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Physiologic Considerations in the Surgery of Infants

C. EVERETT KOOP, M.D., Sc.D. (Med.), F.A.C.S., F.A.A.P.*

The physiologic responses to surgical situations encountered in infancy and early childhood differ from those expected in adult patients. As the age of a child increases, his physiology approaches that of an adult and conversely the younger (or at times the smaller) the pediatric patient, the greater is his variation in physiologic response. The differences are not solely quantitative, and many deviations from the expected are encountered when the sick infant is treated like a miniature adult.

THE LIMITED RESERVE OF INFANTS

It is true that the principle of limited reserve when fully understood in pediatric preoperative and postoperative care serves as a useful guide to management, but other qualitative differences in response must also be appreciated if one is to avoid troublesome morbidity in pediatric surgical patients. In spite of their limited reserve, young children have a surprising way of bouncing back from procedures that leave adult patients in a prolonged debilitated state.

Babies die of exhaustion while more erudite terms are sought to explain their distress. The young infant, especially the premature or immature baby, must be permitted rest that would seem to pamper unnecessarily an adult patient. Several examples might prove profitable. In the planning of x-ray studies, especially when the patient is to be deprived of fluid and nutrition, techniques should be planned in advance, executed promptly, and the patient returned to his normal routine as quickly as possible. His treatments, such as the hypodermic administration of drugs, changes in dressing, and the recording of vital signs should be grouped at the same time interval so that one disturbance can serve three or four needs.

From the Surgical Clinic, Children's Hospital of Philadelphia, and the Harrison Department of Surgical Research, Schools of Medicine, University of Pennsylvania, Philadelphia.

* *Associate Professor of Pediatric Surgery, Schools of Medicine, University of Pennsylvania; Surgeon-in-Chief, Children's Hospital of Philadelphia; Assistant Surgeon, Hospital of the University of Pennsylvania.*

Rest from internal effort is perhaps more important than rest from external stimuli. Infants with an increased respiratory rate, especially those whose inspiratory phase meets with obstruction, tire readily and should be protected early and supported maximally. These infants can maintain a rapid respiratory rate and pull steadily against respiratory obstruction, showing signs of sternal retraction but no cyanosis, with little or no alteration in vital signs. Eventually, they reach the end of their reserve at which time vital signs change rapidly and resuscitation may be impossible. The maintenance of an atmosphere of high oxygen concentration and humidity, aspiration and clearing of the airway, prevention and treatment of abdominal distention which diminishes vital capacity because of elevation of the diaphragm, and a position of maximal respiratory ease should be instituted prophylactically in infants when alteration of respiratory physiology might be expected.

RESPIRATORY PHYSIOLOGY

The subject of respiratory physiology in newborn and young infants deserves some discussion. Young infants have a relative respiratory insufficiency. When under stress, their respiratory function is not adequate. In large measure this is due to anatomical differences in the lung structure, where alveoli are not fully developed saccules.[1] Full alveolar development is probably not complete until about the age of two years. Because of this, the infant has to move about twice as much air to meet basal requirements.

Infants meet stress with an increased rate rather than an increased depth of respiration, which is contrary to the first response in adults.[2] Only late in stress is there an increased volume of air exchange. Along these lines, however, it is noteworthy that there is much normal variation in function. For example, the sleeping respiratory rate of an infant may vary between 20 and 80 per minute, and neither extreme will be maintained for long. The tidal volume is 18 to 20 cc. in the newborn full-term infant, at three months reaches 35 cc., and at one year 60 to 65 cc.

Oxygen consumption is greatly increased in infancy, being 7 cc./kg./m. in a normal newborn and 10 cc./kg./m. in a nine month old youngster. After that age, oxygen consumption tapers off to reach approximately 4 cc./kg./m. in adult life. Figures of this type are most accurate when based upon surface area,[3] but this is not a readily available means in clinical practice and these approximate ages are helpful in knowing the differences in this phase of respiratory physiology.

