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The Pediatric Anesthetist, 1950–1975

Robert M. Smith, M.D.*

To follow the pediatric anesthetist through the past 25 years is to describe the development of pediatric anesthesia. This is a large task, for one must include the contributions of numerous individuals, as well as consider the many forces that have worked towards or impeded the progress of the specialty. The task, however, is pleasant, as dealing with children is in itself a pleasant undertaking, and pediatric anesthesia a most rewarding way of life.

Actually, the year 1950 does not mark the beginning of pediatric anesthesia, nor does 1975 represent its completed development, but the intervening years do stand as an important formative period. Rather than losing ourselves in a continuing account of the individuals or the incidents that have been involved, it would be easier, and hopefully more interesting, to describe the initial setting and then contrast this with the present scene. In so doing, an attempt should be made to point out the changes that have occurred, and the progress that has been made.

The Pediatric Anesthetist—"Then"

To find the real beginning of pediatric anesthesia, we turn to the 1930's, to find Robson[1] first describing techniques especially devised for anesthesia in children. Very soon thereafter, Ayre,[2] of Newcastle-Upon-Tyne, first introduced his simple "T" piece, which is even now widely used. At about the same time, surgeons also first began to look beyond the limitations of tonsillectomy, appendectomy, and simple orthopedic procedures as the only suitable operative procedures for children. With Ladd accepting the challenge of neonatal bowel obstruction and Gross opening the field of congenital cardiac surgery, demands were made for greater anesthetic capability. Ether by open-drop or insufflation quickly became inadequate, and the resulting need for the development of new anesthetics and new techniques constituted the beginning of pediatric anesthesia.

This came about at a fortunate time. Antibiotics had just appeared, the importance of fluid therapy was beginning to be appreciated, and, thanks to World War II, anesthesiology was enjoying its greatest surge of enthusiasm. Nonetheless, the beginnings of pediatric anesthesia were slow, for both surgeons and anesthetists were in unknown territory. Unfortunately, even the now most obvious fundamentals of blood replacement and the control of arterial pressure during repair of coarctation were lessons to be learned by trial and error. Reliable technique for many operations performed routinely today were gained at the expense of early lives lost.

By 1950, a real start had been made. Montreal had contributed Leigh and Belton as early leaders, Smith had been promoting the precordial stethoscope in Boston, Deming in Philadelphia was proving the safety of endotracheal intubation, and McQuiston in Chicago had opened the door to hypothermia with his circulating-water mattress. In England, Anderson[3] had induced hypotension in children with trimethaphan, and Rees's[4] first article suggesting that ether should be used for neonates, since relaxants were not safe, had appeared.

It is obvious that full-time pediatric anesthetists should not take credit for all the advances in the field. In America, early clinical accomplishments were made by several outstanding nurse anesthetists, including O. Berger and B. Lank, upon whom both Blalock and Gross depended during their initial surgical successes. Other important contributions came from a number of versatile general anesthesiologists, as well as from surgeons, pediatricians, and cardiologists, supported by basic scientists in a number of areas.

From a clinical standpoint, 1950 showed enthusiasm and promise, but anesthetic

*Children's Hospital Medical Center, 300 Longwood Ave., Boston, Massachusetts 02115.
Address reprint requests to Dr. Smith.

methods were based more upon tradition and assumption than upon careful measurement. General anesthesia with ether, or occasionally cyclopropane, was dominant, and spontaneous ventilation was mandatory, since the pattern of respiration was considered the most important sign of anesthetic depth. Experience in the anesthetic management of small children was limited, and individual judgment weighed heavily. Local rules mandating the use of, or contraindication to, an agent or method might sometimes be proclaimed following only very limited trial. However, large numbers of operations safely performed under a wide variety of anesthetic approaches made it obvious that there was seldom just one correct road.

There were both successes and failures. One of the greatest challenges of the day was unquestionably the infant with tracheoesophageal fistula (first successfully repaired in 1941 by Haight[5]). The child was frequently rushed to the big center to be operated upon by the chief surgeon, and anesthetized by the most skilled available anesthetist. The great frustration, then as now, came in the last-ditch attempt to save the life of an attractive child who would finally rally, then die suddenly the next day. Another great heart-break was to witness the slow miserable decline of the child with cystic fibrosis; yet, equally great joy existed in taking the baby boy with pyloric stenosis, once a fatal lesion, passing a nasogastric tube followed by adroit anesthesia and a quick operation, to produce an anatomically corrected and normal child.

