The Impact of Surgery on Infants Born at Extremely Low Birth Weight

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Purpose: The aim of this study was to determine the outcome of extremely low-birth-weight infants (ELBW) requiring surgical interventions for the complications of prematurity

Methods: One hundred eighty-seven consecutive infants with a birth weight less than 1,000 g treated over a 5-year period were reviewed. Outcome variables included number and types of surgical procedures; length of stay; survival rate and; pulmonary, neurologic, and gastrointestinal morbidity.

Results: Surgical interventions were required in 66 (35%) infants (group S) weighing less than 1,000 g at birth (33% necrotizing enterocolitis/bowel perforation, 36% patent ductus arteriosus, 56% other). Overall mortality rate for group S infants was 23% compared with 22% for those not requiring surgery (group NS; $P > .05$). Mortality rate rose to 38% for those infants undergoing procedures for necrotizing enterocolitis/bowel perforation ($P < .05$). Although neurologic and pulmonary morbidity for the entire population were high, there was no difference in their incidence between surgical and nonsurgical groups (29% *v* 26% and 44% *v* 65%, group S *v* group NS, respectively; $P > .05$).

Conclusions: These data suggest an improving outcome for ELBW infants. Common associated morbidities of prematurity do not appear adversely affected by surgical interventions supporting an aggressive approach to the care of these infants at the extreme of life.

INDEX WORDS: Prematurity, extremely low birth weight, surgery.

IN 1983, BELL ET AL[1] reported an overall survival rate of 58% in 20 low birth weight infants (birth weight less than 1,100 g) requiring 49 surgical interventions for acquired conditions associated with prematurity.[1] Within this small series, survival rate was similar between surgical and nonsurgical patients (41% in nonsurgery group; $P > .05$). Since their report, advances in neonatalogy have continued to allow the envelope of infant viability to be pushed, permitting survival in smaller and more premature infants. Complete outcomes beyond mortality for these infants remain poorly defined. The recent report of the survival of an infant weighing less than 280 g at birth in Florence, Italy, along with a collaborated editorial from the families of extremely low-birth-weight (ELBW) infants who discussed the faults currently inherent with "informed decisions" prompted us to evaluate this patient population at our own institution.[2,3] The purpose of this study was to better define the outcome for ELBW infants requiring early surgical intervention.

MATERIALS AND METHODS

After study approval from the institutional review board at St Louis University (IRB number 11700), the records of 187 consecutive infants with a birth weight less than 1,000 g treated over a 5-year period (January 1997 to December 2001) at Cardinal Glennon Children's Hospital were reviewed retrospectively. Cardinal Glennon Children's Hospital is a freestanding children's hospital with a level III nursery receiving approximately 700 admissions per year from Eastern Missouri and Southern Illinois. Each infant was managed in a single Neonatal Intensive Care Unit by the same neonatology team with surgical consultation obtained as needed. All study data were obtained from a computerized neonatal database, patient charts, and outpatient nursery follow-up.

To determine the impact of surgery on overall morbidity rate and outcome, infants undergoing surgery (birth weight less than 1,000 g, group S) were compared with an age- and weight-matched cohort who did not require surgical interventions (group NS). Children requiring only central venous or arterial access procedures were included in group NS. Outcome variables included number and types of surgical procedures, length of stay (LOS), pulmonary morbidity (bronchopulmonary dysplasia, BPD), neurologic morbidity (intraventricular hemorrhage/periventricular leukomalacia, IVH/PVL), gastrointestinal morbidity (short gut syndrome, SGS), and survival rate. Bronchopulmonary dysplasia was defined by pulmonary radiographic abnormalities and the need for ventilatory support or supplemental oxygen at discharge (greater than 28 days of life).[4] Neurologic morbidity was documented by head ultrasound scan or computed tomography based on routine screening and physical examination. Short gut syndrome was defined as

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the continued need for supplemental parenteral nutrition after discharge.

All data were entered into a personal computer using commercially available software (Excel 2000, Microsoft Corporation, Redmond, WA). Student's *t* test and Fisher's Exact test were used for statistical analysis. All data are presented as mean ± SD. A *P* value of less than .05 was considered significant.

RESULTS

One hundred eighty-seven ELBW infants with a birth weight less than 1,000 g were treated over the 5-year study period. From this cohort, 66 (35%) infants (group S) were identified who required surgical intervention during their initial hospital course (136 total operations; mean, 2.1 ± 2.3 operations per surgical infant; range, 1 to 12). Surgical procedures are summarized in Table 1. All patent ductus arteriosus ligations (24, 36%), and initial procedures for necrotizing enterocolitis/bowel perforations (22, 33%) were performed on infants weighing less than 1,000 g at the time of surgery. Most surgical procedures were performed in the operating room, reserving procedures performed in the neonatal intensive care unit for those unstable infants requiring high-frequency oscillatory ventilation. The only congenital structural abnormality encountered was inguinal hernia. All inguinal hernia repairs (24, 36%) were performed before patient discharge. All other surgical procedures were performed for acquired conditions.

