Predictors of Postoperative Outcome After General Surgical Procedures in Patients With Congenital Heart Disease

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● **This study was undertaken to evaluate factors predictive of postoperative outcome after general surgical (GS) procedures in patients with congenital heart disease (CHD). All patients with a diagnosis of CHD who underwent a GS procedure under general anesthesia during a consecutive 10-year period were considered eligible for the study. The congenital heart defect was classified as either simple (ASD, VSD, PDA) or complex (endocardial cushion defects, transposition of the great vessels, tetralogy of Fallot), and the GS procedure as either major (intraperitoneal, intrathoracic, or vascular reconstructive) or minor (inguinal herniorrhaphy, vascular access). The overall mortality rate for the patient population was 12% (27 deaths among 226 procedures), minor procedures being associated with a 3% mortality rate (2 of 70 procedures), and major procedures with a 16% mortality rate (25 of 156 procedures). Incremental risk factors for mortality included a preoperative American Society of Anesthesiologists' (ASA) physical status class of IV or higher ($P = .0003$), a preoperative in-hospital stay of 10 or more days ($P = .004$), birth at a tertiary care center ($P = .04$), and emergency operations ($P = .05$). In the subgroup of patients less than 6 months old, weight of less than 2.4 kg at the time of surgery and a 1-minute Apgar score of less than 4 were additional independent risk factors ($P = .04$ and .01, respectively). By logistic analysis, previous corrective cardiac procedures, whether complete or palliative, did not significantly alter the postoperative outcome. The authors conclude that physiologically well-compensated patients with CHD can undergo elective operations at a low operative risk; however, poorly compensated patients undergoing urgent or emergent operations are at high risk. Previous corrective cardiac procedures may improve the overall outcome if the physiological state of the patient could be improved.**

INDEX WORDS: Congenital heart disease, risk factors for general surgical procedures.

SEVERAL LANDMARK studies have been published concerning cardiac risk factors in adult patients undergoing noncardiac surgical procedures.[1] However, no known study has evaluated the presence of congenital heart surgery as a risk factor for noncardiac surgery. Only a few institutions possess the clinical volume of pediatric general surgical patients with congenital heart disease who undergo general surgical operations, thus enabling such an analysis. The purpose of the present study was to evaluate the presence of congenital heart disease (CHD) as a risk factor in patients undergoing general surgical procedures, and to examine whether previous corrective repair of the underlying cardiac defect significantly altered the clinical outcome.

MATERIALS AND METHODS

All patients with a diagnosis of CHD who underwent a general surgical (GS) procedure performed under general anesthesia by staff members of the Pediatric Surgical Service during a consecutive 10-year period (ending in June 1991) were considered eligible for the study. Excluded from the study were patients whose GS procedure consisted solely of cannulation for extracorporeal membrane oxygenation (ECMO), and patients whose CHD diagnosis pertained solely that of persistent fetal circulation. Also excluded were patients undergoing neurosurgical, otolaryngological, urologic, orthopedic, or other subspeciality procedures. Characteristic variables obtained from a review of the charts are shown in Table 1. For patients who underwent more than one GS procedure during a single hospitalization, only the procedure for which the patient was admitted, or the earliest major procedure performed during that hospitalization, was considered for analysis. The American Society of Anesthesiologists' (ASA) physical status classes were defined as follows: class I, healthy patient; class II, patient with a mild systemic disease; class III, patient with a severe systemic disease that limits activity but is not incapacitating; class IV, patient with an incapacitating systemic disease that is a constant threat to life; and class V, a moribund patient not expected to survive 24 hours with or without operation. Postoperative death was defined as that which occurred within 30 days of the operative procedure, or that which occurred at any time during the hospitalization, after completion of the GS procedure.

Statistical analysis was performed using commercially available software (SAS Institute, Cary, NC) on personal computers (IBM Corp). Frequency distributions were analyzed using Mantel-Haenszel χ^2 analysis, and differences in means by the t test and analysis of variance. Stepwise regression analysis was used to test for statistical independence.

