ANAESTHETIC IMPLICATIONS OF NEONATAL NECROTIZING ENTEROCOLITIS

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ABSTRACT

A retrospective analysis of infants with necrotizing enterocolitis was done to evaluate the effects of preoperative abnormalities upon anaesthesia and mortality. Mortality was significantly increased in infants weighing less than 1500 grams ($p < .001$). Sixty-nine per cent of the infants had hyaline membrane disease and 35 per cent had platelet counts less than 50×10^9 cells/litre ($50,000/\text{mm}^3$). Perioperative problems include peritonitis, sepsis, hypovolaemia, acidosis, and prematurity. Other ramifications of prematurity and anaesthesia are discussed.

KEY WORDS: ANAESTHESIA, paediatric: COMPLICATIONS, necrotizing enterocolitis.

INTRODUCTION

NEONATAL NECROTIZING enterocolitis (NEC) is a disease of underweight premature infants¹ which is generally related to some form of perinatal stress, such as asphyxia. The pathology of necrotizing enterocolitis is ischaemic necrosis of the gastro-intestinal tract and may be seen in various stages from mucosal ulceration to bowel perforation with fulminant peritonitis.³ Within the past decade there has been an apparent increase in the incidence of necrotizing enterocolitis which may be related to improvement in perinatal care and increased survival of premature infants. Surgical intervention is necessary in approximately twenty-five per cent of infants with this problem. To provide optimal anaesthetic care to these seriously ill premature infants the anaesthetist should be familiar with the pathophysiology, clinical course, and therapeutic modalities of the syndrome. The purpose of this report is to present an analysis of our experience with necrotizing enterocolitis during a six year period and to review the disease and its anaesthetic implications.

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METHODS

A retrospective analysis was done of all cases of necrotizing enterocolitis presenting for surgery at Riley Childrens Hospital between July 1973 and December 1979. Based upon the pathophysiology of the disease we felt the following parameters were important: birth weight, estimated gestational age, preoperative haematocrit and platelet count, preoperative respiratory status, anaesthetic technique, and postoperative complications.

RESULTS

Necrotizing enterocolitis was diagnosed in 123 infants in the newborn intensive care unit between July 1973 and December 1979. The 32 patients who required surgical intervention are the basis of this report. Average weight was 1.52 kg (range 0.60–3.20 kg) and average gestational age was 32 weeks (range 25–40 weeks).

Mortality was 53 per cent (17 of 32). Six of the 17 deaths were infants with necrotizing enterocolitis of the entire bowel and were not salvagable. Thirteen of the deaths (including one during operation) occurred within 48 hours of operation and the remaining four from 5–66 days postoperatively. We found a very good correlation between mortality and birth weight (Figure 1). Seventy-six per cent (13 of 17) of the infants weighing less than 1500 grams died, while only twenty-seven per cent (4 of 15) of

FIGURE 1 Plot of mortality versus birth weight. Mortality is higher at weights less than 1500 grams ($p < 0.001$)

FIGURE 2 Plot of mortality versus estimated gestational age.

those weighing more than 1500 grams died. This was statistically significant at a p value < 0.001 (chi square test using Yates correction factor). The correlation between mortality and gestational age showed a similar trend but was not statistically significant. Sixty-nine per cent of the infants (22 of 32) had co-existing hyaline membrane disease and of these infants 13 (59%) died (Table 1). Platelet count was available in 23 of 32 patients. Six of eight patients with a

platelet count less than 50×10^9 cells/litre ($50,000/\text{mm}^3$) died. Anaesthetic techniques varied widely, depending upon the severity of the illness. We were unable to make any correlation between type of anaesthesia and outcome.