Adults have sudden cardiac complications during their periods of stress, such as anesthesia and surgery. In children, respiratory crises seem to be more common than cardiac. Many factors, both known and unknown, play their part in this. In early infancy a decrease in arterial carbon dioxide tension will result in depression of respiration. Overventilation, for example, may produce apnea. Newborn infants are generally thought to have a resistance to anoxia, but this should not lead to a feeling of security at the expense of proper respiratory support. True Cheyne-Stokes respirations in infants reflect cerebral damage due to birth injury, or severe anoxia. If no known cause exists, prompt central nervous system investigation should be undertaken. Such patients frequently survive their respiratory crises, however. When cardiac arrest does occur in infants and young children, it is frequently preceded by a long period of respiratory distress.

PRECAUTIONS IN FLUID ADMINISTRATION

It must be remembered that the blood volume of a 6½ or 7 pound infant is not more than 300 cc. If a loss of 10 per cent of that, or 30 cc., is sustained, it would compare with a hemorrhage of 600 cc. in an adult. Therefore calculation for fluid infusion and concern over the prevention of blood loss must be thought of in terms of fraction of the whole rather than in absolute volumes. The infusion of 50 cc. into such an infant would be the equivalent of 750 cc. used in an adult of average weight. Electrolytes in what may seem like small amounts relative to adult requirements are correspondingly large in amount when given to infants.[4]

Although each clinic has its rules-of-thumb for the administration of fluids and electrolytes, no system can replace the value of frequent reevaluation of the patient's state of hydration, urinary output, and special needs.

It may be worth considering that pediatricians are usually called upon to treat dehydrated sick infants with parenteral fluids, while the surgical patient presents chiefly a problem in the maintenance of normal requirements with replacement of loss. The medical pediatrician therefore usually suggests more fluid than surgeons have come to rely upon. Surgical patients in general are maintained on a somewhat smaller volume of fluid than medical patients and salt is restricted to the normal amounts contained in blood or plasma given in transfusions and in the fluids given to replace losses by gastric drainage for at least the first postoperative day. Thereafter normal requirements are met. Every effort should be made to meet fluid requirements by mouth and to use a simple formula as early postoperatively as possible. Even the simplest formula of skimmed milk provides enough electrolytes to avoid parenteral supplement.

A common error in the preoperative preparation of a pediatric patient is the routine withholding of fluids preoperatively, as is the custom in adults, starting with the midnight before operation. While this might be a satisfactory method for adults, it deprives the infant of too great a portion of his need. Therefore pediatric patients should be put on clear liquids six hours prior to operation, and given such fluids up to four hours before operation for the older children and up to two hours before operation for the infants.

When fluids are given young infants parenterally, scalp veins are used until an age where the vessels of the extremities permit an intravenous infusion. When operative procedures are undertaken in which blood loss is expected, when there is uncertainty as to the length of the procedure, or where the operation will be prolonged, intravenous fluids should be given during the operation and a system attached to the infusion apparatus which will permit the rapid administration of blood needed. In the latter instance where maintenance of an intravenous route is essential, a cut-down in an ankle vein is necessary and provides a safety measure of proven merit.

SHOCKLIKE STATES

The signs of shocklike states in infants, like those of impending exhaustion, appear suddenly. The common practice of not taking blood pressures in infants and the uncertainty in counting rapid pulse rates add to the difficulties of assessing impending shock. Pulse rates are most accurately learned by auscultation of the cardiac rate, and blood pressures are reliable if small pneumatic cuffs are properly applied and the examiner has familiarized himself with the technique.

Even under ideal conditions such as these during the recording of vital signs while a patient is under anesthesia, hypotensive states due to blood loss are detected in a small pediatric patient by sudden drop in blood pressure rather than slow alteration in circulatory signs. With sudden hemorrhage, there may be a slowing of the rate and this frequently happens before the blood pressure falls and almost always indicates the need for blood replacement. The response of the hypovolemic patient is frequently delayed and abrupt, in that restoration of blood volume is frequently followed by no apparent improvement in vital signs and then suddenly by restoration of blood pressure and a return of the pulse to normal. In fact, the pulse may overshoot its normal rate on its return. One can easily overtreat the blood loss if he waits for the return of vital signs to indicate the efficacy of replacement. Under such circumstances, pulmonary edema may be present in a patient who a few minutes before showed signs of shock.