Complications occurred frequently, most of them due to blood loss, anesthetic depression, or airway obstruction. The term "cardiac arrest" was heard all too frequently, and connoted an unexplainable act of God. The treatment for cardiac arrest was open-chest cardiac massage, unpleasant enough in the operating room, but horrible in an open ward. Tonsillectomy, appendectomy, pyloromyotomy, and reduction of fractures were widely undertaken in many general hospitals, but a lack of experienced anesthetists resulted in numbers of preventable deaths due to aspiration of vomitus, convulsions, and post-tonsillectomy bleeding. Mortality associated with hare-lip repair was reported with disturbing regularity throughout the country.

Concern with the fears and phobias of children had been voiced since the first discussion of pediatric premedication by Waters.[6] Unfortunately, such concern did not always appear deeply rooted. Although it was felt preferable to have the child asleep through heavy sedation or basal anesthesia, should he still be alert and uncooperative, many believed that further time should not be wasted, and preferred to "get it over with." Survivors of this latter treatment return with their children today, fearful of repetition, and vastly relieved to learn that whatever our technique, the agent will not be ether.

The pediatric anesthetist was also subject to occasional calls outside of the operating room. He could set up an open-top Burgess oxygen tent for the cyanotic or distressed infant, or assist in the control of the child convulsing from epilepsy or tetanus. The anesthetist's role in the treatment of severe asthma consisted in etherizing the patient in order to relieve bronchial spasm and to enable the endoscopist to remove bronchial plugs. Infants with hyaline membrane disease presented an overwhelming problem, with failure attending all attempts at therapy, including oxygen, steam, humidity, or intubation and controlled ventilation. During the poliomyelitis epidemics of the 1950's the anesthetist joined in an all-out attempt to keep these children alive, often anesthetizing them in the tank respirator, sliding the child part-way out for a tracheostomy and then sealing him back in the tank.

Although little was available in the way of exact information, there was a new and strong developing general interest in pediatric anesthesia, and it became a popular topic for refresher courses and lectures. A field of literature in pediatric anesthesia was also becoming increasingly available. The first text on pediatric anesthesia by Leigh and Belton[7] was published in 1948, and numerous articles on topics in pediatric anesthesia began to appear. There was much interest in preoperative medication (Poe and Karp,[8] Leigh and Belton,[9] Burnap, Gain and Watts[10]), and the management of anesthesia for repair of congenital cardiac defects (Berger,[11] Harmel and Lamont,[12] McQuiston,[13] Smith,[14] and Virtue[15]) was another topic of importance.

Research, as we now know it, was severely limited. Preoccupation with the practical demands of the clinic, the high emotional resistance to "experimentation" on children, and the lack of suitable scientific methods and instruments all impeded development. Prior to 1960 only two notable research studies in pediatric anesthesia were published by anesthesiologists, that by Eckenhoff[16] dealing with trauma and that of Bunker *et al.*[17] on the infant's response to anesthesia.

Finally, the stage of the 1950's cannot be correctly set without special mention of Digby Leigh, unquestionably the most colorful personality of early anesthesia. An alert clinician and teacher, he was an especial joy to all audiences whom he delighted with his unforgettable twang and his sharp wit. Further, he had the incredible ability to goad and tease his colleagues, back them into corners, and tweak their noses, without seriously damaging their feelings.

The Pediatric Anesthetist—"Now"

It is 1975. What has happened to pediatric anesthesia and the pediatric anesthetist? What changes and what progress are to be found?

CHANGES

The increased magnitude of the overall production is at once obvious; operating rooms are greatly enlarged and filled with equipment and people. Often ten to 12 individuals will engage in a single operative procedure on a small infant. Gradually it becomes evident that a major development has taken place. The term "pediatric anesthesia" no longer stands for a few circumscribed areas where single individuals work out their answers to individual problems. Pediatric anesthesia now stands as a cohesive medical discipline, encompassing important areas of focal concentration, but with a wide diffusion of skills which, like the skills of pediatric surgery, are practiced by many physicians who do not limit their practice to the pediatric age group. Thus, pediatric anesthesia exists both as a concept and as a medical subspecialty. It has institutional and departmental independence, its own scientific organizations, as well as its own body of literature.

