

# Sudden Infant Death Syndrome

JAMES J. MCKENNA

## Introduction

Since its formal recognition as a medical entity in 1969, well over 290,000 babies in the western world alone have died from the Sudden Infant Death Syndrome (SIDS). Also known as cot or crib death, it is presumed to be a sleep-related infant disorder primarily, but not exclusively, affecting infants in the first year of life, and especially between eight and sixteen weeks after birth. Still aptly described as a 'diagnosis by exclusion,' the pathophysiology of SIDS remains elusive. Yet, after more than forty years of research in which no public health policy or medical intervention reduced SIDS appreciably if at all, SIDS rates per 1,000 live births since 1990 continue to decline to unprecedented levels worldwide (Byard & Krous, 2001).

## Sleeping position and related factors implicated in the decline of SIDS

The breakthrough in reducing SIDS risks came from an unexpected source, namely, child-care practices, or, more specifically, the position in which infants are placed for sleep. In the middle to late 1980s and early 1990s, observations by a number of researchers in different countries pointed to the prone infant sleeping position as being potentially dangerous, and associated with high rates of SIDS. Their observations, preceded by similar observations made in the 1940s, were followed by national, state-of-the-art epidemiological studies in Australia, New Zealand, the United Kingdom, and the Netherlands, all of which confirmed that the prone sleeping position was a significant risk factor for SIDS (Fleming *et al.*, 1996). Between 1990 and 1992, when well-organized national campaigns recommended a change away from the prone position to the supine or side position, dramatic declines in SIDS were experienced in at least eight countries: Tasmania, New Zealand, the United Kingdom, Australia, Denmark, Norway, Sweden, and the Netherlands. In the United

States, the National Institutes of Health and the American Academy of Pediatrics initiated the 'Back to Sleep' campaign in 1992. Since then, SIDS rates have fallen no less than 40 percent nationally.

That a behavioral child-care practice over which parents assert control could make such a difference in reducing SIDS rates worldwide continues to astonish researchers. Its discovery marked the beginning of an important paradigm shift. It is now thought that, regardless of whatever the internal biological defects or causes of SIDS prove to be, they cannot fully be understood without reference to the overall social and physical environment within which they find expression.

The physical environment refers to the qualities of furnishings on which the infant sleeps. Characteristics of the bedding, especially the quality and firmness of the infant's mattress, including the total weight and insularity of the infant's blankets, are thought relevant. Researchers are also interested in whether or not the infant sleeps alone in a separate room, or with another person, whether sleeping partners are sober, and whether the infant sleeps with others on the same sleep surface, as well as the ages and levels of responsibility of the sleeping partners. Whether or not the parents smoke, as well as the nature and quality of the caregiver-infant interactions and mother's choice of feeding method (breast, bottle, mixed), all constitute additional factors potentially able to increase or decrease the chances of an infant dying from SIDS.

The special characteristics of the human infant, including a relatively slow rate of biological and social development and extreme neurological immaturity at birth, suggest that social care of infants is practically synonymous with physiological regulation. In fact, compared with other mammals, young human infants are subject to the most extensive external physiological regulation and support by the mother for the longest period of time. For example, mothers' touches and whispers and odors cause changes in the infant's heart rates, breast feeding, and breathing patterns, to name but a few physiological responses (McKenna & Mosko,

## 454 Developmental pathology

2001). With this in mind, it is not surprising that at least for some types of SIDS, the quality of the social and physical setting within which the infant's development (including sleep) occurs might prove important.

### Potential causes and risk factors associated with SIDS

Although the primary causes of SIDS are still unknown, the most salient SIDS risk factors include the following: infants sleeping prone, maternal smoking during, and after pregnancy, prematurity and/or low birthweight, use of soft sleeping surfaces, covering of an infant's head, placing infants on soft pillows to sleep, over heating, lack of breast feeding, and bedsharing with a mother who smokes, take drugs or who otherwise is unfamiliar with safety factors associated with bedsharing. Infants are also more likely to die from SIDS if their mothers are single, unsupported, less than 20 years of age, exhibit socially chaotic lifestyles, are poor, and lack consistent pre- and/or postnatal care (Byard & Krous, 2001).

