



Humans are born too soon: impact on pediatric otolaryngology[☆]

Charles D. Bluestone^{*}

Department of Pediatric Otolaryngology, University of Pittsburgh School of Medicine, Children's Hospital of Pittsburgh, 3705 Fifth Avenue, Pittsburgh, PA 15213, USA

Received 23 April 2004; received in revised form 16 July 2004; accepted 16 July 2004

KEYWORDS

Bipedalism;
ENT disease;
Infancy;
Development

Summary Humans are born 12 months too early. Gestation should be 21 months. Humans evolved to become the pre-eminent animal in the world, but our big brain, bipedalism, and small female pelvic outlet have caused us to pay the price of being born too soon with all of its disadvantages. Early birth has an impact on diseases and disorders encountered by the otolaryngologist, including otitis media, laryngomalacia, tracheomalacia, congenital vocal cord paralysis, subglottic and tracheal stenosis, gastroesophageal reflux, congenital micrognathia, and congenital nasal alar collapse. Many of these conditions improve or resolve completely in the first year of life as an infant's immune system and anatomy matures. Knowledge of this evolutionary process can help us understand why some infants will grow out of certain diseases and disorders encountered in pediatric otolaryngology, while others will not.

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1. Introduction

On a recent trip to the Rift Valley in East Africa, I became fascinated while watching the birth of an elephant that was able to walk with the herd, albeit with some difficulty, on the first day of life. Since elephants are constantly on the move looking for food, the baby elephant must keep up with the herd or fall prey to natural predators. Keeping up is a survival issue for these babies (Fig. 1). I also reflected that we humans cannot walk until approxi-

mately 1 year of age, and yet our immediate ancestors, such as the chimpanzee, are alert, able to walk, and hold onto their mothers after birth. The question is: since we are not as mature as the subhuman primate at birth, are we born too soon? And if so, why? If we are born too soon, how does this immaturity affect our growth and development during the first year of life? Are there diseases and disorders that affect the ear, nose, throat, and lower aerodigestive tract that are related to being born too soon that will likely improve or even resolve during this period? The following represent my investigations into these questions and hypotheses and a review of diseases and disorders, which I consider related to being born too soon. I also include how this early birth affects management decisions and counseling parents.

[☆] Presented, in part, at the annual Sylvan E. Stool Award Lecture, Society for Ear, Nose, and Throat Advances in Children, Williamsburg, Virginia, December 3, 1999.

^{*} Tel.: +1 412 692 5902; fax: +1 412 692 6074.

E-mail address: bluecd@chp.edu.

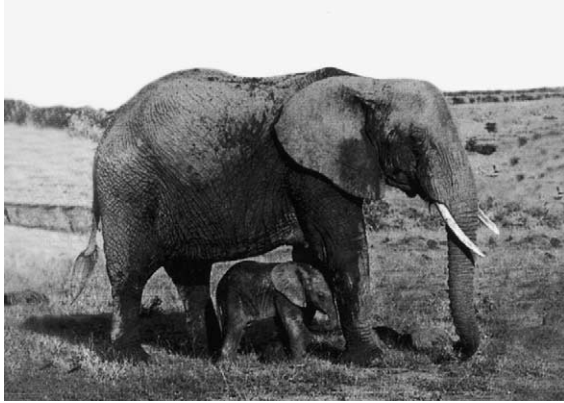


Fig. 1 Photograph of newborn elephant with mother in the Rift Valley in East Africa.

2. Are humans born too soon?

The first question is: are we born too soon? The answer is yes! Anthropologists consider other higher mammals to be “precocious” (mature) as compared to rodents, and even cats and dogs, that are “altricial,” i.e., helpless at birth (Table 1). Since we humans are immature at birth, but should be as mature and alert as our immediate ancestors, we are called “secondarily altricial,” i.e., having precocially adapted ancestors, but with evolved altricial traits [1]. Thus, we must be born too early. In fact, a noted anthropologist has concluded that we should have a 21-month gestation period, instead of 9 months in the womb and 12 months out of the uterus [2]. Naturally, premature humans are born even earlier (putting them in even more jeopardy than infants born at or near term), but the following is directed primarily toward term infants.

