THE NEW ZEALAND MEDICAL JOURNAL
Journal of the New Zealand Medical Association

What is the mechanism of sudden infant deaths associated with co-sleeping?

Christine G McIntosh, Shirley L Tonkin, Alistair J Gunn

Abstract

The risk of Sudden Infant Death Syndrome (SIDS) has fallen dramatically in the "Back to Sleep" era; however, half the cases now occur when the infant has been sleeping in bed with another person. Despite the association of SIDS with co-sleeping, parents are receiving mixed messages. It is often presumed that co-sleeping deaths are due to 'overlaying', when the adult rolls on top of the baby, stopping baby from breathing. We examine research that shows that it is not necessary to cover the face, or squash the body of a baby to restrict or prevent breathing and cause oxygen deprivation. At birth, the temporo-mandibular joint is not yet fully formed, and thus the jaw can be easily displaced upwards and backwards pushing the tongue into the upper airway to form a partial or complete block of the airway. Indeed, this can happen with firm flexion of the infant's head so that the chin pushes against its own chest. Further research is needed, but on present evidence, all parents should be advised to sleep their baby in a cot or similar next to their parent's bed, until baby is at least 6 months of age.

Unexplained infant death and co-sleeping

Recent coroners' reports and related media publicity in New Zealand have drawn attention to the significant number of young infants who still die while sharing a bed with their parents or others. For example, a recent Wellington coroner's inquest examined the cases of seven babies who died suddenly and unexpectedly and found that four died while sharing a bed.[1,2] The remaining cases involved other known unsafe sleeping environments, including prone sleeping, v-shaped pillows, and loose covers over the face.[3,4]

The associated case summaries make an apparent presumption that the adults probably had rolled upon the infants during the night—i.e. 'overlaying'.[2] However, although this may be the cause of some deaths, there is little direct evidence in most cases. Other potential contributing factors include covering the infant's face with the adult's blanket or duvet, rebreathing, thermal stress, or splinting of the infants chest by the adult's arm.[2]

Based on close examination of the circumstances of similar deaths with co-sleeping, and of the anatomy and physiology of infants in the very narrow age range of these deaths, we would like to propose that there may be another, more subtle explanation for some cases of SIDS occurring while co-sleeping.

In the present discussion paper, the terms co-sleeping and bed-sharing are used interchangeably to describe a baby sharing the same sleep surface with another person at times when the adult is asleep, however, technically bed-sharing may used to refer

to when a baby is brought into an adult bed for feeding or settling without the intention of sleeping.[5]

The epidemiology of sudden infant death syndrome (SIDS) has changed dramatically in some respects since the 1991 *Back to Sleep* campaign. In the UK, along with a remarkable fall in the risk of SIDS, the proportion of children dying while co-sleeping with an adult has risen from 12% to 50%.[6] Other changes included an increase in the proportion of SIDS associated with financially deprived families (from 47% to 74%), maternal smoking in pregnancy (57% to 86%), and pre-term infants (from 12% to 34%).[6] This is consistent with data in other countries.[4,7]

The same is true in New Zealand. For example, as highlighted by the 2005 Auckland Coroners Report, 19 sudden infant deaths were classified as "not due to sepsis or birth defects" (obscure natural causes).[8] Of these, 12 were sleeping with another person, 10 of these were with their parents, and 2 were with siblings; 9 of these 12 were in double beds.

It is noteworthy that even amongst the other deaths attributed to "infection" 6 were co-sleeping at the time they died. Thus of a total of 39 dead babies, 18 were sleeping with a person who did not wake to their distress although with them in bed at the time. Similarly, in the recent Wellington Coroners report on 7 unexplained infant deaths: "All either slept with their babies or had slept them on their tummies or on pillows where they had been found face down or partly covered in a blanket".[1,2]

Why is co-sleeping dangerous for sleeping babies?

Sudden Infant Death has several features that are unique. The age range is surprisingly limited; it peaks at 2 months of age and is rare after 6 months.[9] This remains true for co-sleeping infants; indeed the large UK case-control Avon study suggested that the age of infants dying of SIDS while bed-sharing has fallen (from a median of 88 days before 1992, to 54 days subsequently).[6] Further, autopsies suggest an asphyxial death, frequently showing pulmonary oedema and petechial haemorrhages in internal organs.[3,10]

Although the mechanisms contributing to SIDS in general are incompletely understood, there is evidence that in part it may be related to a brainstem abnormality in the neuroregulation of cardiorespiratory control, with independent reports of nonspecific gliosis in the brainstem of infants dying of SIDS and of abnormalities of serotonin activity in the medulla oblongata, as comprehensively reviewed by Kinney and colleagues.[11] Presumptively, such an inherent susceptibility must interact with other intrinsic and external risk factors.

In particular, the narrow age of vulnerability suggests that whatever the risk factors are the infant is able to 'grow out of them'—i.e. there must be an anatomical or physiological predisposition which resolves with age. Given the magnitude of the difference in size between an adult and even say a 6-month infant, it seems unlikely that mere growth of the baby would be enough to explain this very narrow range.