In many situations pediatric anesthesia has extended itself in a somewhat ameboid fashion, encompassing, in addition to surgical anesthesia, many other areas of activity including the Recovery Room, Intensive Care Unit, Neonatal Nursery, Emergency and Resuscitation Services, and Pulmonary Therapy. Indeed, it is in these newer territories that much of the current activity is taking place, the technique of surgical anesthesia having now become comparatively stable and predictable.

Picturing pediatric anesthesia as an entity makes it easier to visualize the effect that certain external forces have played in shaping its development, for it has been subject to many outside influences, including the progress of pediatric surgery itself, the rate of population growth, the evolution of preventive medicine, and even the state of the economy. Anesthetists are proud of their freedom from surgical domination, but certainly we cannot deny that our own welfare has depended considerably upon the status of the surgeon. Thus, for many reasons, it is of interest to find out what has happened in pediatric surgery. There was reason to hope, in 1950, that a system of special pediatric centers would be established throughout the country, where teams of qualified surgeons, anesthetists and other professionals could provide optimal care for children with serious problems. The belief was maintained that such a system would be best for the patient and for those caring for him. In an excellent recent critique on the present status of pediatric surgery, Ravitch[18] has re-emphasized his conviction that 50 major pediatric hospitals and 300 pediatric surgeons could easily care for all of the critical pediatric lesions† that develop in a given year.

† Ravitch lists the following lesions as critical: 1) esophageal atresia and tracheoesophageal fistula; 2) omphalocele and gastroschisis; 3) imperforate anus; 4) intestinal atresia; 5) congenital diaphragmatic hernia; 6) Hirschsprung's disease; 7) rhabdomyosarcoma; 8) Wilms' tumor; 9) neuroblastoma.

Regionalization, however, has not developed. The dozen promising centers that existed in 1950 did not seed widely, and indeed have had difficulty in surviving. The failure to advance toward a program of regionalization has been due to a number of factors. Construction and maintenance of such regional institutions has become enormously expensive. The new 259-bed Children's Hospital of Philadelphia is said to be the most costly building ever erected by the State of Pennsylvania. In 1974, Boston's Children's Hospital Medical Center faced a severe deficit in spite of a 53-million-dollar income.

One result of active teaching programs has been to reduce admissions to the "mother" hospital. Young surgeons accomplished in the difficult procedures that were developed in the centers have moved to the periphery and now intercept the patient on his way to the city. To survive, the teaching hospital has to develop new techniques by which to reach yet-untapped categories of patients. This has involved ever-increasing expenditure of time, effort and money, and the viable product, whether a child surviving an 80 per cent burn or a spastic 800-gram neonate, often represents dubious achievement.

The result of these natural forces has created the present scattering of pediatric patients among hundreds of partially equipped hospitals, where they are attended by a qualified but heterogeneous group of surgeons and anesthetists. G. J. Smith[19] has compared the types of pediatric procedures performed in pediatric centers, large general hospitals, and small general hospitals. Throughout the country more pediatric operations are now being performed in general hospitals than in specially equipped pediatric hospitals. This includes not only tonsillectomy, herniorrhaphy, appendectomy and traumatic surgery, but complicated congenital heart surgery and correction of other serious congenital defects.

The effect of this diffusion of pediatric surgery upon the development of pediatric anesthesia has not been beneficial. The anesthesia staff of a large general hospital may well include one or more members highly skilled in pediatric techniques, but it would be most unlikely, in such a hospital, to find a team qualified or sufficiently motivated to develop new pediatric concepts or techniques. The anesthetist who wishes to concentrate on pediatric anesthesia requires the facilities of an organized pediatric center to which a large proportion of the major pediatric surgical cases will be attracted, and in which he will be surrounded by colleagues working in closely related fields. To provide a more promising future we may well require corrective planning and action on a national scale. Otherwise, the pediatric centers are likely to continue their present restrictive trend, and the pediatric anesthetist will soon face the prospect of a gradual limitation of his work to the care of children with exotic diseases, cancer, and chronic renal failure.

In addition to the disadvantageous distribution of pediatric patients, there has also been an absolute reduction in total numbers. The combined effects of birth control, elective abortion, and the decreasing incidence of birth defects in the population have significantly reduced the total need for pediatric care. Thus, when looking at the whole picture, we see a subspecialty which has survived, grown, and undergone extensive change, but the external forces that surround it have altered its course and now threaten its very future.

