27 Apnea of Infancy, Apparent Life-Threatening Events, and Sudden Unexplained Death in Infancy

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Apnea of Infancy

Definition

The American Academy of Pediatrics defines apnea of infancy as "an unexplained episode of cessation of breathing for 20 seconds or longer, or a shorter respiratory pause associated with bradycardia, cyanosis, pallor, and/or marked hypotonia" [1]. There is no qualification included regarding the degree of bradycardia or cyanosis to be concerned about. Also, there is no evidence to be found in the literature for the 20-second length definition [2]. For infants in the first year of life, the American Academy of Sleep Medicine guidelines recommend that all types of apnea be defined using a two missed breath definition, but for central apnea, an arousal or defined change in oxygen saturation and heart rate are also required to formally score and count the apnea [3].

Physiology of Breathing in Early Infancy

An understanding of normal breathing patterns in newborn term infants is important before considering the pathophysiology. In the first few months of life, two main sleep states are recognized in infants: active sleep (AS), the equivalent of rapid eye movement (REM) sleep, and quiet sleep (QS), the equivalent of non-REM sleep [4]. As with older children and adults, breathing tends to be regular in QS and more irregular in AS. Apneic pauses are more common in REM than non-REM sleep. Sometimes this irregularity can be noticed by infant caregivers and cause concern. The presence of sighs may also be noted. Sighs are more frequent in the newborn than the adult and can be followed by a respiratory pause which may occur immediately after the sigh or after one to three normal breaths [5].

Another normal physiological breathing pattern that may be noted by caregivers is periodic breathing. Periodic breathing (PB) is characterized by brief pauses in breathing, alternating with periods of regular respiration also of short duration, and is defined as ≥3 cycles of respiratory pauses ≥3 seconds in length with the duration of regular respiration between each respiratory pause being ≤20 seconds [3]. Periodic breathing is seen more frequently in preterm than term infants, and the periodic cycle duration decreases from birth to 6 months of age in both groups [6]. Variation in oxygen desaturation occurs with the respiratory pauses of PB and can be more marked in hypoxic infants [6, 7].

Arousal from sleep is an important contributor to the maintenance of continuous respiration. Term and preterm infants frequently encounter situations where the airway is compromised either internally by secretions or airway collapse or externally by obstruction of the nose or mouth. In these situations, arousal enables the infant to clear the airway and recommence regular respiration [8]. Thresholds to arousal from sleep are greater in QS than AS throughout early life in healthy term infants [9].

Pathophysiology

The prevalence of habitual snoring (snoring ≥3 nights/week) in infants varies across studies and is estimated to be 3.0–6.6% [10–13] in the first year of life, with some studies reporting it as high as 9–14.5% [14, 15]. The variation may be explained by the heterogeneity of the studies, variation in the definition of habitual snoring, presence of colds, and protective effects of breastfeeding [13]. Data from a large (n = 12,477) epidemiological study, the Avon Longitudinal Study of Parents and Children (ALSPAC), indicate that 19% of parents note habitual apneas in their children at 6 months of age [14]. It could not be determined whether those were central or obstructive events,

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but rates for habitual mouth breathing and snoring were similar, suggesting that this likely represented a degree of sleep-disordered breathing. These symptoms appeared to resolve to some degree by 18 months of age and increased in prevalence again after the age of 2. Cluster analysis of these data indicated that in the total group followed to 81 months of age (6.75 years), 50% remained asymptomatic throughout this time period, and the "late snore and mouth breathing" cluster (20%) remained asymptomatic until 4 years of age [16]. The "early snores" (10%) and "early apnea" clusters (10%) had peak symptoms at 6 and 18 months of age, respectively. The remaining "all SDB after infancy" cluster (10%) had peak symptoms from 30–42 months that remained elevated.

Respiration can be interrupted in a number of ways in infancy through the disturbance of physiological processes. Congenital anomalies [17] or upper body positions can result in, or predispose to, upper airway obstruction, e.g., an immature infant with head unsupported in a car seat [18]. In healthy newborn infants, passive neck flexion can diminish airflow or functionally occlude the upper airway for periods ranging from 3 to 18 seconds [19]. Infants are also vulnerable to external obstruction of the airway, and factors that affect arousal may affect an infant's ability to respond to an external obstruction. Exposure to maternal smoking is associated with decreased arousability to hypoxia in QS in infants at 5–6 months of age despite an intact ventilatory response [20]. Obstructive apnea is also more frequently found in cigarette-exposed healthy infants than in controls [21]. Brief obstructive events have also been reported as being more frequent in overweight infants compared with controls [22]. Infants with significant viral and bacterial illness can present with apnea. This classically can occur with the initial presentation of an infant with bronchiolitis and is most usual in infants less than 3 months of age [23].