RESULTS

A total of 226 general surgical operations were performed on 208 patients with CHD over the course of the study period. Follow-up data were obtained for 201 patients (96%). The mean age (±SEM) of the study population was 2.2 ± 0.3 years, the mean weight was 8.2 ± 0.8 kg, and the mean ASA score was 2.98 ± 0.06. The average length of hospitalization before surgery was 17 ± 3 days; the length of stay after surgery was 24 ± 3 days. Eighty-four patients were on an average of 2.1 ± 0.1 cardiac medications at the time of surgery. Forty-seven percent (107) of the patients were referred from the outpatient depart-

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Table 1. Profile of the 226 General Surgical Procedures

	Patient Age		
	≤6 Mo	>6 Mo	*P* Value
General patient characteristics			
No. of operations	138	88	
No. of deaths (%)	21 (15)	6 (7)	.05
Gestation (wk)	35 ± 1	35 ± 1	NS
Apgar at 1 min	5.4 ± 0.2	6.2 ± 0.8	NS
Apgar at 5 min	7.2 ± 0.2	7.8 ± 0.5	NS
Age at time of surgery (yr)	0.13 ± 0.01	5.4 ± 0.6	<.0001
Weight at time of surgery (kg)	3.2 ± 0.1	16.7 ± 1.9	<.0001
ASA score	3.1 ± 0.1	2.7 ± 0.1	.002
Percentage of males	59	63	NS
Urgency of operation (%)			
Elective	17	64	<.0001
Urgent	5	11	
Emergent	78	25	
Admission pattern (%)			
High-risk birth center	20	0	<.0001
Emergency room	2	6	
Outpatient	25	82	
Referring hospital	53	12	
Characteristics of the congenital heart defect			
Frequency of cyanosis (%)	12	19	NS
Frequency of complex lesion (%)	26	44	.007
No. of cardiac medications	2.1 ± 0.1	2.0 ± 0.2	NS
Correction of CHD lesion (%)			
None	43	33	NS
Palliative	14	22	
Complete	43	45	
Characteristics of the general surgical procedure			
Major procedure (%)	72	65	NS
LOS before procedure (d)	21 ± 3	11 ± 4	.06
LOS after procedure (d)	34 ± 4	9 ± 2	<.0001
Disposition (%)			
Home	79	92	.02
Transfer	5	1	
Death	16	7	

Abbreviations: LOS, length of stay; NS, not significant.

ment. The others were transferred from an outside hospital (84; 37%), were born at a tertiary care center (27; 12%), or were admitted through the emergency department (8; 4%).

Two thirds (152) of the congenital heart defects were classified as simple; one third (74) were classified as complex (Table 2). The more common simple lesions included ventricular septal defect and patent ductus arteriosus; the more common complex lesions included tetralogy of Fallot and endocardial cushion defect. At the time of the GS procedure, 52% (73) of the simple lesions and 74% (54) of the complex lesions had undergone either complete or palliative repair; the average age at time of repair was 1.7 ± 0.3 years.

The overall mortality rate for the patients with simple congenital heart defects (152 procedures) was 9% (13); that for the patients with complex lesions (74 procedures) was 19% (14; $P \leq .05$). The highest operative mortality rate among the cases with simple congenital defects was in patients with patent ductus arteriosus (26% of 43 operations); the highest mortality rate in the group with complex lesions was in patients with hypoplastic left heart syndrome or complex cardiac anomalies (both greater than 50%). Preoperative correction of the congenital defect did not appear to significantly alter the operative mortality rates, being 12%, 14%, and 12% for no, palliative, and complete repairs, respectively (Table 2).

The majority of the GS procedures were major intraabdominal or intrathoracic operations (156; 69%); the remainder (70; 31%) were subcutaneous or vascular access procedures (Table 3). A wide spectrum of operations was performed; the most com-

Table 2. Frequency of Congenital Heart Defect, and State of Repair at Time of General Surgical Procedure

	State of Repair				Mortality
	None	Partial	Complete	Total	(%)
Simple					
Ventricular septal defect	34	3	17	54	2 (4)
Patent ductus arteriosus	11	1	31	43	11 (26)
Atrial septal defect	14	0	6	20	0
Isolated pulmonic stenosis	11	0	1	12	0
Coarctation of aorta	1	0	7	8	0
Aortic stenosis	2	2	2	6	0
Mitral insufficiency	4	0	0	4	0
Aortic insufficiency	2	0	0	2	0
Vascular ring	0	1	1	2	0
Mitral stenosis	0	0	1	1	1 (100)
No. of simple defects	79	7	66	152	
No. of deaths	4	0	9	13	
Mortality (%)	5	0	14	9	
Complex					
Tetralogy of Fallot	3	8	9	20	3 (20)
Endocardial cushion defects	7	4	4	15	2 (13)
Transposition of great vessels	3	4	2	9	1 (11)
TAPVR	0	0	6	6	0
Truncus arteriosus	0	1	3	4	1 (25)
Hypoplastic left heart	3	3	0	6	3 (50)
Double-outlet right ventricle	2	1	1	4	1 (25)
Pulmonary atresia	0	3	0	3	1 (33)
Ebstein's anomaly	0	2	0	2	0
Tricuspid atresia	1	1	0	2	0
Others*	0	1	2	3	2 (66)
No. of complex defects	19	28	27	74	
No. of deaths	7	5	2	14	
Mortality (%)	37	18	7	19	
Totals					
No. of lesions	98	35	93	226	
No. of deaths	12	5	11	27	
Mortality (%)	12	14	12	12	

Abbreviation: TAPVR, total anomalous pulmonary venous return.
*One each with atrioventricular canal, congenital aortic stenosis with complex anomalies, and complex anomalies not otherwise specified.