Progress

Change is usually the more obvious, but progress is certainly a better measure of accomplishment. The important question is not what changes have been made, but what is the progress we have made? Progress in any field can best be evaluated by measuring the advances towards a given goal. The goal(s) of the pediatric anesthetist have not been officially set down, but might be assumed to include the following:

Goals of Pediatric Anesthesia ‡

1. To establish the specialty on the basis of rational scientific knowledge concerned with the child's response to anesthesia and surgery.
2. To extend the capabilities of the pediatric surgeon through the development of

‡ Formulated in collaboration with D. J. Steward, M.D., Toronto.

increased anesthetic skills and the wide availability of pediatric anesthetists.
3. To reduce mortality, morbidity, and the suffering of children undergoing surgery.
4. To improve resuscitative and supportive therapy for infants and children with non-surgical problems.
5. To broaden the educational and investigative aspects of pediatric anesthesia.

To what extent have we advanced toward these goals? The first seems definitely within reach. Sufficient documentation has been gained as to the characteristic responses of the infant and child to justify the establishment of pediatric anesthesia as a separate discipline. Gross anatomic differences are obvious, and the emotional variances reach an extreme. Pharmacologic and physiologic differentiation have been clearly defined. For example, the different effect of muscle relaxants in the neonate, as demonstrated by Stead,[20] Churchill-Davidson,[21] Bachman,[22] and others, is but one of many differences in pharmacokinetic activity of the infant. Another variable relates to the more rapid uptake of inhaled anesthetics, due to the relatively greater cardiac output of the infant and the greater flow to richly perfused tissues, which Salanitre and Rackow[23] and Eger[24] have reported.

Since much of the pediatric anesthetist's activity has been in the delivery of clinical service, it is to be expected that our greatest progress would be in extending the capability of the surgeon. This certainly has been true. With ample assistance, the anesthetist has taken tremendous strides, removing physiologic barriers and medical traditions with apparent impunity. The surgeon can now perform longer operations, and can operate on sicker patients than was ever believed possible. He may schedule a 12-hour elective mid-face advancement on a 6-year-old for cosmetic improvement, or a Dwyer anterior spinal fusion on a 5-year-old with neuromuscular disease, complicated by mitral stenosis. He can operate with confidence on the premature infant, and can take liberties in opening the head, chest, or abdomen, with respiration, blood pressure, and temperature controlled and altered to suit his needs. He is allowed to perform renal transplants on children with hemoglobin levels of 5 gram/100 ml, and excise brain tumors from patients for whom blood transfusion has been denied by parental religious convictions.

Perhaps the greatest physiologic transgression has been permitted the cardiac surgeon, whereby a neonate in congestive heart failure is anesthetized, paralyzed, immersed in ice water until cooled to 15 C, ventilation and circulation arrested during a 60–90-minute intracardiac repair, and the child finally warmed, awakened and restored to life. Toward this accomplishment, surgeons, cardiologists, and others have contributed heavily, but anesthesiologists have also played a significant role.

If we can determine which of these changes have made possible the greatly improved operating conditions, we can then see which steps denote true progress. In actuality, there have been many such steps, and they include many areas of preoperative preparation, operation, and recovery.

We have learned how important it is to restore and maintain the optimal physical state in the preoperative period. The use of adequate laboratory tests for blood and electrolytes, followed by replacement therapy, has been highly rewarding.

In the intraoperative period the greatest change, and probably the most practical improvement, has been the reduction in use of explosive anesthetic agents. Rees proved their total abolition possible by substitution of muscle relaxants; however, it took halothane to provide the Americans a similar opportunity. While anesthetic explosions by themselves were extremely rare, the required associated restriction of cautery and many monitoring instruments was detrimental to surgical progress. In fact, the ease of administration of halothane, its freedom from airway irritation, and the rapid post-anesthetic recovery have proved to be of even greater importance than its nonflammability. Ketamine and intravenous narcotics have shown definite but relatively limited usefulness.