3. Why are we born too soon?

The next question is: why are we born too soon? The most important reasons are our upright posture and

Table 1 Differences between altricial and precocial infants

Altricial	Precocial
Short gestation	Longer gestation
Born helpless	Born alert
Brain small and immature	Big brain
Small-bodied	Large-bodied
Fast-breeding	Slow-breeding
	CNS more advanced
	Eyes open
	Able to control limbs
Example: mouse	Example: gorilla

CNS: central nervous system; Adapted from [1].

our big brains compared to our closest ancestor, the chimpanzee. During evolution, humans gradually developed bipedalism. The reason for this change is still a matter of speculation, but some think it is the development of our unique manual dexterity instead of walking on our knuckles like the great apes [3]. The evolution of our hands to make tools and weapons provided a competitive advantage over other faster and larger animals. An alternative theory is that by standing upright we could see over the savanna to be on the lookout for potential predators. Both theories may be correct. But, why did the upright posture result in an earlier birth? With erect posture, the pelvis had to support the abdominal contents, and we developed stronger pelvic muscles, e.g., the gluteus medius and minimus, which resulted in broadening the ilium in a ventral direction to support our bodies on only two legs. The human pelvis transmits the weight of the trunk to the legs and gives attachment of our legs to the vertebral column. Furthermore, during the evolutionary process to bipedalism, the goal was not only to stand upright, but also to walk and run with the body balanced in the frontal plane on one leg [4]. Thus, the human pelvis has changed its shape during evolution.

During evolution, the female pelvic outlet also became smaller than our primate ancestors making birth more difficult for humans [5]. At the top, the human birth canal is widest in a lateral plane, but the longest dimension of a newborn’s head is anteroposterior, i.e., from the nose to the back of the skull. The infant enters the canal facing sideways. Lower in the canal, the shape changes so that the longest dimension is in the anteroposterior plane. Thus, during birthing, the infant must rotate 90° [6]. Humans need assistance in the birthing process, whereas other primates do not. Since we also evolved bigger brains than our ancestors, twice as big as any other primate – mainly through increased encephalization [7] – the larger human head cannot pass through the narrowed pelvic outlet without extreme difficulty during parturition. The chimpanzee and gorilla have relatively no pelvic outlet obstruction during delivery of a full-term newborn since the outlet is large for the size of their brain and body weight, but the opposite is true in the human (Table 2). On the positive side, however, our large brain gave us other, crucial competitive advantages over our primate ancestors.

4. Human growth from birth to 12 months of age

During the first year of life, we humans triple our birth weight with rapid growth in height and an

Table 2 Shape and dimensions of human pelvis compared with chimpanzee

Pelvic characteristic	Chimpanzee		Human
Diameter of inlet	Anteroposterior > transverse	vs.	Transverse > anteroposterior
Ilium	Long and slender	vs.	Short and thick
Sacrum	Long and narrow slightly curved	vs.	Short and broad markedly curved
Ischio-acetabular distance	Long	vs.	Short
Symphysis pubis	Vertical	vs.	Inclined at 45°
Subpubic angle	Narrow	vs.	Wide
Conclusion	Sacrum non-obstructive to outlet	vs.	Wider, thicker and obstructive to outlet

Adapted and modified from [5].

increase in brain size. As shown in Table 3, from birth to the age of 12 months, we have about a 65% increase in weight, a 31% increase in height, and our head circumference increases 23%. Thus, it is obvious that an infant at age 1 year would not be able to be delivered through a pelvic outlet that has evolved to be smaller than the other primates. This growth and development during the first year of life is important to remember when considering the diseases and disorders confronted during early infancy, as described below.

5. Maturation of vision, hearing, and immunity

Thus, we are born 12 months too early compared to our mammalian ancestors, but what impact does our relative immaturity have on our development during the first year of life? Maturation occurs in vision and the central auditory system during this period. Our vision (acuity, contrast sensitivity, stereo depth, fine spacial relations, color vision) is poor at birth and doesn't reach adult levels until the second 6 months of the first year of life [8]. Similarly, measures of auditory brainstem responses in the newborn are immature but rapidly mature in the first year of life [9], which should be kept in mind when hearing loss, such as from otitis media, occurs during this period.