McNamara and Sullivan described polysomnography data for 11 infants with symptomatic apnea who were studied at monthly intervals to 6 months and then at 9 and 12 months of age [24]. Infants were included in the study if they had either at least 30 apneic events per hour or 5 obstructive events per hour. All pauses of at least two respiratory cycle lengths were included. The apnea index (number of events per hour) decreased over time in both REM and NREM sleep. Apnea was most common at 2 months of age, and associated decreases in oxygen saturation were also more common at this age. Both obstructive and central apnea showed resolution in the first year of life.

Diagnostic Approaches: History and Examination

Infants may present with an initial severe apneic event. If that is the case, then a careful history needs to be taken about the event itself. The history should particularly address whether the infant airway may have been obstructed by an external barrier such as if the infant were in an unsafe sleeping situation. An acute presentation with apnea may be the first sign of sepsis, so other symptoms of sepsis or viral infection should be considered. For other infants, the concerns may relate to a number of issues about the infant's breathing that the caregivers have been concerned about over time. Enquiry should be made about snoring and sweating and frequent wakening. Preterm infants have an increased risk of obstructive sleep apnea (OSA), so a perinatal history should be obtained. History should be followed by a complete examination including a neurological examination assessing tone and development. A priority should be to consider whether the infant is acutely unwell. As with the older child, the examination should consider face shape, the nasal airway, and the oral airway. In the newborn or younger infant, congenital anomalies should be ruled out.

Differential Diagnoses: Causes

Congenital anomalies apparent in the newborn period are usually associated with obstructive rather than central apnea. These can include syndromes associated with face shape such as Treacher Collins and Goldenhar syndromes and syndromes associated with large tongue size such as Beckwith-Wiedemann and Down syndromes. Laryngomalacia can also present in the newborn and may be associated with obstruction demonstrable on polysomnography. Pierre Robin syndrome includes micrognathia and a cleft palate, but micrognathia may also occur in isolation and be associated with increased respiratory effort and failure to thrive in infants sleeping supine. Infants with syndromes associated with hypotonia, such as Prader-Willi syndrome, may also present because of caregiver concern about their breathing. Failure to extubate an otherwise healthy term infant who presents with severe apnea may be an indication of congenital hypoventilation syndrome. This disorder is discussed in Chap. 53. In the first few months of life, a new presentation of apnea may be associated with both viral infections, including bronchiolitis, and bacterial infections which are either systemic or affecting the central nervous system.

As the first year of life continues, infants may present with sleep-disordered breathing in a manner similar to older children with snoring, sweating, and waking at night. In a report of a single-center 7-year experience in the management of OSA in 97 infants, snoring was an indication for referral in 53% and concern about nocturnal desaturations, an indication in 24% [25]. Other reasons included previous abnormal pneumogram, suspected apparent life-threatening event, screening for sleep-disordered breathing, hypoventilation, diaphragmatic flutter, failed car seat testing, suspected apnea of prematurity, and as a routine test before growth hormone treatment. Of these infants 41% had mild OSA, 20%

had moderate OSA, and 39% had severe OSA based on the usual definitions for apnea hypopnea index (AHI) of 1–5/hr, 5–10/hr, and >10/hr, respectively. Risk factors noted were hypotonia (53%), gastroesophageal reflux (30%), laryngomalacia 24%, Down syndrome 19%, craniofacial abnormality 16.5%, adenotonsillar hypertrophy 3%, epilepsy 5%, and neuromuscular disease 2%. As well as the infants with Down syndrome, genetic abnormalities were found in a further 34% of the patients.

Management

Polysomnography is now the investigation of choice for assessing apnea of infancy but may not be readily available in all areas. Also, the interpretation of these studies remains hampered by the paucity of normal data in this age group. Snoring in infants has not always been treated aggressively in the past, and it is not unusual for parents, who present to a pediatric sleep clinic with their child at an older age, to describe that the snoring has been present since birth. It has perhaps been considered that snoring in young infants is benign, but this is not clearly so. Piteo et al. [26] demonstrated increased risk of neurocognitive deficits in 16 infants who commenced snoring soon after birth and were snoring for 3 or more nights a week, when they were compared with 88 healthy non-snoring infants. Also, the increased work of breathing associated with upper airway obstruction in young infants can lead to failure to thrive. There are therefore cogent reasons to offer treatment for these infants. Otolaryngologists may be cautious about undertaking surgery in these young infants and require definitive evidence of obstruction on polysomnography before proceeding. Shatz reported outcomes for 24 infants who had adenoidectomy for documented obstructive sleep apnea [27]. There were no complications related to the surgery, and all infants had resolution of symptoms and failure to thrive resolved. Increasingly nasal CPAP is being successfully used to treat young infants with obstruction, although there are still limitations in mask suitability in this age group. This is a reasonable first step. For infants with severe retrognathia such as in Pierre Robin syndrome, mandible distraction is another option [28].