It is generally thought that there may well be more than one cause of SIDS, but the most compelling general hypothesis is that the fatal event is related to the control of breathing and/or arousal during sleep. Perhaps an infant has a normal breathing pause during some phase of sleep, but the arousal mechanisms in the brain are unable to awaken the baby thus permitting the use of voluntary brain structures to breathe, or to reinitiate breathing. We know that deeper stages of sleep (Stage 3 or 4) as measured by EEG, which are prolonged by solitary infant sleep environments, are more difficult stages of sleep from which to awaken during a respiratory crisis than are lighter stages of sleep (*viz.*, Stage 1 or 2, the latter complying with REM sleep). Or, it could be that some kind of fast-acting bacteria place a strain on the entire cardiorespiratory apparatus of an infant and, in combination with an arousal deficit, or some other as yet unidentified factor, the bacteria prove fatal.

One current theory is that, for one sub-class of infants, a fast-acting bacteria strain, which in one study was found in all SIDS victims, might paralyze the respiratory muscles leading to death. It has also been proposed that SIDS generally tends to occur after the regulatory mechanisms of the cardiorespiratory system have failed to monitor some combination of oxygen levels, breathing, heart-rate rhythm, and body temperature, which altogether fails to promote the minimal number of breaths or heart rates per minute required for life.

The unfolding pattern and characteristics of infant sleep architecture, including how many minutes infants spend in the various stages or types of sleep (light, deep, or REM sleep) and how infants arouse, are believed to be

controlled by the brain stem. This area is composed of clusters of differentiated cells that receive and send messages from and to the heart, hormonal centers, lungs, muscles surrounding the ribs, diaphragm, and airway passages, as well as structures that specifically help to balance the proper amounts of oxygen and carbon dioxide in the blood and regulate body temperature.

One series of SIDS studies focused on the arcuate nucleus located on the ventral surface of the brain stem that monitors the proper balance of carbon dioxide and oxygen. When carbon dioxide builds up in the blood, the respiratory neurons are activated to expel it, thereby causing fresh oxygen to be inhaled and reducing the acidity of the blood. A significant number of SIDS victims compared with control infants had fewer 'acetylcholine binding sites' in this area of the brain (Kinney *et al.*, 1995). This suggests that in a variety of circumstances, including prone sleeping, infants may not have optimal or even minimal ability to reinitiate breathing following some types of apnoea or exposure to their own exhaled carbon dioxide. This could occur, for example, if the carbon dioxide is trapped in a mattress as the baby lies face down, or if the infant is under thick blankets. Alternatively, it might mean that some infants simply cannot arouse to breathe after particularly long breathing pauses or apnoeas.

### Diversity among SIDS victims

The fact remains that there is no single, consistent criterion or pathological marker that can be used either to predict potential SIDS victims or identify them post-mortem on autopsy. Nor is there an animal model of SIDS since there is no condition like it that is known to occur in any species other than humans (Rognum, 1995; Byard & Krous, 2001).

The SIDS population remains exceedingly heterogeneous. However, SIDS rates remain highest amongst minorities who are economically disadvantaged. The rate of SIDS for African-Americans, for example, is at least twice as high as it is for Caucasians, being about 1.4 per 1,000 live births and 0.6, respectively. Politically, socially, economically marginalized and often indigenous groups (e.g., Maori, Cree, Australian Aboriginal, Native Americans, Alaskan Inuits) around the world likewise experience significantly higher rates of SIDS than do members of the majority, usually white, cultures (Byard & Krous, 2001). Some SIDS victims may appear to suffer from subtle deficits that develop during intrauterine life, but are not apparent in the neonate. In addition, preterm and low-birthweight infants are at increased risk.

One group of researchers suggests that especially SIDS victims found 'faces straight down' could actually have

suffocated. These deaths are labeled 'other infant deaths.' The thinking here is that some infants sleeping prone may not yet be strong enough to turn or lift their heads well enough to get fresh air, especially when sleeping face down on soft mattresses. Unfortunately, on postmortem examination death by asphyxiation is practically indistinguishable from SIDS. With this in mind, dead infants found sleeping on beanbag cushions, with an obese adult on a couch, or found sleeping in a bed with a mother who smokes or is intoxicated, or found with the head covered by blankets, increasingly are thought to have been asphyxiated rather than as having died from SIDS. In some of these cases, infants may have been forced to re-breathe lethal doses of their own expelled carbon dioxide, and been unable to get enough oxygen.

### Epidemiological findings

Although the situation may change with recommendations to position infants on their backs for sleep, in many countries SIDS occurs most frequently in winter, and usually in the early morning or evening hours, when the infant is out of sight of the caregiver and presumably asleep. However, SIDS is also known to occur while babies are riding around in strollers, sitting in car seats, dozing in baby carriers, and even sleeping on their mother's chests, following a breastfeeding episode.