Changes in the design of inhalation apparatus have been numerous. During the past decade a widespread preference seems to have emerged for use of the standard adult circle systems for larger children, and the T-tube with expiratory extension, bag, valves, humidification, heating and finally scavenging devices now is losing ground to circle absorption for infants. Substitution of light plastic masks and breathing tubes, use of low gas flows with more efficient humidification, warming, and scavenging make such a change reasonable. In addition, many safety features developed for adults have now been adapted to pediatric use, especially including the more accurate anesthetic vaporizors, tissue-tested endotracheal tubes (Guess and Stetson[25]), and reintroduction of transparent anesthesia masks (Stetson[26]).

A remarkable advance in intraoperative anesthesia has been in our ability to maintain patients within normal physiologic limits by acute observation and by accurate methods of monitoring. Although the use of muscle relaxants has reduced the importance of spontaneous respiration as our most valued sign of depth of anesthesia, alterations in ventilation and blood pressure have now become more easily measured and defined. There has been an increasing development and use of monitoring instruments. In America the monitoring stethoscope has become mandatory in pediatric anesthesia, the measurement of blood pressure and the determination of temperature being employed with almost equal frequency. These three basic approaches would seem to provide adequate monitoring for most operations on good-risk children. For more extensive procedures or for operations on poor-risk children, many of the monitors useful in the adults may also be adaptable for pediatric use (Talbert[27]). On the other hand, it can probably be said that the use of pediatric monitoring methods is yet in an early phase of development and capability. Few pediatric monitors approach the ideal of practicality, safety, accuracy, and reliability (Cox[28]). Even the measurement of temperature carries certain hazards, and heating devices may have done more damage than the hypothermia they are designed to prevent. Furthermore, our monitors fail to tell us what we really need to know, *i.e.*, the presence of pain, the measurement of cardiac output, or the metabolic changes occurring within the cell.

Judgment in the use of monitors suggests two stages of maturity; the older anesthetists perhaps not using them enough and relying instead on clinical observation and the educated hand, while the younger anesthetists use them too much, unnecessarily exposing the infant to excessive manipulation, electrical hazards, possible vascular damage, and postoperative immobilization.

There have been at least three major advances in the postoperative phase. The first consists of extending the concept of the Recovery Room to the pediatric age group. The establishment of an individual area planned, staffed, and equipped solely for early postoperative care has served to curtail the incidence and severity of many preventable complications. Second, the development of total parenteral alimentation (Dudrick *et al.*,[30] Filler *et al.*[31]) has saved innumerable small infants who previously would have died of inanition. Third, the problem of mechanical ventilation for children, and especially small infants, has been satisfactorily met after years of combined effort on the part of pediatricians, physiologists, and anesthetists. This represents an achievement of tremendous importance. Since ventilatory therapy pertains to many areas it is commented upon separately.

Unfortunately, our progress in increasing the availability of the skilled pediatric anesthetist has not kept pace with the increasing demand. A crude approximation suggests that there are presently 800 trained pediatric surgeons, in addition to perhaps 4,000 general surgeons who claim that at least 30 per cent of their work is pediatric. To match this group, we can muster the 70 members of the Anesthesia Section of the American Academy of Pediatrics (full-time pediatric anesthetists) and an additional estimated 200 well-trained non-members. This lack of growth is difficult to explain, especially in view of the extensive need for pediatric anesthetists, the high potential for achievement, and the stimulating way of life.

The reduction of anesthetic mortality should provide a fundamental basis with which to measure progress, and one would

TABLE 1. Operative and Postoperative Mortality in Children

	University General Hospital		University Pediatric Hospital	
	0–1 Year	1–10 Years	0–1 Year	1–10 Years
Total number of operations	1,638	4,722	11,817	42,920
Total number of deaths	88	52	495	354
Mortality (per cent)	7.5	1.1	4.0	0.8

TABLE 2. Operative and Postoperative Mortality by Decades, General Hospital Series

	Age (Years)									
	0–1	1–10	10–20	20–30	30–40	40–50	50–60	60–70	70–80	80+
Total number of cases	225	829	704	605	550	693	805	782	500	147
Total number of deaths	12	8	6	8	11	19	22	28	19	14
Mortality (per cent)	5.3	1.0	0.9	1.3	2.0	2.7	2.7	3.6	3.8	2.5

TABLE 3. Incidence of Operative and Postoperative Deaths during the First Year of Life

	Age			
	0–7 Days	7 Days–1 Mo.	1–6 Mo.	6–12 Mo.
Number of deaths	218	95	128	54

expect such mortality records to be mandatory in any well-organized department. Unfortunately, few institutions are able to produce the data by which one can evaluate the improvement in anesthetic mortality. While it is true that a precise definition of anesthetic death has not been produced (it is often difficult to indict or exonerate anesthesia when there have been several contributing causes of death), nevertheless, there is an important need for methods of evaluating anesthetic safety. It seems imperative that a practical set of standards be adopted.