As with older children, the gold standard for documenting the severity of the sleep-disordered breathing is overnight polysomnography. At times, these studies can be challenging as young infants are less likely to tolerate nasal prongs and as they get older are more able to remove them. Oximetry can also provide useful information in the older infant if positive and consistent with REM-related OSA. However, there are still no clear guidelines for the interpretation of oximetry for infants in the first few months of life.

Apparent Life-Threatening Events (ALTE)

Definition

For many years, it has been recognized that infants in the first year of life may present with respiratory events concerning to their parents. In the 1970s when research into the reasons for sudden infant death syndrome (SIDS) was in its own infancy, these events were referred to as "near miss SIDS" events as it was thought they represented an aborted sudden unexplained infant death [29]. In 1986 the term "Apparent Life Threatening Event" (ALTE) was proposed to describe these events [30]. Although this term was an improvement, it has been clear over time that these events are most usually not "life-threatening." Therefore in 2016, the American Academy of Pediatrics recommended a change to the term brief resolved unexplained event (BRUE). A BRUE is defined as "an event occurring in an infant younger than 1 year when the observer reports a sudden, brief, now resolved episode of ≥1 of the following: (1) cyanosis or pallor; (2) absent, decreased, or irregular breathing; (3) marked change in tone (hyper- or hypotonia); and (4) altered level of responsiveness" [31].

Pathophysiology

It is now recognized that the causes of these events are multifactorial, and the pathophysiology of the event therefore depends on the specific cause. At one end of the spectrum, parents may be concerned about events that represent normal physiology. Examples would be the infant who has post-sigh apnea, or the infant who looks very pale during non-REM sleep with shallow and periodic breathing. A parent may observe these events, be concerned about the infant, and pick them up and then find the infant hard to arouse because of the characteristics of the sleep state at the time of observation. The term BRUE particularly applies to these sorts of events. At the other end of the spectrum are presentations that may indeed be potentially life-threatening such as inflicted head injury or infection or cardiac arrhythmias.

There have now been a number of reports regarding presentations considered life-threatening in infants in the first few days of life. Initially these were reported as deaths or very severe events in infants thought to be healthy and at low risk [32, 33]. In a number of these cases, an identifiable serious cause such as sepsis was found. For other infants, the event occurred in association with feeding. Espagne et al. in 2004 described two newborns who died unexpectedly in the delivery room [34]. They were sleeping prone on their mother. A number of reports have now been published describing apparent life-threatening events in infants in the prone position hav-

ing skin-to-skin contact with their mother in the delivery room or during breast-feeding on the postnatal ward [35–39]. In response, in 2016 the Academy of Pediatrics documented clinical practices intended to facilitate safe positioning of the infant during skin-to-skin contact [40].

Diagnostic Approaches: History and Examination

The critical component of assessment after an infant presents with a BRUE is a careful history to differentiate between a likely physiological event and an event of clinical significance that could potentially be life-threatening such as the acute onset of any infection. For example, apnea with cyanosis may be the initial presentation of an infant with bronchiolitis. In this case, symptoms are not likely to resolve but to persist with increasing evidence of respiratory distress. The Academy of Pediatrics Clinical Practice Guideline provides a comprehensive list of historical features to be considered [31]. In the older infant, it is important to understand exactly where the infant was at the time of the event as infant holding practices have been associated with ALTE presentations [41]. A precise understanding of the event and where and how it happened is critical to the diagnosis.

The examination needs to consider the clinical status of the infant at the time of assessment. If resuscitation is required, this should be the priority. When the infant is stable, a thorough examination needs to be undertaken. Documentation of acid-base balance on arrival to the emergency room can provide evidence of the severity of the event if significant resuscitation has been required, and the infant has not yet returned to their pre-event clinical state. There should be a low threshold for assessing sepsis, especially in the younger infant.

Differential Diagnoses: Causes

If the history, including careful review of the circumstances the infant was found in, and examination do not provide an explanation for the event, then a physiological variation in breathing pattern is the most likely explanation, and the application of the term BRUE would be appropriate. If the infant has not returned fully to normal, then other reasons for the event need to be considered. Particular diagnoses to be considered are infection, cardiac arrhythmias, and child abuse.