We also have an immature immune system at birth, despite having all the components of the

immune response in place prior to leaving the uterus. Even though neonates are somewhat protected against some infections during the first month of life due to the carryover of maternal antibodies, their functional immune response (e.g., reduced ability to accept skin grafts, develop Tcell cytotoxicity, mount a full antibody response to diphtheria toxoid until 6 months of age) and the immune-related functions of chemotaxis, inflammation, and opsonization are immature. Since these functions rapidly improve during the first year, Gill [10] has concluded that the maturation of the immune response in humans occurs both during intrauterine and extrauterine phases of embryonic and fetal development. There is an impact of this immature immune system on the susceptibility for infections during early infancy that affects pediatric otolaryngology.

6. Impact of being born too soon on pediatric otolaryngology

Early birth has an impact on diseases and disorders encountered by the otolaryngologist, and of course, the parents of these babies. An understanding of why they occur, what the best management options are, and counseling for the families of these infants are important in the decision-making process between watchful waiting (while the baby matures) versus non-surgical or surgical management during the first year of life.

Table 3 Average weight, height, and head circumference of newborns and 12-month-old infants

		Weight (kg)	Length (cm)	Head circumference (cm)
Birth	Male	3.53	56.60	35.8
	Female	3.40	55.30	34.7
12 months	Male	10.46	82.40	46.50
	Female	9.67	80.80	45.20
Percentage of change	Male	66.25	31.31	23.01
	Female	64.80	31.59	23.23

Modified from [35].

6.1. Otitis media

At birth, the eustachian tube is immature (e.g., short, with floppy cartilage support), but the tube rapidly elongates during the first year after birth and becomes stiffer [11,12]. The shorter the eustachian tube, the more likely nasopharyngeal secretions will enter the middle ear due to reflux, insufflation, and aspiration [13]. Given this immature eustachian tube structure and the immature immune system described above, it is no wonder otitis media is so common during the first year of life [14]. Also, since the young infant's auditory system is not yet fully matured, middle-ear effusion at this age – with its associated conductive hearing impairment – is more problematic than in older infants and children.

Today, this combination of immaturity factors is magnified when young infants are exposed to frequent viral upper respiratory infections, such as in group child daycare settings. Rhinosinusitis is also common in this age group and environment. Thus, the clinician can be conservative in management of otitis media during the high-risk first year of life since with each succeeding year, the incidence usually decreases as the immune system and eustachian tube matures [15].

6.2. Laryngomalacia

Laryngomalacia is the most common congenital laryngeal cause of stridor. It is most frequently symptomatic at or soon after birth, but most infants outgrow this malformation without any intervention during the first year of life as the supra-laryngeal airway matures [16]. Nevertheless, when it is severe, medical or surgical management or both may be necessary, especially when a synchronous lesion of the airway such as subglottic stenosis is present [17]. A complete endoscopic examination of the remaining distal airway is recommended when laryngomalacia is diagnosed [18,19]. Also, in some infants, laryngomalacia can persist into later childhood, which may then require intervention [20]. Severe laryngomalacia may require supraglottoplasty [21], but for most infants who have only this abnormality and mild-to-moderate symptoms, watchful waiting during the baby's first year of life is successful. Laryngomalacia is frequently associated with extra-gastroesophageal reflux, which is discussed below.

6.3. Tracheomalacia

Congenital tracheomalacia (and bronchomalacia) can be either primary (idiopathic) or secondary, and, like laryngomalacia, is usually diagnosed in

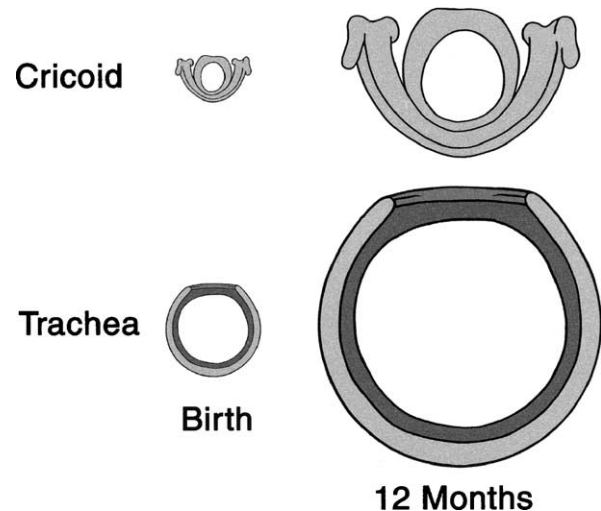


Fig. 2 Relative enlargement of the lumen of the subglottic and tracheal airway during the first year of life as the infant triples its birth weight.

the neonatal period. When primary, it is a somewhat uncommon malformation but can be the cause of expiratory stridor due to floppy tracheal and bronchial cartilages. It frequently resolves during the first year of life if it is not associated with another airway problem, as the cartilage becomes stiffer [22]. Thus, when the obstructive symptoms are mild-to-moderate, growth and development during the first year will allow the infant's airway cartilage to mature. Also, similar to stenosis of the subglottis and trachea, described below, the lumen of the airway enlarges during the baby's rapid growth and development during the first year of life (Fig. 2).