In the United States, the highest SIDS rates occur amongst mothers less than 20 years of age, who smoked during their pregnancies, are unmarried, and lack access to prenatal care. From an international perspective, and where comparative protocols for identifying SIDS victims are used, SIDS rates appear lowest within Japanese, Dutch, Swedish, Finnish, Norwegian, English, and Israeli populations. In these low SIDS countries, infants are positioned to sleep in the supine position and most mothers breastfeed.

Some countries claim that SIDS is virtually unknown (e.g., China, former Czechoslovakia). While this might be true, it is difficult to know until more careful and standardized autopsy procedures are employed in these countries. The most recent international study of child-care practices in relationship to SIDS rates was conducted by the SIDS Global Task Force (Nelson *et al.*, 2001). It revealed an unexpected finding. The study shows dramatically that low SIDS 'awareness' and low SIDS rates per 1,000 live births are also associated with cultures within which parents and infant sleep within proximity to each other, such that they co-sleep often in the form of some sort of bedsharing (Fig. 1).

Bedsharing is, however, controversial in many western industrialized cultures. Particularly in the context of SIDS research, this is because amongst at-risk urban, impoverished populations, most notably African-

Americans in the United States and the Maori in New Zealand, bedsharing is associated with relatively high SIDS. This leads some SIDS researchers to argue that mother-infant bedsharing is inherently dangerous (Kemp *et al.*, 2000). Other researchers point out that the positive relationship between high SIDS and high bedsharing rates in these sub-groups can be explained by the convergence of multiple SIDS risk factors in conjunction with bedsharing (McKenna & Mosko, 2001; Fleming *et al.*, 1996), and is not due to bedsharing *per se*. For example, higher rates of infants sleeping prone, maternal smoking or drug use, lack of breastfeeding, and an array of other unsafe sleep practices including use of unsafe sleep furnishings for infants are found in those populations where infant death rates are high. The growing consensus is that bedsharing behavior is diverse, and can be practiced safely or unsafely. One way to conceptualize this issue is to think in terms of a 'risks-benefits continuum' wherein, depending on the presence or absence in the bedsharing environment of known risk factors, bedsharing can be protective in some situations and risky in others (McKenna & Mosko, 2001; Fig. 2).

Bedsharing is not the only issue around which SIDS researchers disagree. Only a relatively small number of SIDS victims show any signs that something might be wrong with them before they die. As a result, the medical community is engaged in another volatile debate, and are continuing research, on whether or not infants with a history of repeated apnoeas should be sent home from the hospital with breathing monitors. At any given time, between 40,000 and 45,000 monitors are put to use in the United States. As yet, however, no evidence indicates that monitors prevent SIDS deaths, and there are no data to suggest how or under what circumstances infants die from SIDS when monitors are available. At present, the effectiveness of home monitors in preventing SIDS deaths is highly questionable (Byard & Krous, 2001).

### New perspectives on SIDS: the importance of parental night-time contact, breastfeeding, and how the brain uses serotonin

Regardless of routine sleep practices, most infants in western countries die outside the supervision of a responsible adult caregiver, either from SIDS or from various kinds of asphyxial deaths. Indeed, an infant who sleeps within proximity of an adult caregiver in the same room is only half as likely to die from SIDS than is an infant sleeping in a crib in a room by itself (Blair *et al.*, 1999).

Historically, infants sleeping alone is a relatively new cultural custom no more than 100 years old, and limited