One would hope that figures could be made available from at least all major pediatric centers. These figures should indicate the total number of procedures in which anesthesia is used, the total incidence of operative and postoperative deaths, etc. Patients should be further categorized by age, limiting pediatrics to the first decade, and subdividing the first year into periods of 0–7 days, 7–30 days, 30 days–6 months, and 6 months–1 year. In addition, all patients should be further categorized in accord with the American Society of Anesthesiologists physical status rating, as well as by type of operation. Deaths could then be investigated for the exact etiologic factors, and recorded as anesthetic, surgical, patient disease, combined or undetermined, with criteria supplied for each grouping.

Efforts to collect mortality statistics have frequently broken down, in that patients with multiple causes of death defy precise classification. Anesthetic deaths cannot always be defined to fit each category, but certainly anesthetic deaths following explosion, aspiration of vomitus, untreated apnea, or obstructed endotracheal tube and other errors are recognizable and justify the endeavor (Kok and Mullan[32]). Early anesthetic mortality studies showed a tenfold increase in anesthetic mortality throughout the first decade (Beecher, Todd[33]). On this basis, the unfortunate misconception that all children represent poor anesthetic risks was established.

Although reliable data are not generally available, figures have recently been obtained from two university teaching hospitals, one a general hospital and the other a pediatric center. Data from both these hospitals over a six-year period provide total operative and postoperative mortality rates for children 0 to 1 year of age, and between 1 and 10 years of age. From the data in table 1 it is evident that in both the general hospital and the pediatric hospital, operative and postoperative mortality in the first decade is concentrated chiefly in the first year of life. In children 1 to 10 years of age mortality and anesthetic risk are actually markedly reduced. While the differences in mortality between the two hospitals with respect to the first year of life are rather large (7.5 *vs.* 4.0 per cent), that for the 1–10-year-old group is remarkably small.

In comparing the mortality rate in the 1–10-year-old group with that of older patients, the risk presented by the children appears to be in the same range as that in the 20–30-year age group (table 2). Conversely, a breakdown of those infants who died during their first year (pediatric hospital series) shows a maximum peak in the perinatal period, tapering off rapidly after 6 months of age (table 3).

Data such as these may be helpful in predicting the results one might expect in dealing with children. On the other hand, individual records that probably stand more as single hospital performances, rather than standard levels of achievement, have been published. For example, there was a recent series of 35,710 children anesthetized over a ten-year period for tonsillectomy, without mortality.§ Another series includes 7,500 harelip and cleft palate repairs with no mortality.¶ Needless to say, the fact that 35,000 children can undergo tonsillectomy without any death is an excellent achievement, that cannot in any case be denigrated. A reduction of anesthetic morbidity is evident from several sources. The elimination of ether has greatly reduced the danger of vomiting and aspiration during anesthetic maintenance. In fact, we actually awaken patients electively during spinal fusion to test spinal cord integrity.

Prompt postoperative recovery, minimal excitement, and decreased incidences of ileus, nausea, vomiting, and respiratory irritation all have combined to make operations less unpleasant, to shorten postoperative hospitalization, and even to promote the development of ambulatory surgical facilities (Ahlgren,[34] Steward[35]). Known hazards, such as the full stomach, preoperative fever, and hypovolemic shock, have been greatly reduced by increased experience and knowledge. It would be difficult (and distressing) to find an anesthetist who would put a child to sleep without full preparation for the management of possible vomiting.

Important progress related to morbidity concerns the discovery of several previously unknown and potentially lethal syndromes whose presence is now suggested by familiar signs. Among these are the succinylcholine apneas related to deficient or defective acetylcholinesterase and phase II block, abnormal breathing responses in children with pathologic neuromuscular conditions, curare–antibiotic interactions, hypo- and hyperpotassemia, hyperthermia, distention of closed spaces by nitrous oxide, induced pneumothorax, and oxygen toxicity.