Management

The management depends on the information gathered from the history and examination. If serious illness has been ruled out, then reassurance can be given to the caregiver. The clinician needs to be aware that the experience of these events for parents can be quite frightening, so reassurance needs to be given carefully with a full explanation of the likely nature of the event. Enquiry should be made about a family history of sudden infant death or friends and acquaintances of the parents who may have experienced the death of an infant as this will affect their ability to be reassured that the event was not potentially life-threatening. If no concerning features are identified on history and examination, then infants are considered to be low risk, and any diagnostic procedures or tests are unlikely to be helpful. Cardiac testing is positive in less than 1% of patients [42]. If the initial clinical assessment reveals concerning historical features or examination findings, then the infant should be investigated in line with the most likely differential diagnosis appropriate to those findings. For example, if an infant was not fully alert on assessment and there was bruising noted on the trunk, then it would be appropriate to consider abusive head trauma as a possible reason for the presentation and investigate accordingly [43].

Infants considered at low risk of a recurrent event are those aged >60 days, infants with a gestational age ≥ 32 weeks and postconceptional age ≥ 45 weeks, infants experiencing their first BRUE, events lasting <1 minute, events with no CPR required, events with no concerning historical features, and events with no concerning examination findings [31]. Young term infants and premature infants are more likely to have a recurrent BRUE presentation.

Sudden Unexplained Death in Infancy (SUDI)

Although sudden death in infancy has been the subject of much research over the last three to four decades, it has been reported since the earliest times. The Bible documents a report of an infant being overlain and found dead ("And this woman's son died in the night, because she lay on him." 1 Kings 3:19 English Standard version).

With the increased use of the prone sleep position for preterm infants as neonatal intensive care developed in the 1960s and 1970s, this sleep position became increasingly used also for term infants, as infants were thought to sleep better in this position. The large epidemiological studies set up in the 1980s to try and establish the reasons for the increasing prevalence of sudden infant death syndrome (SIDS) found a strong association between use of the prone sleep position and the risk of SIDS [44–46]. Consequent research has provided some insights into the mechanisms by which the prone sleep position might contribute to the sudden and unexpected death of an infant. Numbers of infant deaths have dropped dramatically since the introduction of "Back to Sleep" public awareness campaigns internationally [47–49]. In the current era, the focus is on "Safe to Sleep." However, sudden infant death is still the largest

category of post-neonatal deaths, and the burden now lies with the most disadvantaged and socially vulnerable families [50].

Definition

The term sudden infant death syndrome (SIDS) was initially coined by Beckwith in 1969 [51] and then updated in 1989 [52] as follows: "the sudden death of an infant less than one year of age which remains unexplained after a thorough case assessment, including performance of a complete autopsy, investigation of the death scene, and review of the clinical history." In more recent years, the term sudden unexplained death in infancy (SUDI) has been used and will be used from here onward. This is a global term as depicted in Fig. 27.1 and includes all deaths of an infant not anticipated as a significant possibility in 24 hours preceding death. All such deaths are referred to local coronial services for investigation. One of the main reasons for autopsy is to rule out an organic diagnosis that would fully explain the sudden death. Possible diagnoses would be overwhelming infection, inflicted head injury, or previously unrecognized congenital anomaly [53]. The death would then be classified as "explained SUDI." As well as the autopsy, investigation of such deaths should include a death scene examination and a clinical history of the infant up to the time that they were found deceased as well as a full past medical, family, and social history. This information might provide further information to enable the cause of death to be classified as accidental suffocation. Information that would confirm this diagnosis would be a clear history that the infant was found wedged between an adult bed and a wall with the chest compressed or a history of the infant being observed by a reliable witness to have been found completely overlain by a co-sleeping adult or older sibling. As in the SUDI case illustration at the end of this chapter, for some deaths, there may be circumstantial evidence that accidental asphyxia was the cause of the death. In the case discussed, a reasonable diagnostic conclusion would be that the cause of death is possible accidental asphyxia in an unsafe sleeping position. If the death scene examination, clinical history, and autopsy are all non-contributory, then a diagnostic label of sudden infant death syndrome would be appropriate.

