible for the absence of pulmonary venous obstruction in our series. Extending the atrial incision between the right superior and inferior pulmonary veins also permits the use of a larger baffle, thus minimizing the chances of caval obstructions.

The incidence of arrhythmias after Mustard operation varies greatly [5, 7, 9, 12]. Damage to atrial conduction has been related to various operative steps of the Mustard operation [20]. In order to avoid damage to the sinoatrial node, we cannulate the superior vena cava directly cephalad to the cava-atrial junction or when deep hypothermic circulatory arrest is used, a single venous cannula is placed through the right atrial appendage. Since we use a transverse atriotomy, which reportedly interferes with posterior activation of the atrioventricular node [20], we refrain from incising the coronary sinus and carry the baffle suture along the line demarcated by the ligament of Todaro, potentially preserving the area of anterior activation. Although we have not done electrophysiological studies on these patients, we presume that this extrapolation of the observations of Wittig and associates [20] is correct, given the low incidence of nodal rhythms after the Mustard operation in our patients.

The recent report of Quaegebeur and associates [15] on the Leiden experience with the
Senning operation is noteworthy. The low hospital mortality (2/20 patients), the absence of pulmonary venous obstruction, the insignificant caval gradients, and the 75% incidence of early postoperative sinus rhythms are major accomplishments and are competitive with the results obtained with the conventional Mustard operation. An important advantage of the Senning operation is the need for little or no foreign material, thus allowing for potential growth of the biological baffle. If these excellent results can be maintained in a larger number of patients and duplicated by other surgical teams, the Senning operation might well deserve a universal renaissance.

Physiologically, the arterial switch operation is the most appealing of all procedures developed for the surgical treatment of TGA. In view of reports of several successful operations by Jatene and associates [10, 11], it is important to define more precisely the indications for this operation. Obviously, a left ventricle capable of acutely maintaining an effective output against systemic resistance is of central importance. In addition to the apparent requirement that the left ventricle be “accustomed” to function as the systemic ventricle, there must be no obstruction to left ventricular outflow and pulmonary vascular resistance ought to be as near normal as possible. At present, these conditions are limited to those patients with TGA and VSD or those patients with patent ductus arteriosus in whom pulmonary vascular obstructive disease has not developed yet, or perhaps to neonates with TGA and IVS. Obviously, the anatomy of the coronary arteries and the spatial relationships between both great arteries must also be suitable for the switch operation. In spite of these real or theoretical limitations, Jatene’s accomplishment must rank with the pioneering efforts of Senning and Mustard in the surgical treatment of TGA. With improvement in technique and better understanding of indications and contraindications, the operative mortality should eventually decrease and the Jatene operation will prove an important addition to the surgical management of TGA.

Based on this evaluation, we conclude that mortality following Mustard repair is predominantly determined by the complexity of the lesion, the maturity of the infant, and the degree of pulmonary vascular changes.

Although in general, children with TGA markedly improve following repair, residual hemodynamic abnormalities and conduction disturbances are, nevertheless, sufficient in number and degree to warrant continued appraisal of surgical alternatives to the Mustard technique. After long-term evaluation of recent exciting developments, principally Jatene’s success with the arterial switch operation and Brom’s renewed interest and excellent results with the Senning operation, these procedures may provide further improvements in the management of infants with d-TGA.

References


Discussion

DR. ALBERT D. PACIFICO (Birmingham, AL): Dr. Castaneda and his colleagues have once again presented superb surgical results in this group of infants and small children. Since 1967, we have had a similar experience with 172 Mustard procedures for patients with transposition of the great arteries and agree in general that it is a good procedure and that particular attention to baffle design and insertion is especially important in the infant group. We also believe that the ultimate position of the baffle, at least in some patients, is beyond the control of the operating surgeon. For example, in an 8-month-old infant who underwent a Mustard procedure, an angiogram showed a widely patent inferior vena caval pathway during an early postoperative study. A few minutes later during the same film sequence severe inferior vena caval obstruction was revealed. The ultimate position this baffle will occupy seems unpredictable.

The Mustard technique has some disadvantages. There is a rather large amount of nonviable material, be it pericardium or Dacron, that will not grow as a child increases in size. There is a significant incidence of "subclinical" and "clinical" vena caval obstruction in patients in this and other series, who are reevaluated. The incidence of postoperative dysrhythmias is also remarkable.

Influenced by the early experience with the Senning I technique and the impressive recent experience of Professor Gerard Brom in Leiden, we have begun to use this method. Our experience thus far is small and, therefore, I would like to present, with his permission, Professor Brom's data. The hospital mortality among 29 patients who underwent the Senning I operation for various subsets of transposition is similar to that presented by Dr. Castaneda's group.

Nineteen patients with intact septum underwent repair. Although none of the patients were less than 3 months old, the procedure was nicely performed, which indicates it can be used even in neonates. Seventeen of these patients have sinus rhythm.

The basic idea of the Senning I procedure is to use the atrial septum and a part of the free right atrial wall as the caval pathway and to reconstruct the pulmonary venous pathway with the remaining right atrial wall. Very little foreign material is required and a more reproducible geometry of this predominantly viable "baffle" results.

DR. L. HENRY EDMUNDS (Philadelphia, PA): I also would like to congratulate the Boston group on the fine results and wish to discuss the problem of postoperative arrhythmias. In Philadelphia in the past three years we have performed the Mustard operation for D-transposition and an intact septum on 27 consecutive patients less than 2 years old. There were 3 hospital deaths and no late deaths. All of the patients had a vertical atriotomy perpendicular to the axis of the cavae, and a patch was applied to enlarge the functional left atrium. No or minimal dissection of the anterior limbus of the atrial septum was carried out. With the exception of 1 patient in whom the sinus node was knowingly injured, all of the patients have been in sinus rhythm at some time postoperatively. Ordinary electrocardiograms showed that all had sinus rhythm or at worst first-degree heart block at some time in the postoperative course. In 1 patient, nine consecutive random electrocardiograms over a 1-year period all showed sinus rhythm, yet the Holter monitor indicated that the patient was going in and out of sinus rhythm and nodal rhythm.

Ongoing analysis of our patients with Holter monitors demonstrates that sinus rhythm is present some of the time in nearly all patients and is present all of the time in a few patients. The explanation for
this is, of course, that the operation changes the conduction times or rate of depolarization as the sinus impulse moves across the atrium to the atrioventricular node. This was beautifully shown by Dr. Wittig and Mr. Stark from The Hospital for Sick Children in a paper published about a year ago.

Unfortunately, atrial dysrhythmias are the rule after the Mustard operation, and the fact that random electrocardiograms show sinus rhythm does not signify that the patient will be free of a disastrous complication or a slow junctional rhythm. In fact, 2 of our patients did come into the hospital with nodal rhythms of 40 beats per minute. These were transient, but they occurred in spite of the fact that both patients are in sinus rhythm part of the time.

DR. EGLOFF: Controversy about type of operation or surgical technique will probably go on until further long-term results are available. I should add that Holter monitoring was done on all patients at hospital discharge but we do not have the results of 1-year postoperative monitoring. Thus our results of about 84% normal sinus rhythm 1 year after repair are not confirmed by Holter monitoring as yet.