The evolution of the establishment of a new syndrome might proceed as follows: First, an alert clinician notes and reports an unusual finding and anesthetists become aware of an unexplained hazard. Thus, Allen *et al.*,[36] Bush,[37] and McCaughey[38] noted an increased incidence of cardiac arrest during the induction of anesthesia in burned children, and implicated succinylcholine. This suggestion was first refuted, then substantiated when evidence that succinycholine might initiate potassium flux in injured tissues became available (Tolmie *et al.*[39]). Meanwhile, activity to find the mechanism sets off extensive new research in cell membrane kinetics (Gronert *et al.*,[40] Kendig *et al.*[41]), including the review of important early work by Cannon and Rosenbleuth,[42] and we then arrive at the real truth.

During the past 25 years we seem to have made the least progress in reducing the suffering of the hospitalized child. Undoubtedly, it is before and after operation and certainly outside the operating room that children suffer the most. Postoperative pain represents only a small part of the problem. Children have many fears—fears of the un-

§Pittsburgh Eye and Ear Infirmary.

¶ Children's Hospital Medical Center, Boston.

known, fear of separation from parents, and fear of castration and death (Vernon and Schulman,[43] Hunt[44]). Both adults and children fear needles, and with just cause. In a pediatric center the problems may be especially complicated. The same child may return for ten, fifty or even a hundred operations (two patients on record). Others must undergo amputation or other disfiguring procedures which bring ridicule from schoolmates. "Battered" children with broken bones and cigarette burns have their own special fears.

The sights and sounds of the hospital experience add to the child's anxieties, and obvious discomforts associated with dressing changes, tracheal suction, and removal of sutures and chest tubes are frequently overlooked by seasoned personnel. Other shortcomings may be pointed out. We frequently fail in our attempt to provide rational sedation. We have not yet found either a suitable tranquilizing agent to help children tolerate hospitalization or a satisfactory method of preanesthetic sedation. Instead, we continue to inject illogical doses of unpredictable agents. Nor have we worked sufficiently to encourage the alternative concept, as have many pedodontists, *i.e.*, that normal children gain valuable self-confidence by facing such trials without utilizing a pharmacologic crutch upon which they may become increasingly dependent (Croxton[45]).

The advent of more extensive operations has introduced new forms of post-operative distress. Children may be unable to communicate for days because of tracheal intubation, and literally unable to move because of nasogastric and chest tubes, cardiac pacemaker wires, urethral catheters, arterial cannulas, and intravenous infusions. However, signs of concern have begun to appear, and several articles (Cox,[46] Kiely,[47] Reinhart *et al.*[48]) have been devoted to the psychological stress to which children are exposed during intensive therapy.

Most pediatric anesthetists have been deaf to the warnings concerned with parent–child separation, and to parental requests to stay with children during induction of anesthesia. The few trials that have been staged have been unconvincing, but parental pressures are mounting. In such relationships, the parents themselves must be carefully considered, for parental fear must first be controlled if the child is to be calmed. Furthermore, not all parents are drawn together by a child's illness. Too often, fixations of guilt or blame may actually pull the parents apart.

Among pediatric surgeons, Potts[49] and Koop[50] have written extensively in terms of the need for compassion for both parent and child. It would appear that since pediatric anesthetists have seldom written concerning the suffering of children, these thoughts have not been sufficiently prominent in our minds. Regrettably, even in this symposium, we borrow our compassion from the pediatrician and the psychiatrist.

The areas of pediatric resuscitative and supportive therapy have shown remarkable advances. In a sense, the resuscitation of 30 years ago may be exemplified by the university surgeon who is said to have summoned the fire department when his patient's heart stopped. Ventilatory support consisted in the use of the tank respirator and tracheostomy. From these beginnings we have progressed to mouth-to-mouth resuscitation, closed-chest massage, long-term tracheal intubation, the development of a variety of mechanical ventilators, establishment of the critical care concept, 24-hour blood–gas monitoring, as well as other modalities of support.

With children, as with adults, the development of the respiratory care facility first consists of organization and administration. The organizational aspects, based on economy of space and maximal effectiveness of personnel, are similar for adults and children. Some of the problems, however, may be very different, including special considerations in cases of children with poliomyelitis, cystic fibrosis, asthma, pneumonia, near-drowning, and airway emergencies. Poliomyelitis was an early scourge, but fortunately is no more. However, cystic fibrosis, asthma and epiglottitis continue to provide the anesthetist with serious concern. Status asthmaticus is a major cause of respiratory death in children, but important gains have been made (J. J. Downes[51]).