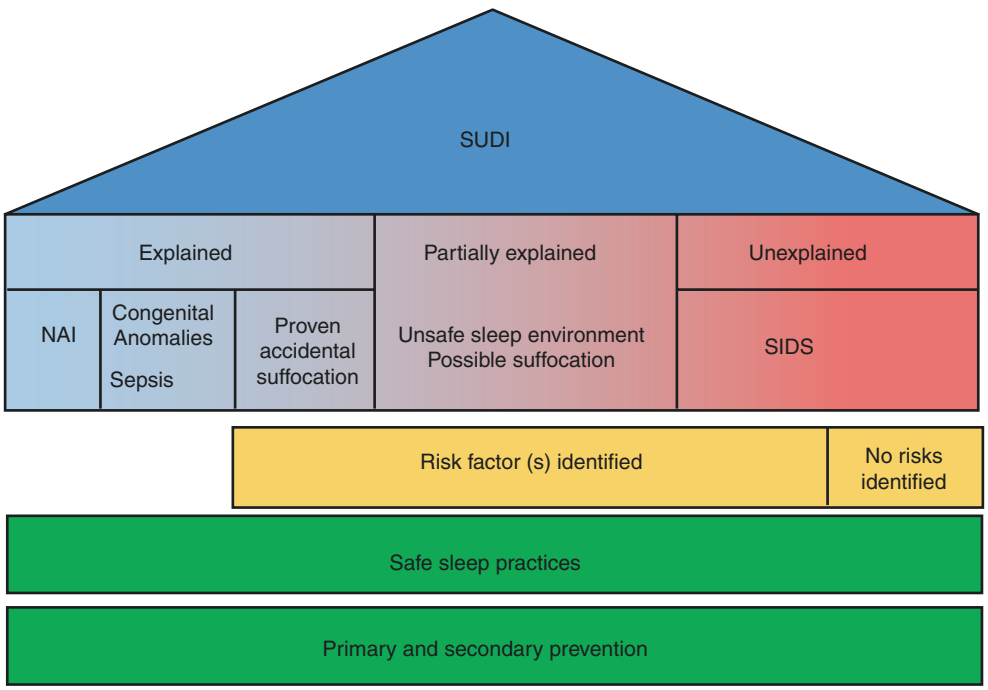

Fig. 27.1 Sudden unexpected death in infancy classification. Explained deaths are sudden deaths that are explained after investigation and include cases that are clearly attributable to factors which on their own alone would be enough to cause death, e.g., accidental suffocation, asphyxia, entrapment, infection, ingestions, metabolic diseases, arrhythmia-associated cardiac channelopathies, and non-accidental injury (NIA). Partially explained deaths (also called unascertained) are cases where a pathologist or coroner is unclear to what extent the deaths are explained, often because they do not have complete information about the circumstances of death in front of them. Unexplained sudden deaths remain unexplained after a thorough case investigation, including death scene investigation, autopsy, and review of the clinical history. SUDI risk factors are usually identified in the explained deaths involving accidental suffocation, partially explained deaths and unexplained deaths, but there will always be a minority who dies suddenly for whom no risk factors or reason can be ascribed. SUDI preventive measures and safe sleep practices apply to all infants to reduce risks of sudden death, regardless of SUDI risk

Pathophysiology

Research into potential biological mechanisms is severely compromised by the absence of a "disease state" and "natural history of disease." However, the epidemiologic approaches have been rigorous with consistent findings from many studies across the globe integrated into highly effective risk reduction strategies centered on "safe sleep" for all infants. The challenge remains to successfully integrate findings from the many other disciplines involved in SUDI research to "discover" a "cause," although all evidence to date points to a myriad of factors involved [54], and therefore a single "cause" is likely to be elusive.

The infant can die at any time of the day or night, but deaths occur most frequently at night, quietly during sleep, and mostly unobserved. There are no consistent warning signs to alert the caregiver to an impending death, as per the SUDI definition. The baby may have been a little unsettled or might have had a slight cold or tummy upset, or there might have been a change in circumstances as to where the baby slept on the night they died. The triple risk model, first described in 1972 by Wedgwood [55] and revised in 1994 by Filiano & Kinney [56], presents a hypothetical working model to help explain why SUDI may occur. The model suggests that an infant may succumb if three critical factors occur at the same point in time: (1) the infant has an intrinsic vulnerability that for the most part is not modifiable, e.g., male gender, prematurity, indigenous ethnicity, poverty, adverse prenatal exposures (e.g., maternal smoking, alcohol, illicit drug use, inadequate nutrition), and genetic polymorphisms, (2) an external stress is involved (e.g., the infant is in a bed with an adult, sleeping face down into soft bedding, an infection is present), and (3) a critical window in development where the vulnerable infant is most at risk of a fatal event brought on by an external stressor (e.g., young infants can be more at risk because of their inability to arouse or have the motor ability turn their head away from a potentially suffocating environment because of their postnatal risk of small size and physical or developmental immaturity).