456 Developmental pathology

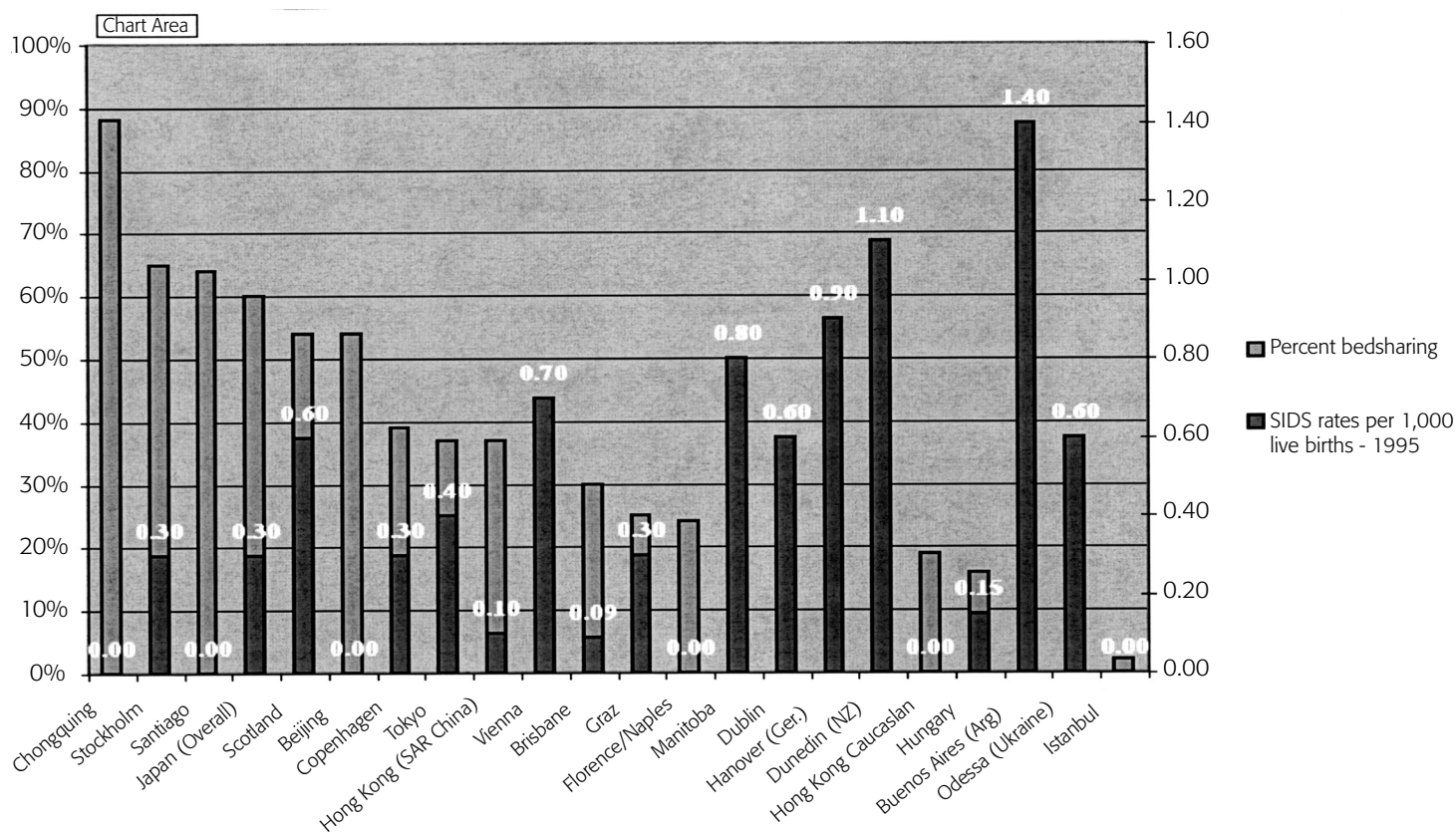


Figure 1. SIDS rates (1995) per 1,000 live births in relationship to percent bedsharing across various cities and countries throughout the world. From E. A. S. Nelson, B. J. Taylor, A. Jenite *et al.* 2001.

International Child Care Practice Study: infant sleeping environment. *Early Human Development*, 62, 43–55.

to the industrialized western world. There is no scientific doubt that mother-infant co-sleeping in conjunction with baby-controlled night-time breastfeeding is the usual human pattern practiced by almost all contemporary people. Given this fact, it seems appropriate to ask whether the biological mechanisms evolved to control human infant sleep and breathing, and which functions alongside and in relationship to night-time breastfeeding, are subject to physiological regulation through maternal contact. The more specific question is whether or not breathing and arousal mechanisms thought to be involved in some SIDS are able to change as quickly in any particular infant as do culturally based social ideas about where infants should sleep. In other words, where and when infants sleep alone, their sleep, breathing, thermoregulation, and arousal mechanisms could be functioning in environments for which they were not selected for during evolution. As a consequence of this, perhaps some human infants, especially those born with deficits, have an increased risk of dying from SIDS, when the mother's body is not present during sleep to provide what some call 'physiological (sensory) regulatory stimuli.'