Demographic and outcome data are listed in Table 2 There was no difference in mean gestational age or birth weight between the 2 groups (25 ± 3 *v* 26 ± 2 weeks' gestation, 715 ± 127 *v* 742 ± 144 g birth weight, group S *v* NS, respectively; $P > .05$). Overall, 42 (22%) of the 187 infants died of complications of their prematurity. Survival to hospital discharge was not different between the 2 groups (51, 77% *v* 94, 78%, S *v* NS, respectively). Age and weight at first operation were significantly less

Table 1. Surgical Procedures

Operation	No. (%)	Performed <1,000 g	Performed >1,000 g
PDA ligation	24 (36)	24	0
Inguinal herniorraphy	24 (36)	0	24
Celiotomy for NEC/perforation	22 (33)	22	0
Peritoneal drainage	4 (6)	4	0
Tracheostomy	4 (6)	0	4
Coagulation for retinopathy	3 (5)	0	3
Ventricular shunt	2 (3)	0	2
Gastrostomy	2 (3)	1	1
Fundoplication	1 (2)	0	1
Rectal biopsy	1 (2)	0	1
Open lung biopsy	1 (2)	0	1
Cricoid split	1 (2)	0	1

NOTE. Subsequent abdominal operations for intraabdominal complications and ostomy closures not included.

Abbreviations: PDA, patent ductus arteriosus; NEC, necrotizing enterocolitis.

Table 2. Comparison of Surgical and Nonsurgical Groups

	Group S	Group NS
No. (%)	66 (35)	121 (65)
Gestational age (wk)	25 ± 3	26 ± 2
Birth weight (g)	715 + 127	742 + 144
Male:female	42:24	61:60
Length of stay (d)	104 + 66	74 + 29*
Survival rate (%)	51 (77)	94 (78)

*$P < .05$, Student's *t* test.

in nonsurviving infants within group S (24 ± 23 *v* 47 ± 36 days of life and 884 ± 390 *v* 1520 ± 956 g, nonsurvivors *v* survivors, respectively; $P < .05$). The causes of death in group S were necrotizing enterocolitis (8, 53%) and respiratory failure (7, 47%) compared with primarily respiratory failure (23, 85%) observed in group NS. Other causes of death in group NS were 2 intracranial hemorrhages, one liver failure, and one congenital heart disease. Infants surviving to discharge in group S required a significantly longer LOS when compared with those in group NS (104 ± 66 *v* 74 ± 29 days, respectively; $P < .05$).

To determine if the stresses of acquired surgical morbidities and their managements affected other nonsurgical morbidities, common complications of extreme prematurity were analyzed between the 2 groups. Neurologic morbidity for the entire ELBW infant population, as defined by the radiographic presence of acquired brain pathology IVH/PVL, was uniformly high for both groups but not statistically different (19, 29% *v* 32, 26%, group S *v* group NS, respectively; $P > .05$). Intracranial hemorrhage grades were also similar between the 2 groups (2.47 ± 1.18 *v* 2.16 ± 0.36, IVH grade, S *v* NS, respectively; $P > .05$). Retinopathy of prematurity was documented with equal frequency in both groups (23, 35% *v* 63, 52%; $P > .05$). Audiology testing results were unavailable for review. Long-term neurologic follow-up for the entire cohort is insufficient at this time to determine the actual functional outcome and frequency of cerebral palsy in affected infants.

Pulmonary morbidity, defined as BPD, was common but not different between the 2 infant groups (44% *v* 65%, group S *v* group NS, respectively; $P > .05$). The trend for less BPD in the surgical group likely represents a selection bias caused by early deaths in this group before the development and documentation of chronic lung disease. When these early deaths are excluded, the incidence of BPD for group S survivors is also 65%. Tracheostomies were required in only 4 (2%) surviving infants to allow for postdischarge mechanical ventilation (2 acquired subglottic stenosis from prolonged intubation, one laryngomalacia, one BPD).

Overall, 24 (13%) infants had necrotizing enterocolitis confirmed by abdominal radiographs (Bell stages II and

III). Only 2 (8%) children weighing less than 1,000 g at diagnosis with Bell stage II NEC documented by pneumatosis intestinalis, could be identified who were successfully treated nonoperatively. Because of the difficulties in distinguishing Bell stage I NEC cases from other sources of sepsis in these infants, the true frequency of successful medical management for this disease could not be determined in this series. Within group S patients, mortality rate rose significantly for those infants undergoing procedures for necrotizing enterocolitis (NEC) and isolated intestinal perforations (41% operatively managed NEC, 37.5% all confirmed NEC). These infants were no different from the entire cohort in gestational age and birth weight (25 $\pm$ 3.6 weeks, 709 $\pm$ 125 g; $P >$ .05). All deaths within this subset were the result of extensive unresectable disease. Isolated ileal perforations were infrequently distinguishable from isolated, small-segment NEC as an etiology of intraabdominal sepsis.