Still robust in 2019, the model has rarely been challenged and has survived the many shifts in the epidemiological landscape of SUDI affecting the critical window of vulnerability (the mortality still peaks from the 2nd to 4th month of life [57], but there has been a shift in the median with more infants dying under the age of 2 months), change in seasonality (decreased from one historically observed more frequently in the colder months [57, 58]), predominance of risk factors (sleep position falling dramatically, while bed-sharing has gained more prominence [59, 60]), and an increase in the proportion of SIDS associated with poverty [50, 53, 60], alcohol consumption [61], and preterm birth [59, 60, 62]. Although SUDI is believed to occur as a result of the intersection of all three components of the triple risk model, reducing the risk from one factor may decrease the overall risk of SUDI. The "Back to Sleep" campaign has focused on this sleep position as the key factor and yet has resulted in a significant decrease in SUDI wherever it has been implemented.

For SUDI cases, where no specific cause is identified, causes may be varied, and several hypotheses overlap. Autopsy findings do exist but are usually inconclusive as to the mechanism of death. Multiple neural mechanisms may contribute to the final event, but these are still speculative. For example, subtle asphyxiation or airway obstruction may happen when a baby slips under adult bedding or finds him/herself face down into soft bedding, or any position that could squeeze the nostrils together or block the mouth compromising breathing can be hazardous. This includes anything in a baby's sleep space that can move into their breathing space, e.g., the domestic cat. Neural processes that could overcome this and restore airway patency or cardiovascular control via reflexive compensation may be impaired in infants that eventually succumb to SUDI. The evidence from early studies in SIDS cases ranges from subtle physiological signs related to impaired autonomic control [63, 64] to autopsy findings of altered neurotransmitter systems including the serotonergic system that plays an extensive homeostatic role in cardiovascular and respiratory control and thermoregulation [65, 66]. Processes may be altered by the vulnerability of the infant due to age or prematurity, or a genetic predisposition [67], or the infant may have a seemingly innocuous viral illness [68]. The fatal event may occur in a sleep state which can suppress muscle tone (REM sleep) [64] essential to restore airway patency.

Diagnostic Approaches

To be able to classify SUDI correctly, a careful clinical history needs to be undertaken, as well as a death scene investigation and an autopsy. The history needs to address the past medical history of the infant and the clinical history in the days before the death. Also, the history needs to document risk factors such as parental smoking and usual sleep practices. The death scene needs to consider carefully where the infant was found including detailed documentation of the sleep environment. The autopsy needs to be undertaken by a pathologist who has appropriate expertise and experience for this age group of children and who also understands the forensic role of the autopsy in the context of sudden infant death.

Differential Diagnosis

As discussed above, two important priorities are to rule our organic disease and inflicted injury. Then the issue is to consider whether there is evidence to suggest that accidental suffocation has definitely occurred or whether it is possible that this may have occurred. The diagram (Fig. 27.1) summarizes

the main differential diagnostic areas that need to be considered within the various levels of classification of SUDI.

Management

The immediate management issue is to manage the acute presentation of the death. Mostly this occurs in the community and police are notified, and the case is referred to the coroner or medical examiner depending on local practices. In jurisdictions where a medical practitioner is not required to certify death, a clinician may not be involved at this stage. Some hospital protocols recommend that a pediatrician or health worker have some involvement with the family at this stage. It is useful for a pediatrician to be able to meet with a family to discuss the results of the autopsy when they are available, but sometimes it can be difficult to get families to engage with a clinician they have not met previously.

Families may seek advice after the birth of a subsequent sibling. They should be made well aware of the primary prevention factors and may need some support with follow-up until the infant has passed the age of the deceased sibling. There is no evidence that cardiorespiratory monitoring prevents sudden infant death, but parents sometimes buy respiratory monitors for reassurance as well as using intercom systems for remote noise monitoring.

Primary Prevention

Those at greatest risk of SUDI are well described, but no objective marker exists for identifying the infant that may eventually succumb. Therefore, the key to SUDI "cure" lies in "prevention," capitalizing on the known risk factors that are modifiable, with a key emphasis on *safety in sleep*, i.e., a safe sleep environment for every sleep. Efforts at prevention must begin early in pregnancy in recognition of the heightened risk of maternal smoking in pregnancy.