In the patient under anesthesia, with cut-down in place, blood loss should be measured, weighed in discarded sponges, or otherwise estimated and replaced as loss occurs. In long procedures additional blood is given in quantities of approximately 5 to 10 cc. per pound per hour. In newborn patients with high hemoglobin concentrations, or in cardiac patients with polycythemia, plasma is used as the initial replacement for blood loss and whole blood is given only if the operative loss is excessive. With either blood or plasma, the "maintenance" transfusions of babies during operation can be less in the robust infant. The chronically ill child, especially the neurosurgical patient, does far better when adequately supported with blood transfusions over and above his loss.

When one encounters an infant in shock from blood loss, overwhelming sepsis, or other causes not intracranial in origin, intravenous fluid therapy should be given immediately. Blood replacement is begun as soon as possible using O-Rh negative blood, but transfusion is not pushed until a satisfactory return of vital signs is seen. Rather, blood is given in reasonable quantity, say 5 cc. per pound in young infants, and that is followed by a period of waiting to see what the delayed response might be. If no improvement is noted after ten minutes or so, additional blood is judiciously given intermittently, waiting again a few minutes for delayed response. Peripheral constriction apparently persists in some young children who have had prolonged hypotensive states; and long after there has been improvement in color, body temperature and respiratory effort, and when blood replacement has been carried as far as seems safe volumetrically, peripheral pulses remain difficult to feel and mottling persists in the extremities. This situation is perhaps most commonly seen after neurosurgical procedures, following resuscitation after cardiac arrest, or after severe untreated hemorrhage. The continued transfusion of blood is a tempting therapy but dangerous, and gentle support is frequently followed by a return of a physiological peripheral circulatory state.

Studies by Beecher and his group[5] suggest that the infant's adrenal is immature and he produces chiefly norepinephrine. The most peripheral of the palpable pulses disappears first, to be followed by those more central. Then there is a drop in norepinephrine secretion or the discrepancy between blood volume and vascular bed becomes too great and peripheral dilatation follows.

This mechanism may also account for the fact that there is a metabolic acidosis following open-drop ether in most infants under one year of age and in about one-half of those between the ages of one and ten. This acidosis is not prevented but is lessened by glucose administration. The severity is apparently proportional to the depth of anesthesia rather than its duration.

GASTROINTESTINAL CONSIDERATIONS

Abdominal distention is a serious hazard in the age group in which preventive and therapeutic measures are most difficult to use. The young infant who develops a paralytic ileus not only has disturbed nutrition and requires parenteral fluids but also has a respiratory problem produced by elevation of the diaphragm.

Trauma which appears to be trivial in an infant, such as mild bowel damage from incarceration of a hernia, may produce an ileus with distention which presents a serious challenge in management. In such a patient or in one whose intussusception has been reduced and the extent of bowel damage is known, the prevention of distention is far superior to its treatment a few hours later. The use of a high oxygen atmosphere seems beneficial and suction drainage by means of a No. 8 or No. 10 rubber catheter keeps the stomach contents from running into the small bowel. Multiple holes in the catheter are helpful in maintaining adequate drainage. The usual gastric suction tubes, even those of small caliber, have their holes too far apart for efficient use in small stomachs.

Babies are air swallowers, especially when crying, and this phenomenon increases the problem in the patient with a paralytic ileus. Long tubes such as the Miller-Abbott variety are not feasible in the small infant for many reasons. Drugs are occasionally helpful, and both prostigmine and Pitressin have been used to advantage.

Gastric secretion under anesthesia seems to be comparatively greater than that seen in adults and for that reason we find it profitable to aspirate the stomach at the close of anesthesia in order to lessen the danger of pulmonary aspiration in the patient who vomits postoperatively in a state of hyporeflexia.

The evaluation of a surgical patient is almost always difficult. Not only is he unable to tell of his symptoms, but he may be on the verge of shock and not show it, or he may be ill with infection and have no fever, or he may be approaching exhaustion and appears no different than he has in the previous several hours.

In addition to the broad principle of the infant's limited physiologic reserve, many specific situations might be enumerated dealing with the problem of preoperative and postoperative care in reference to the various lesions amenable to surgical correction. These are beyond the scope of this clinic, however, but most can be anticipated by maintaining a real suspicion that physiologic changes in small children may remain hidden until they are frankly pathologic and by planning prophylaxis and therapy of narrow scope and with constant re-evaluation.

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1740 Bainbridge Street
Philadelphia 46, Pennsylvania