In our behavioral and physiological studies of mother-infant co-sleeping and breastfeeding in a sleep

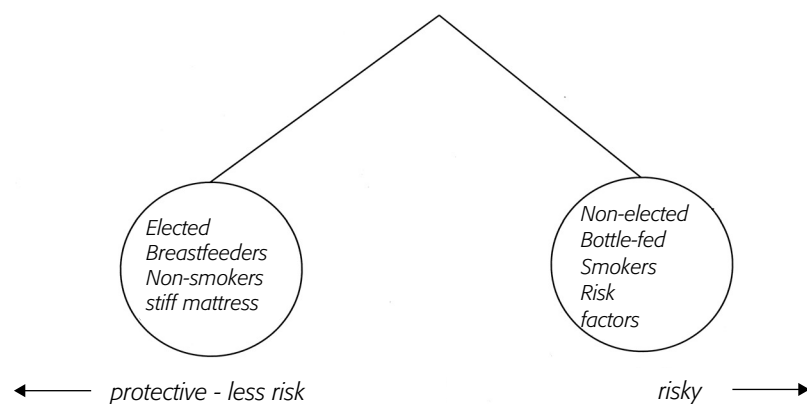


Figure 2. The 'risks-benefit continuum' of bedsharing with infants.

laboratory, we find that, compared with when they slept by themselves, bedsharing mothers and infants aroused more frequently, usually as a result of the other's movement or sound. Bedsharing mother-baby pairs spent more time in the same state of sleep and wakefulness simultaneously, and significantly more sleep time in lighter stages of sleep (Stages 1 and 2). We also found that, compared with infants who regularly slept in a different room from their mothers, bedsharing infants spent less time in deeper stages of sleep (Stage 3 or 4),

the stages of an infant's sleep from which awakening to arouse the re-initiation of breathing is more difficult. We postulate that more infant arousals, and increased sleep time in light rather than deep sleep, may be advantageous for young infants. Our thinking is that some infants might also need more 'practice' in learning how to awaken quickly and effectively than do other infants, and that mother-infant co-sleeping with breastfeeding provides the appropriate biological context for such practice (Byard & Krous, 2001).

While not all epidemiological studies suggest that breastfeeding reduces the chances of SID, at least half of them do. Research from several laboratories shows that, in contrast to breastfeeding mothers and infants who sleep apart, bedsharing mother-infant pairs breastfeed twice as much per night and for three times the total night-time duration than do solitary-sleeping, breastfeeding infants. This finding raises the possibility that with more of mother's milk, and thus more of her antibodies consumed, the intensely breastfed infant might better fight off any threatening fast-action bacteria potentially involved in SIDS.

Most recently Deborah Weese-Mayer and her colleagues at Rush-Presbyterian St. Lukes Medical Center in Chicago found that SIDS victims tended to have a different version of one key gene called 5-HTT, which effects how the brain uses serotonin, an important brain neurotransmitter involved in maintaining (among other functions) rhythmical breathing. In her control group, 71 percent of African-Americans (who have high SIDS rates) had the suspect variant, while only 47 percent of the white population did. This same gene appears to be relatively rare among the Japanese whose babies die much less frequently from SIDS than all other groups. Gene-environment interactions are still thought to be very important in determining whether or not the gene finds expression in the form of SIDS, but this is the first time an underlying genetic component has potentially been identified.

## Conclusions

Much research is needed in these and other areas. No answer will come easily, and no one solution to the SIDS tragedy will be applicable to all infants. The fact remains that an understanding of what causes SIDS and what can prevent it has not been achieved. However, since the early 1990s, an appreciation has been acquired of the importance of the infant's caregiving environment in moderating whatever the primary causes prove to be. This acceptance of the fact that the human infant's biology is best understood in terms of the context of the mother-infant dyad promises to yield a better understanding of this syndrome, and makes it more likely that this tragic syndrome will be eliminated sooner rather than later.

### See also:

**Cross-cultural comparisons; Epidemiological designs; The status of the human newborn; Brain and behavioral development (I): sub-cortical; Sleep and wakefulness; 'At-risk' concept; Prematurity and low birthweight; Anthropology**

## Further reading

- McKenna, J. J. (1986). An anthropological perspective on the sudden infant death syndrome (SIDS): the role of parental breathing cues and speech breathing adaptations. *Medical Anthropology*, 10, 9–53.
- McKenna, J. J., Mosko, S. and Richard, C. (1997). Bedsharing promotes breast feeding. *Pediatrics*, 100, 214–219.
- McKenna J. J., Mosko, S. and Richard, C. (1999). Breast feeding and mother-infant cosleeping in relation to SIDS prevention. In W. Trevathan, N. Smith and J. J. McKenna (eds.), *Evolutionary Medicine*. New York: Oxford University Press, pp. 53–74.