SUDI prevention messages for parents can vary slightly by country, but consistent key messages are:

- Making sure baby is on their **back** for *every* sleep
- Keeping baby **smoke-free** from the start
- **No bed-sharing** or no bed-sharing if mother smoked during pregnancy, or baby is less than 1 month of age
- **Breastfeeding** baby
- **Immunizing** baby on time

Creating a Safe Sleep Environment

- *Face up and clear at all times*. Ensure the baby's head never becomes covered. Some SUDI infants have been discovered with the bedclothes covering the face and head. Using infant sleeping bags or placing the feet of the infant at the foot of the cot under a tucked cotton sheet reduces the possibility of head covering.
- *Use a firm sleep surface.* A firm cot/bassinet mattress, covered by a fitted sheet, is the recommended sleeping surface to reduce the risk of SUDI and accidental suffocation. Mattresses should be firm and maintain their shape even when the fitted sheet is used, so no gaps between the mattress and the side of the cot/bassinette occur.
- *Other infant bed types*. Baby boxes and clip-on cots have been developed to provide a separate sleep space for infants sleeping close to parents [69, 70], and for some communities where bed-sharing is common practice and considered culturally important, specialized infant safe sleep devices have been developed similar to the baby box. For example, in New Zealand, the wahakura (woven bassinet) and Pēpi-Pod on-bed baby beds [71, 72] are considered an acceptable alternative to having the baby in the parental bed [73].
- *Keep soft objects and loose bedding out of the cot* to reduce the risk of SUDI, suffocation, entrapment, and strangulation. Pillows or cushions should not be used in the cot, and other soft materials or objects such as pillows, quilts, duvets, or sheepskins, even if covered by a sheet, should not be placed under a sleeping infant.
- *Sitting devices, such as car safety seats, strollers, swings, infant carriers, and infant slings, are not recommended for routine sleep.* Infants who are younger than 4 months of age are particularly at risk because they can get into positions that create risk of suffocation or airway obstruction.
- *Tummy time.* Supervised, awake tummy time is recommended on a daily basis, beginning as early as possible, to promote motor development, facilitate development of the upper body muscles, and minimize the risk of positional plagiocephaly.
- *Keep the baby in the same room for the first 6 months.* SUDI mostly happens unobserved; therefore sleeping infants in the parental bedroom in the first 6 months of life reduces the risk.
- *Prevent overheating.* Dressing the infant in too many layers, using duvets/doonas and thick quilts, and having the sleeping environment too hot are all associated with an increased risk of SUDI. It is especially important that outdoor hats are not used indoors for sleeping; the inability of young infants to easily control their own body temperature means that the head is an important area for heat regulation/dissipation.

Illustrative Cases

Apnea of Infancy: Case 1

A male and a female twin born at 36 weeks gestation were followed up in the pediatric clinic. The male twin had hypoglycemia in the neonatal period because of intrauterine

growth restriction. It was noted at the first follow-up that he had an occasional blocked nose. At 3 months of age, it was noted that he was wakeful at night, but his parents thought that was due to wind. His blocked nose was less of a problem. At 6 months of age, his parents reported recurrent nasal snuffliness that still interfered with feeding at times. He demonstrated good catch-up growth. At 8 months of age, his parents reported nasal snuffliness by day and night. He was waking a lot at night, whereas his twin was now sleeping through the night. His parents thought he was waking with a cough. On examination, nasal snuffliness was noted, and some increased respiratory effort was noted. The tonsils were large in size. An overnight sleep study was undertaken which showed an AHI of 36.6 events/hr. This was initially treated with CPAP, but although this was established in the hospital, it was difficult for the parents to manage at home. An adenotonsillectomy was carried out at 9 months of age without complication. He was seen for follow-up at 10 months of age and was found to be eating well including eating more solid foods than he had been able to tolerate previously. His parents reported he was not as "grumpy" and was improving in his language skills. Snoring by night and noisy breathing by day had completely resolved, and there was some catch-up growth demonstrated.

Apnea of Infancy: Case 2

A male aged 10 months presented with parental concern with his breathing since the age of 4 months which had become progressively worse over the last 4–5 months. His parents observed snoring, increased respiratory effort, and respiratory pauses followed by a gasp and arousal. He was a restless sleeper and slept with his mouth open all the time and his neck hyperextended. He was waking 2-hourly through the night and was slow to wake up and tired by day. His growth had been progressing normally along the 50th centile for the first 4–6 months of life but had dropped off to below the 3rd centile. Perinatal history and other medical history are unremarkable. He was described as being snuffly in the first 6 weeks and was noted to periodically struggle to breathe through this nose right from birth. His 2-year-old brother and his father required adenotonsillectomy in early life for obstructive sleep apnea symptoms. Development was normal on initial history. On examination, he was thin with a weight of 7.3kgs (<3rd percentile) and height 74cms (<50th percentile). He had adenoidal facies with mild retrognathia and small nares which were obstructed. His oropharyngeal exam revealed a Mallampati score of 2–3 and tonsils that were grade 3. He had a small appearing posterior oropharynx. Oximetry was undertaken at home and showed evidence suggestive of REM-related OSA with a DSI3% of 25 events/hour and an oxygen saturation nadir of 83%. He had adenoidectomy and diathermy of his inferior turbinates just before his first birthday. There was some improvement in symptoms, but there were still symptoms of obstruction. In clinic, poor concentration was noted, and he continued to have poor weight gain. At 15 months of age, he had tonsillectomy. As he lived some distance from the hospital, the family was asked to stay locally to the hospital for a 2-week period post-surgery. One week after surgery, he had a hemorrhage from the tonsillar bed which was successfully managed under general anesthesia. At follow-up, his symptoms had completely resolved, and there was demonstrable improvement in his weight, daytime concentration, and behavior.