When tracheomalacia is secondary, it is usually due to extrinsic compression of the trachea from a vascular malformation [23]. But even this type, if the obstruction is mild and not associated with frequent lower respiratory tract infections, can resolve with growth in the lumen size of the trachea and increased maturity (stiffness) of the cartilage support during the infant's first year. This is especially true of mild anterior compression due to the innominate artery (Fig. 3). On the other hand, a severe vascular compression of the trachea requires prompt diagnosis and a chest surgical procedure to relieve the obstruction [24].

6.4. Congenital vocal cord paralysis

Idiopathic congenital vocal cord paralysis is relatively uncommon, but is an indication for tracheotomy in the neonatal period when there is bilateral paralysis causing significant airway obstruction. However, vocal cord function usually improves and the paralysis can even completely resolve

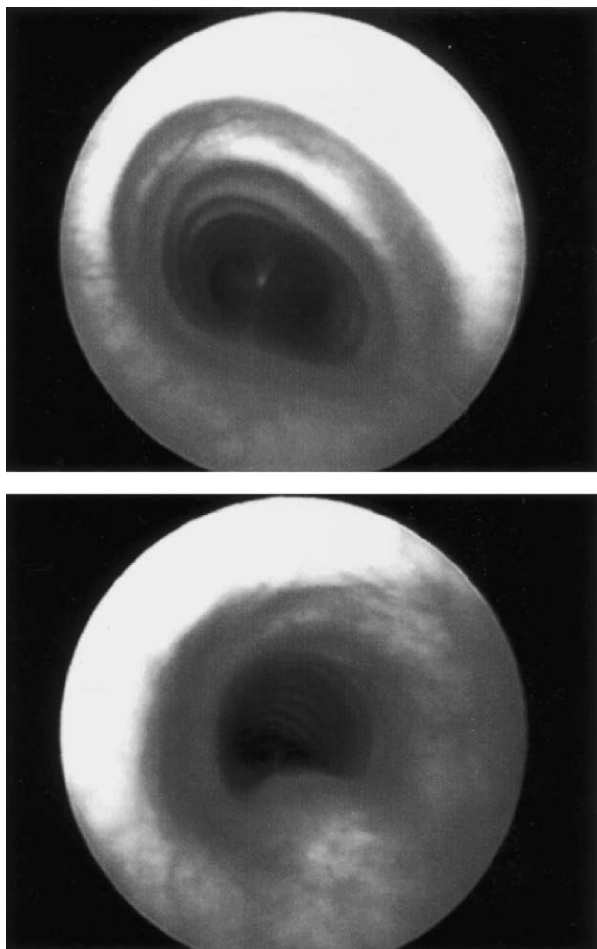


Fig. 3 Endoscopic photographs obtained in two neonates showing a mild anterior tracheal compression secondary to an innominate artery (upper frame) and mild congenital subglottic stenosis (lower frame). In both infants, the airway symptoms resolved within the first year of life without any intervention.

during the infant's first year of life, after which the baby can be decannulated [25]. Some infants resolve the dysfunction as early as 6 months of age [26]. The etiology of this congenital abnormality is unknown, but it may be due to immaturity of the vagus nerve or brainstem or both. Watchful waiting during the first year of life, with or without a tracheotomy in place, is prudent, and it is only the unusual child who will require corrective laryngeal surgery if the paralysis persists past the infant years.