As expected, surviving infants affected by NEC/bowel perforation required more operative procedures (4.5 $\pm$ 3; $P <$ .05) and correspondingly, had longer hospitalizations (170 $\pm$ 80 days; $P <$ .05) than the remainder of the cohort because of recurrent intraabdominal complications. Four (18%) infants (weight less than 800 g) had placement of peritoneal drains as the initial procedure in the management of intestinal perforation. Only one (25%) of these patients was treated successfully without further laparotomy. This child, with a likely indomethecin-induced isolated ileal perforation, had an enterocutaneous fistula, which spontaneously closed after 45 days of drainage. The remaining 3 infants did not improve after their drainage procedure and required laparotomy, resection, and enteric diversion. Five (23%) infants treated with primary laparotomy required multiple abdominal procedures before their planned ostomy closure for additional complications (2 obstructions, one perforation, one ischemia, one abscess).

Long-term gastrointestinal morbidity was greater in infants within group S, requiring procedures for NEC/bowel perforations. Eighty-six percent of the infants from group S were tolerating full enteral feedings in contrast to 100% for group NS at the time of discharge ($P <$ .05). Short gut syndrome, defined as the need for supplemental parenteral nutrition after hospital discharge, was documented in 3 (14%) of the infants requiring abdominal surgery. These 3 infants each required 6 abdominal operations with extensive intestinal resections for the management of NEC and complications. None of these infants, however, continue to require parenteral nutrition at one-year outpatient follow-up.

DISCUSSION

Numerous reports describe improved survival outcome in ELBW infants in association with recent advances in neonatal intensive care.[5,6] These critically ill infants, however, continue to pose significant management and ethical challenges for their caregivers and families. Frequent morbidities of extreme prematurity often have a long-term impact on the quality of life for the infant and family and call into question if outcome variables beyond simply survival are appropriate considerations for true informed decision making.[7]

Our data and outcomes compiled from a large contemporary series of infants treated at a single institution compare favorably with the outcome results reported for other ELBW infant series. Survival rates in excess of 75% (compared with the 58% of Bell et al)[1] point to the recent overall improvements in all aspects of care for these patients. Excluding those infants with NEC, complications requiring surgical interventions did not increase the risk for death when compared with an age- and weight-matched cohort. As such, it appears that these extremely premature infants are able to tolerate both the stresses of their surgical diseases and their managements. Despite these gratifying survival rates, however, the frequency of infants completely normal at discharge, with no neurologic, pulmonary, or gastrointestinal deficits was low.

Unfortunately, both cerebral palsy and chronic lung disease remain frequent sequelae of extreme prematurity. Radiologic evidence of intracranial injury was identified in 27% of the ELBW infants managed at our institution and remains consistent with rates reported in other large series.[8] Long-term outcome for this morbidity is unknown given the limitations of our study and poor predictive value of these radiographic findings with adverse functional outcome and cerebral palsy.[9] Chronic lung disease (bronchopulmonary dysplasia) was an even more prevalent complication in both surgical and nonsurgical patients with an overall rate in excess of 60% for this population. Fortunately, most (98%) of the surviving infants did not require long-term mechanical ventilation after their extensive hospitalization, and many could be weaned from supplemental oxygen at home. Frequent readmissions after discharge caused by transiently worsening respiratory status were uniform to this patient population. Overall, the complications of prematurity requiring surgical intervention and their managements did not appear to affect the frequency or severity for either of these common nonsurgical morbidities.

When analyzing specific surgical diseases, NEC continues to be a frequent morbidity in these high-risk infants carrying with it the greatest mortality risk and management challenges. Although the use of peritoneal drainage procedures is well described for the management of critically ill ELBW infants with NEC/bowel perforations, our experience with this technique remains limited.[10] Similar to other reports, it has been the pref-

erence of the authors to perform primary celiotomy if medical interventions fail to allow definitive management of localized disease and appropriate immediate family counseling for diffuse, unresectable, and unsurvivable intestinal involvement.[11,12] Seventy-five percent of our infants treated initially with peritoneal drainage did not improve with this approach, but ultimately responded to salvage laparotomy. Because of the difficulties in differentiating infants with Bell stage I NEC (suspected) from other sources of sepsis, which result in ileus, the true incidence of this morbidity and overall success rate for medical management could not be determined retrospectively. Of note, the frequency of successful management without surgical intervention was low in our series once NEC was confirmed radiographically by the presence of pneumatosis intestinalis (2 of 26, 8%).

We believe these data provide a contemporary analysis of outcomes for ELBW infants. Overall, survival in these infants, including those requiring surgical interventions for the complications of prematurity is improving. Common nonsurgical morbidities of prematurity do not appear to be adversely affected by the addition of associated morbidities requiring surgical management. These results provide important information for families and caregivers regarding the management, outcomes, and informed decision-making processes for these challenging patients at the extremes of life.

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