ALTE Case

A male infant was first admitted when he was 3 weeks of age. A family member had bought an apnea mattress for the baby when it was thought he was going to be born preterm after a presentation with threatened labor. He was born at term, but the parents started using the apnea mattress. There were no alarms until 3 weeks of age when the alarm went off, and he was noted to be pale and floppy and was thought to be not breathing. His parents were not able to say if he had a palpable heartbeat. They did not notice color change. They wondered if there was something wrong with the monitor but felt he was symptomatic. They did not notice any gasping breaths to resume breathing. He settled to regular breathing again, and then when they put him back to sleep, the alarm went off three more times that night. He did not take as long on those occasions to come back to what they thought was normal for him. He presented to hospital in the morning and was admitted. During the day, he had seemed his usual self. He was described as being a little fussy about feeding and to have some spilling. It was thought he might have gastroesophageal reflux. As he appeared well, he was discharged home 2 days later, and the parents were given advice about resuscitation. After they went home, the parents were informed about another type of monitor that had an abdominal sensor that monitors breathing. They therefore rang the hospital and were given one of these monitors. Five days after discharge, the alarm went off. He was seen by his primary care doctor and thought to be normal. He did not appear to need stimulation when the alarm went off. The monitor was alarming more frequently, and he would also appear to the parents to be apneic when he was awake. There was one time when he was on the breast and the monitor alarmed. He was not cyanosed at that time. He had another admission because of his monitor alarming more often and alarms were occurring every night. He had otolaryngology review as an outpatient and an awake endoscopy was normal. A slightly recessed jaw was noted. He was otherwise well and gaining

weight. His spilling had improved on thickened feeds. His developmental progress was normal. There was no family history of sudden infant death syndrome or recurrent miscarriage. There was no family history of known obstructive sleep apnea, but the father and paternal grandfather were snorers. At 4 months of age, the infant was reviewed by the pediatric sleep service, and an overnight polysomnography was arranged. The infant was kept on his usual home alarm during the study. There were alarms going off as the home alarm was set at 10 seconds over night, and it could be demonstrated that these alarm periods coincided with a sigh followed by a short period of central apnea, sometimes followed by a few breaths and another short respiratory pause. Some of these events were associated with a brief 3% oxygen desaturation. There were no findings outside the range of normal for age and in particular no evidence of obstructive apnea. Continued monitoring was not recommended, but the parents were advised that if they did intend to use the monitor, the breath indicator alarm should be set to 20 seconds.

SUDI Case

A 6-week-old male infant was found dead in a bed with his mother. He had reportedly been well previously. The infant had been born at term, but there was intrauterine growth restriction and the birth weight was 2.3 kgs. His mother smoked in pregnancy up to ten cigarettes a day. There had also been some marijuana use. Neither parent had been working, and the mother was 19 years of age and the father 21 years of age. They both came from families where there was a history of violence during their own childhood. The infant was growing well with some catch-up growth demonstrated. His mother was well but was very tired because the infant was feeding 3-hourly at night. Her BMI was 35. The evening before his death, the infant had been put down to sleep in his cot at 7.30 pm but woke for a feed at 10.30 pm. His mother was already in bed at this stage, so she brought him into her bed and fell asleep with the infant in her arms. When she next awoke, she expected she would need to feed him again. She found that his face was turned away from her, and when she brought the face back toward her, she found he was floppy, there was no observable breathing, and he was cool. There were some slight bloody secretions at his nose. This was about 1 am in the morning. The ambulance and police were called, and the case was referred to the coroner. There was no death scene investigation. At post-mortem, there were some petechiae found on the thymus and the lungs but no other relevant findings. The infant appeared to be well-cared for. The coroner's final verdict was sudden infant death in infancy in an unsafe sleep situation.

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