DISCUSSION

The classic clinical features of necrotizing enterocolitis include abdominal distention, bloody diarrhea, and retention of gastric contents. Non-specific symptoms include lethargy, irritability, apnoea, jaundice, and temperature instability.⁴ Abdominal radiography may show intramural bowel gas (pneumatosis intestinalis) or hepatic portal venous gas, both of which are highly suggestive of necrotizing enterocolitis.⁵ In later stages of the disease radiography may show evidence of bowel perforation. The absolute aetiology is unknown and may be multifactorial.^{6,7} Infection, umbilical artery catheterization, altered host defense, endotoxin, hyperosmolar feedings, and exchange transfusions have all been implicated as causative agents.^{2,8} Necrotizing enterocolitis has also been reported after abdominal⁹ and cardiac surgery.¹⁰ A final common pathway in the pathogenesis does seem to exist. The initial insult is bowel ischaemia with damage to the intestinal mucosa. Bowel gas enters the sub-mucosal region and may enter the mesenteric veins and hepatic portal venous system.^{11,12} Bowel necrosis may result in multiple perforations with generalized peritonitis, hypovolaemic shock, and metabolic acidosis. Initial medical management includes discontinuation of oral feedings, nasogastric suction, intravenous fluids, and systemic antibiotics.² Indications for surgical intervention include perforation, progressive acidosis and generalized peritonitis.¹³ Thrombocytopenia has been reported in 88 per cent of infants with necrotizing enterocolitis and thirty per cent developed clinical bleeding.¹⁴

TABLE I

Parameter	Number	Died
Platelet count ($N = 23$)		
$50,000 / \text{mm}^3$	8	6 (75%)
$50,000 - 100,000 / \text{mm}^3$	4	0 (0%)
Appropriate for gestational age	23	12 (52%)
Small for gestational age	9	5 (56%)
Hyaline membrane disease	22	13 (59%)

Anaesthetic Considerations:

In infants with necrotizing enterocolitis the anaesthetist is confronted with the problems of prematurity, hypovolaemia, sepsis, acidosis, and hepatic portal gas.

Ninety per cent of these patients are premature and many have co-existing hyaline membrane disease which requires varying amounts of supplemental oxygen and mechanical ventilation. Preoperative respiratory status must be carefully evaluated and ventilatory support during opera-

tion should be oriented to the maintenance of preoperative oxygen tensions. These infants are also at risk for development of retinopathy of the premature (retrolental fibroplasia). Excessive oxygen tension in the retinal vessels interferes with normal vascularization of the developing retina. Newly formed capillaries are destroyed and abnormal vessels are formed. The more severe cases of retinopathy can ultimately progress to retinal scarring and blindness. Eighty to 90 per cent of the cases of retinopathy will show regression of the retinal changes.¹⁵ To minimize the risk of retinopathy we recommend that arterial oxygen tensions be maintained at 7.98 to 11.9 kPa (60 to 90 mmHg) during operation. Hypoxia is a greater danger to the infant than retinopathy and must be avoided. The use of a continuous inline oxygen monitor and an air flowmeter on the anaesthetic machine will permit the fine control of inspired oxygen concentrations. Direct intra-arterial monitoring of oxygen tensions and transcutaneous oxygen monitoring will allow better control of arterial oxygen tensions. Continuous transcutaneous oxygen monitoring is an important addition to monitoring capability. Transcutaneous oxygen monitoring has become a routine part of monitoring in the neonatal intensive care unit. Anaesthetic gases, especially nitrous oxide and halothane, can interfere with transcutaneous oxygen electrode function.¹⁶ It has been shown that during anaesthesia transcutaneous oxygen tension correlates well with arterial oxygen tension if skin flow is maintained, arterial oxygen tension is between 7.98 kPa (60 torr) and 13.1 kPa (100 torr), and a Mylar membrane is used in the skin sensor. The Mylar membrane minimizes interference from nitrous oxide and halothane.¹⁷

Hypovolaemia from peritonitis and sepsis can be profound and intraoperative fluid resuscitation is critical. Perioperative fluid administration including blood and crystalloid solutions can approach 150 to 200 ml·kg⁻¹. Because of varying degrees of hypovolaemia from sepsis and peritonitis it is not possible to recommend rigid guidelines for fluid replacement during operation. Infusion rates for crystalloid solutions (5 per cent dextrose in lactated Ringer's solution) approach 8 to 10 ml·kg⁻¹·hr⁻¹. The use of blood and plasma solutions are best guided by serial acid-base and haematocrit measurements. Thrombocytopenia and the associated coagulopathy may require blood and platelet transfusions. The normal platelet count for the preterm infant is 280 × 10⁹ cells/litre (280,000/mm³) which is

similar to that of the normal adult. Normal bleeding times are maintained in the adult when the platelet count is above 100 × 10⁹ cells/litre (100,000/mm³). Although preterm infants usually have a platelet count above this level they do have a propensity for bleeding which may be secondary to vessel fragility or reduced platelet function. Suggested minimum platelet counts for surgery from adult studies range from 50 to 100 × 10⁹ cells/litre (50,000–100,000/mm³). For transfusion with platelet concentrates the following formula can be used to calculate the expected increase in platelet count:

$$\text{Expected increase} = 2 \frac{0.7 \times 10^{11} \times N}{\text{Blood volume}} \\ \text{(cells/litre)}$$

where the blood volume is given in litres and N is the number of units of platelet concentrate administered.¹⁸ Using .085 litres·kg⁻¹ (85 ml·kg⁻¹) as the blood volume for newborns this formula suggests that the administration of 0.18 unit·kg⁻¹ would increase the platelet count by 100 × 10⁹ cells/litre. The newborn has low levels of coagulation factors II, VI, IX, X, XI, and XII.¹⁹ Factors II, VII, IX, and X are all vitamin K dependent factors. Therefore it is recommended that vitamin K be administered routinely to all newborns. In the event that coagulation needs to be restored to normal immediately, fresh plasma, fresh-frozen plasma, or prothrombin complex can be administered. The administration of 10 ml·kg⁻¹ of fresh frozen plasma or platelet concentrate will supply the minimum haemostatic factors for most newborn haemostatic problems.

These small infants can lose heat rapidly and core body temperature (oesophageal or nasopharyngeal) should be monitored. The administration of warm, humidified anaesthetic gases will reduce heat loss and minimize the risk of tracheal tube occlusion from inspissated secretions.²⁰ Administration of warmed blood and intravenous solutions, temperature controlled blankets, and overhead radiant warmers will also reduce heat loss.

Routine monitoring during neonatal anaesthesia includes continuous electrocardiogram, core temperature, stethoscope (oesophageal or precordial) and blood pressure. Monitoring of blood pressure in infants with necrotizing enterocolitis is especially critical. The use of an indwelling arterial catheter for direct blood pressure monitoring and measurement of acid base status is most helpful in guiding fluid

resuscitation. The most frequently cannulated arteries for direct intra-arterial monitoring of blood pressure are the radial and posterior tibial arteries.

There is no single anaesthetic agent which is superior. The potent halogenated agents may produce an undesirable degree of myocardial depression and hypotension. Fentanyl causes less hypotension and is a more desirable drug for maintenance. We feel that the use of nitrous oxide in patients with necrotizing enterocolitis is unwise. Although there is no experimental clinical evidence to support this contention, the theoretical implications of expansion of intramural and portal gas pockets should caution against its use. Mural gas from infants with necrotizing enterocolitis is composed of hydrogen, nitrogen, carbon dioxide, and traces of oxygen.²¹ Due to the greater blood solubility of nitrous oxide (0.47) relative to nitrogen (0.0122) and hydrogen (0.0149)²² the size of bubbles could increase. Expansion of submucosal gas bubbles could further compromise bowel blood supply. an additional hazard of mesenteric vein gas is the risk of gas embolism from the passage of gas through the ductus venosus into the inferior vena cava. The ductus venosus may be patent for two to three weeks after birth in term infants.²³

These infants receive potent antibiotics and the interaction of these antibiotics and neuromuscular blocking drugs must be considered.²⁴

The mortality in our group of infants with necrotizing enterocolitis is comparable to other reports.² Despite aggressive medical and surgical therapy the mortality continues to be high. The premature infant with necrotizing enterocolitis may be extremely ill with profound hypovolaemia and significant pulmonary disease and successful perioperative management presents a formidable challenge.

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RÉSUMÉ

Les auteurs ont fait la revision des dossiers de trente deux enfants opérés pour entéro-colite nécrosante du nouveau-né. Le but de l'étude était de mettre en évidence l'impact des anomalies pré-opératoires sur la mortalité et la conduite de l'anesthésie. La mortalité totale a été de 53 pour cent (17/32). On a observé entre autres: 1) une mortalité plus élevée ($p < 0.001$) chez les bébés de moins de 1500 g. 2) un syndrome de membrane hyaline chez 69 pour cent des patients et 3) un décompte plaquettaire inférieur à 50×10^9 /litres ($50,000/mm^3$) dans 35 pour cent des cas. Parmi les principaux problèmes péri-opératoires, on a relevé la péritonite, l'état septique, l'hypovolémie, l'acidose et la prématurité. La conduite de l'anesthésie et les problèmes liés à la prématurité sont discutés.