6.5. Subglottic and tracheal stenosis

Congenital and acquired subglottic and tracheal stenosis are other causes of airway obstruction in neonates and are frequent indications for tracheotomy in these babies [27]. However, since the

diameter of the lumen of the trachea and cricoid cartilage approximately triples during the first year of life, the infant may outgrow the obstruction, i.e., the lesion is the same, but the lumen size becomes larger [28]. As depicted in Fig. 2, the subglottic and tracheal lumen increases dramatically by the end of 1 year. Thus, when the obstruction is mild, not progressively becoming worse, and not associated with other abnormalities, many infants can outgrow the lesion with the rapid growth and development of the airway during the first year of life (Fig. 3). In a review of 37 neonates and young infants who had congenital subglottic stenosis, 23 (59%) had spontaneous resolution of their airway obstruction by their first birthday; 31% without the need of a tracheotomy [29]. However, when the obstruction is severe, tracheotomy is indicated, with possible subsequent laryngeal and tracheal surgery an option.

6.6. Gastroesophageal reflux (GERD) and the airway

There is growing awareness today that gastroesophageal reflux (GERD) is extremely common during the first post-natal year and can be associated with respiratory symptoms. A likely cause for this condition is that the young infant needs a tremendous amount of calories to triple the birth weight during this period. The principal source of nutrition is a great deal of milk per day to satisfy the needed calories. However, when the stomach is overloaded, the lower esophageal sphincter "pops off" and the gastric contents enter the airway. Fig. 4 shows how the relatively short esophagus in the neonate (as compared with the adult) is more likely to permit gastric contents to enter the airway. This extra-

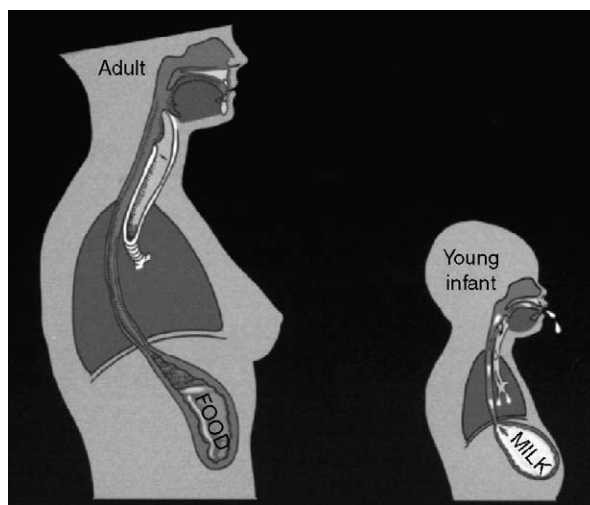


Fig. 4 Comparison of length of esophagus between young infant and adult.

Table 4 Selected developmental milestones at end of first postnatal year in humans

Milestone	Developmental implications
Gross motor: walks alone	Exploration, control of proximity to parents
Fine motor: turns pages of book	Increasing autonomy
Communication and language: speaks first real words	Beginning of labeling
Cognitive: egocentric pretend play	Beginning of symbolic thought

Modified from [35].

esophageal reflux is manifested by recurrent and chronic stridor, cough, wheezing, and hoarseness, and recurrent “croup” commonly is diagnosed. The gastric contents can compound a synchronous airway abnormality (congenital or acquired), such as laryngomalacia, tracheomalacia, and subglottic stenosis [30,31]. Often, GERD rapidly resolves during the later part of the first year, but may continue into the second year of life and beyond [32].

These infants, when symptomatic, should have endoscopy of the airway and esophagus to confirm the diagnosis and to determine if any other abnormality exists. Even though pH probe can determine the presence or absence of GERD in most of these infants, this study is not diagnostic of an underlying concurrent airway abnormality. The reflux can increase the obstruction causing recurrent and chronic airway obstruction. For most of these infants, medical management is sufficient until the child “outgrows” the GERD, but when severe and unresponsive to current maximum medical management (e.g., anti-reflux medicines, alteration in diet, and positioning), surgery such as a fundoplication, or even gastrostomy and tracheotomy may be required. There is also some evidence that GERD may be involved in the etiology of otitis media and sinusitis.

6.7. Congenital micrognathia

Congenital micrognathia can be an isolated condition (or part of the Robin sequence) causing glossoptosis, airway obstruction, and feeding difficulties that may require tracheotomy or mandibular surgery to secure the airway [33]. However, when mild, the mandible grows significantly during the first year of life with progressive relief of the airway obstruction and without vigorous intervention [34]. Waiting until the child outgrows the obstruction is successful in most infants, when symptoms are mild and not associated with other airway malformations.

6.8. Congenital nasal alar collapse

Congenital nasal alar collapse is a relatively uncommon cause of stertor during the first month of life. The condition appears to be due to floppy nasal alae

that collapse during inspiration. This abnormality also progressively improves during the first 6 months after birth.