Table 3. Type and Frequency of General Surgical Procedures

Type	No.
Minor	
Inguinal herniorrhaphy	41
Soft-tissue biopsy	11
Endoscopic procedures	7
Orchiopexy	5
Venous access procedures	4
Arteriography	2
Total	70
Mortality (%)	2 (3)
Major	
Small bowel procedures*	57
Colonic procedures†	27
Fundoplication‡	25
CDH repair	13
Cholecystectomy	6
Abdominal herniorrhaphy§	5
Noncardiac thoracic‖	5
Other¶	18
Total	156
Mortality (%)	25 (16)

Abbreviation: CDH, congenital diaphragmatic hernia.

*Includes enterectomy, enterostomy, enteroenterostomy, pyloromyotomy, hepaticoenterostomy, and tracheoesophageal fistula repair.

†Includes appendectomy; right, left, sigmoid, total, and subtotal colectomy; creation or takedown of colostomy; and endorectal pull-through.

‡Transabdominal approach.

§Includes omphalocele repair and incisional herniorrhaphy.

‖Includes pulmonary lobectomy, open lung biopsy, and CDH repair.

¶Includes exploratory laparotomy (5), nephrectomy (3), open liver biopsy (3), perineal anoplasty (2), splenectomy (2), femoral patch angioplasty (1), renal artery revascularization (1), and total abdominal hysterectomy (1).

mon major procedure was a small bowel operation, and the most common minor procedure was an inguinal herniorrhaphy. Approximately two thirds of the operations were performed emergently (130) or urgently (17) (58% and 7%, respectively); only one third (79; 35%) were performed electively.

Risk factors associated with postoperative mortality included young age, low operative weight, low Apgar score, presence of complex cardiac lesions, high ASA score, urgent or emergent operation, major operation, and prolonged preoperative and postoperative hospital stay (Table 4). By stepwise multiple regression analysis, an ASA score of IV or higher, age of less than 6 months, preoperative hospital stay of 10 or more days, delivery at a tertiary care center, and emergency operations were found to be independent predictors of postoperative mortality.

Perhaps the most accurate predictor of postoperative mortality was the preoperative ASA score (Table 5). There were no operative deaths among the patients in ASA classes I and II; the mortality progressively increased for patients in ASA class III or higher

Table 4. Independent Variables Associated With Postoperative Survival

	F	*P* Value
General patient characteristic		
Age*	13.83	.001
Weight	4.13	.04
Apgar at 1 min	5.82	.01
Admission pattern*	7.97	.005
Characteristics of the congenital heart defect		
Complex *v* simple defect	3.84	.05
Characteristics of the surgical procedure		
ASA score*	67.96	.0001
Urgency of operation*	11.13	.001
Major *v* minor procedure	8.18	.004
LOS before procedure*	14.76	.0002
LOS after procedure	8.81	.003

Note. The following were not statistically significant: birth weight, gestational age, Apgar at 5 min, sex, race, surgical correction of the congenital defect, presence of cyanosis, and number of cardiac medication.

Abbreviation: LOS, length of stay.

*Statistically independent predictors of postoperative outcome.

(Fig 1). The urgency of the GS procedure was also an independent risk factor for postoperative mortality. The mortality for patients operated on electively was 4%; that for patients with emergency operations was 18% ($P \leq .05$). The pattern of referral to the GS service was also an independent risk factor, being associated with 30% mortality among patients transferred from a tertiary care birth center, and 6% mortality among those referred from an outpatient setting ($P \leq .05$).

The overall mortality rate for patients aged 6 months or younger was 15% (Table 1); that for

Table 5. Operative Mortality for Patients Undergoing General Surgical Procedures

	Minor Procedures (%)	Major Procedures (%)
ASA score *		
I	0/1	0/2
II	0/28	0/29
III	0/27	3/61
IV (5)	2/4 (50)	16/41 (39)
V	—	5/7 (71)
Urgency of operation*		
Elective	0/39	3/40 (7)
Urgent	0/7	0/10
Emergency	2/24 (8)	22/106 (21)
Admission pattern*		
Outpatient	0/49	6/58 (10)
Emergency room	—	0/8
Outside hospital	1/14 (7)	12/70 (17)
High-risk birth center	1/7 (14)	7/20 (35)

*$P \leq .05$ by χ^2 analysis.

†ASA data missing for 10 minor procedures and 13 major procedures.