The premature neonate with respiratory distress syndrome has presented particularly difficult problems, especially during the first seven to ten critical days that frequently determine his fate. Innumerable false clues have been followed in the treatment of this syndrome, with hypothermia, hyperbaric oxygen, tracheostomy, patent ductus division, acetylcholine injections and mechanical ventilators producing little increase in survival. Finally, combinations of helicoptor transport; temperature control; correction of metabolic imbalance; the monitoring of blood gases, heart rate and apnea; plus important modifications in positive-pressure ventilation, including positive end-expiratory pressure (PEEP), continuous positive airway pressure (CPAP), and intermittent mandatory ventilation (IMV), have produced significant headway. Perinatology has become the most dynamic of fields, and preservation of the premature infant has become a science in itself.

Teaching and Research

A growing awareness of the importance of pediatric anesthesia, and the complexity of surgical procedures, have increased the demand for training. The existing centers are pressed from all sides. The pediatric anesthetist finds much, or most, of his time devoted to clinical instruction in the operating room, where he is drawn by the patient's need, the surgeon's concern, and student's interest. At present, seven pediatric centers offer an approved third-year residency in pediatric anesthesia.** The association with these third-year residents is most rewarding to the teacher, for these individuals come with particular interest in children and also stay long enough to acquire real facility and a deep appreciation of the problems in the field.

Coordinated didactic instruction is offered at all approved training centers. Excellent national symposia in anesthesiology have been organized by the Children's Hospital of Los Angeles (13 consecutive years) and by the Hospital for Sick Children of Toronto. Although very busy, pediatric anesthetists have also found time to write. In addition to numerous journal publications, full-length texts and symposia have been written or edited by Davenport,[52] Leigh and Belton,[53] Levin,[54] Smith,[55,56] Rondio,[57] Stephen, Bennett and Ahlgren,[58] Wilton and Wilson,[59] and Rackow and Salanitre.[60] Major texts have been written by Young and Crocker,[61] Egan,[62] and others in the field of pediatric respiratory therapy.

While natural forces have tended to encourage teaching, these same forces frequently result in an opposing effect upon research in pediatric anesthesia. With reduced staffs and impoverished hospitals, personnel and funds for research have become more difficult to find. Popular opinion also stands in the way. Rightfully, additional hazards imposed upon small patients in the name of research bring serious objections. Federal regulations have severely curtailed the use of new drugs in children, and the reasonable insistence of professional groups upon "informed consent" has rendered many forms of pediatric investigation practically impossible (Inglefinger: *Ethics of Experiments on Children*[63]). However, there remains an immense fund of untapped information that can be obtained by acceptable methods, and considerable progress is bound to be made.

The area of clinical investigation has included a number of drug evaluation studies, and the introduction of many new techniques and devices. For example, Graff *et al.*[64] have clarified the child's reaction to the adult circle absorption systems, and similar work is now being carried on by Dery[65] and Chalon.[66] The British rebreathing T-systems have been analyzed extensively by Onchi,[67] Inkster,[68] Mapleson,[69] and others. Evidence of the infant's greater anesthetic requirement has been documented by Deming[70] and Reynolds[71] using cyclopropane, and by Gregory *et al.*[72] with halothane. Hypothermia and induced hypotension are being explored. Moffitt's[73] series of measurements of myocardial metabolism are of special interest. A practical contribution in the field of blood

**Children's Hospital of Akron; Children's Hospital Medical Center, Boston; Children's Hospital of Buffalo; Children's Hospital, Denver; Children's Hospital, Detroit; Children's Mercy Hospital, Kansas; Children's Hospital of Los Angeles.

and fluid replacement is that of Davenport and Barr.[74]

It is quite impossible to mention the multitude of physicians who must be acknowledged as having produced important achievements. They and many "silent" workers have generated much progress. Unfortunately, while we have learned to measure many of the factors that enable children to survive and to maintain adequate tissue oxygenation, we have not yet learned how to monitor consciousness, and how to measure pain or fear. When we do, and succeed, when we not only keep children "pink" and alive, but also keep them smiling, we shall then have achieved something truly important.

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