7. Are there advantages to being born too soon?

Even though we are born in an immature state and do not walk alone until approximately 12 months of age, there are distinct advantages during the first year of life that are not present in the subhuman primate. During this period, there is growth and development of uniquely human characteristics as the brain matures, such as communication and language; the first real words are at 1 year of age [35]. Also, at the end of the first year of life, the infant has cognitive advances, such as egocentric pretend play, which implies the beginning of symbolic thought (Table 4).

8. Counseling parents

Counseling parents can be helpful related to cause and prognosis. It is important that we understand that we are born too soon and that neonates can have diseases and disorders such as GERD that are the consequence of this early birth and that may be worse during early infancy due to immaturity. Also, when a newborn has an airway problem, such as idiopathic congenital vocal cord paralysis or congenital mild subglottic stenosis, the parents can be appraised of the probability of resolution with growth and development during the first year of life. Nevertheless, some of these conditions will not improve or completely resolve during this period, which will require an explanation related to possible intervention.

9. Conclusions

Humans are born 12 months too early. Gestation should be 21 months. Our big brain, bipedalism, and small female pelvic outlet are the causes. However, we became the preeminent animal in the world –

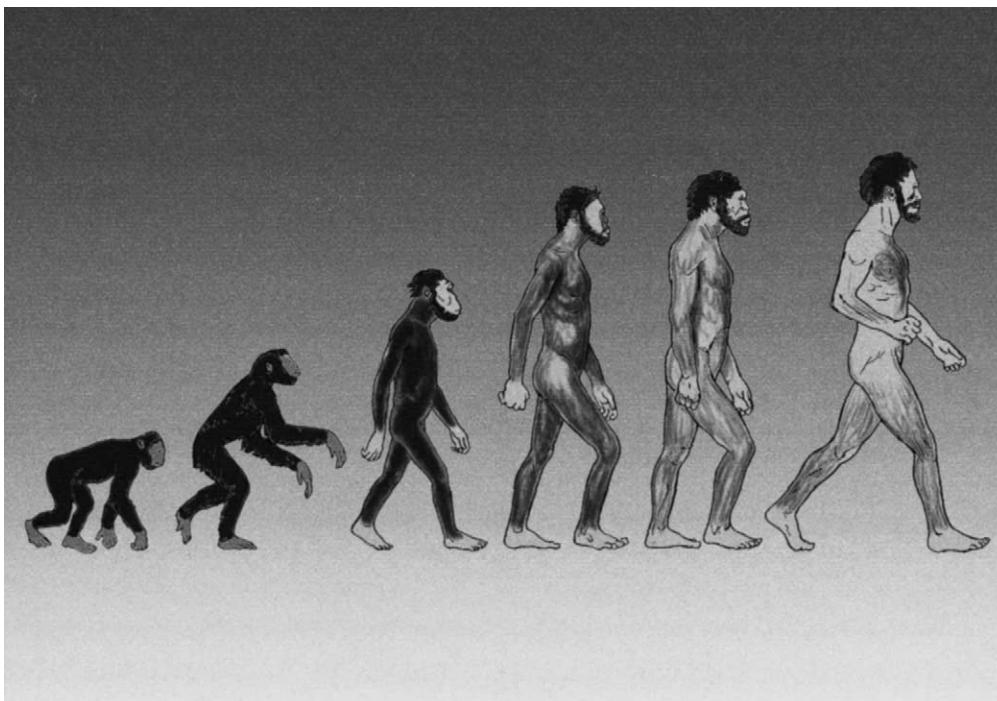


Fig. 5 The descent of man with our big brain to bipedalism to become the “King of the Rift Valley”.

the “King of the Rift Valley” – due to our big brains and our unique human hands (Fig. 5), but we have paid a price: we were born too soon with all of the attendant disadvantages. Knowledge of this evolutionary process can help us, and our infant’s parents and families, understand why some infants will grow out of certain diseases and disorders encountered in pediatric otolaryngology, while others will not.

Acknowledgments

J. Douglas Swarts, PhD, provided advice regarding the anthropological aspects of this manuscript. Maria B. Bluestone provided editorial assistance. Deborah A. Hepple assisted in the preparation of the manuscript. Jon Coulter provided the artwork and prints.

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