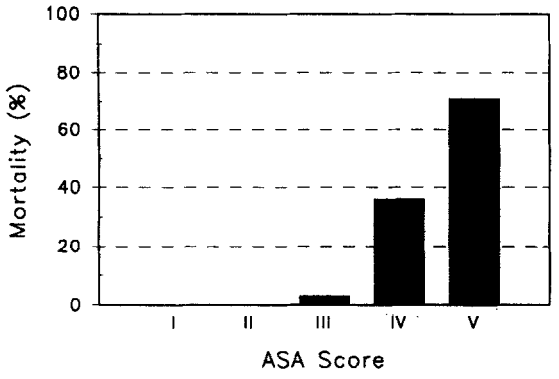

Fig 1. Predictive value of the ASA physical status class on postoperative mortality after general surgical procedures in patients with congenital heart disease.

patients older than 6 months was 7% ($P \leq .05$). Patients under 6 months of age had a higher preoperative ASA score, were more frequently operated on urgently or emergently, were more often transferred from an outside hospital or a tertiary care birth center, and were hospitalized longer both before and after the operation. In this group of patients, operative weight of less than 2.4 kg was an additional independent risk factor for mortality. The mortality rate for patients who weighed less than 2.4 kg was 32% (10 of 31); that for patients who weighed more than 2.4 kg was 13% (9 of 68 patients; $P \leq .05$). The 1-minute Apgar score was another independent risk factor. Patients whose score was less than 4 had an operative mortality rate of 28% (13 of 46); those whose score was greater than 4 had an operative mortality rate of 11% (6 of 63; $P \leq .05$). Two neonates with simple heart disease died after undergoing a minor surgical procedure. Both had multiple medical problems and protracted hospitalizations in the intensive care unit. Both underwent ligation of a patent ductus arteriosus weeks before the emergency inguinal herniorrhaphy because of concern over bowel obstruction or strangulation. Neither was discharged home; both died of respiratory failure and sepsis, more than 1 month after the operation.

DISCUSSION

The incidence of CHD is approximately 0.8% of live births; the surgical management has witnessed marked improvement in the past decade.[2-5] This fact, along with continued advances in medical management has resulted in an ever-increasing population of CHD patients living into adulthood.[6,7] In addition, especially in pediatric tertiary care centers, a significant number of patients are referred for urgent or emergent management of noncardiac problems that arise either during the management of the heart defect or thereafter. The operative mortality rate of noncardiac procedures in patients with congenital heart defects is not known, although the perioperative anesthetic morbidity has been reported to be approximately 47%.[8] The purpose of the present study was to evaluate the operative mortality in patients with CHD who undergo GS procedures, to define risk factors associated with the increased postoperative mortality, and to propose strategies that might improve the operative risk.

The operative mortality rate in this study was 12% (16% for major procedures, 3% for minor procedures). These statistics are higher than those associated with corrective cardiac procedures, for which the reported operative mortality rate approximates 5%.[9] Our statistics also exceed those associated with GS procedures in otherwise healthy children, for which the mortality rate is less than 1%.

By stepwise multiple regression analysis, several risk factors were identified that could account for this seemingly high mortality. The ASA score, the urgency of the operation, and the referral pattern were all found to be statistically independent predictors of postoperative outcome. Hence, physiologically well-compensated patients referred from the outpatient setting would be expected to have an acceptable risk for undergoing elective GS procedures. In fact, there was only one death among the 65 elective cases performed for patients in ASA classes I through III (overall mortality, 1.5%) a result comparable to those of studies in patients without underlying CHD.

A second group of patients, typical of those cared for in tertiary care centers, had increased operative mortality. Generally, these patients were operated on urgently or emergently, underwent major intraabdominal or intrathoracic procedures, and were referred from acute care settings such as tertiary care birthing centers, emergency departments, or outside hospitals. The operative mortality in this group was high, as exemplified by the 41 emergency cases, classified as ASA IV or V, in which the operative mortality was 51% (21 deaths). In this latter group, identification and reversal of risk factors may decrease operative mortality.

Several risk factors, such as young age, prolonged hospital stay, and delivery at a tertiary care center, are not amenable to reversal before surgery, and must be accepted as part of the overall health profile of this high-risk population. However, several aspects of the preoperative and postoperative care should be addressed as a means of decreasing the operative risk, including early referral of patients with GS problems, emphasis on good preoperative nutrition, and control

of sepsis. Finally, in very young patients who are physiologically compromised, elective or semielective surgical intervention should be delayed when possible. Neither the presence of simple heart defects nor the repair of the congenital defect was independently associated with reduction of operative mortality, implying that the patient's physiological state is the primary determinant of postoperative outcome.

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