There is increasing evidence for anatomical factors.[12] At birth, the infant head is very large (third to quarter of total length). The neck is short with the small chin almost touching the chest. The toothless mandible is flat, without any vertical ramus, and is attached to the skull by a loose capsule (as shown in Figure 1).

Within the mandible the relatively large infant tongue fills the oral space between the soft palate and the gums. Stark and Thach have shown in newborn infants that pressure on the jaw from neck flexion, submental pressure, or mandibular pressure from face masks caused backwards displacement of the jaw, leading to obstruction of the airway.[13,14]

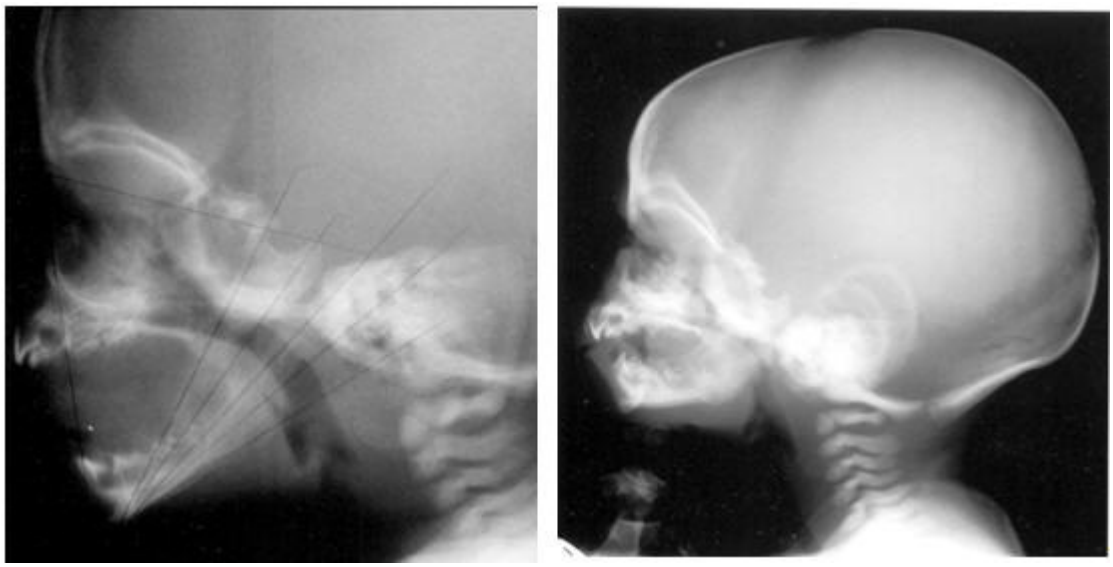
Figure 1. The mandible and its articulation at different ages (reproduced with permission from Tonkin et al[12])

(a) Infant skull showing the surface tympanic membrane and the horizontal mandible. The mandible is mobile and can be pushed up and backwards by any pressure, towards the tympanic membrane.
(b) Adult skull and mandible. The mature head of the mandible and the mandibular fossa, which restrict its backward movement, are displayed.

The increased incidence of oxygen desaturation in premature infants placed in semi-upright infant car seats compared with lying in cots[15,16] has been shown to be associated, at least in part, with flexion of the head on the body and marked narrowing of the upper airway on respiration-timed upper airway X-rays.[16] Although most of these observations were made in preterm infants, there is evidence that the similar albeit lesser frequency of oxygen desaturations in term infants restrained in car seats[17–19] may also be related to forward slumping of the head on to the chest and consequent pressure on the chin.[20] Indeed, even at term, displacement of the jaw with oxygen desaturation can be obtained by any pressure on the chin, including forward flexion of the infant's head onto its own chest in some cases.[21]

An example of a baby with a very narrow upper airway when the mother pressed on her baby's chin is shown in Figure 2. We have seen a number of infants up to 5 months old who were referred to the Auckland Cot Monitor Service by the Auckland Starship Children's Hospital after major, unexplained apnoeic episodes in circumstances where detailed reconstruction of the scene and events suggested that the lower jaw was being pressed upon whilst they were asleep. For example, we have reported eight cases of apparent life-threatening events in young full term infants restrained in car safety seats who were admitted to hospital, and found to be otherwise normal.[19]

Figure 2. Inspiratory-timed lateral neck X-rays



Left, an example of a normal upper airway in a young infant. Right, an infant whose mother has pressed gently on the chin with a finger. Note the marked narrowing of the upper airway due to upwards and backwards displacement of the jaw.

Scene reconstruction showed that while asleep in their car safety seats these infants' heads flexed forward, so that their chins pressed down onto their chests. This position was associated with intercostal recession on inspiration in all cases, consistent with the hypothesis that this position was associated with upper airway restriction.[19] Further, we have shown that a simple foam insert that allows a baby's head to rest upright, in a neutral position, while restrained in a car seat was associated with improved oxygen saturations in preterm and young term infants,[16,20] and with improved upper airway size as shown by lateral timed radiographs.[16]

Upper airway compromise and SIDS during co-sleeping

These findings suggest the hypothesis that co-sleeping could lead to SIDS through inadvertent pressure on the infant's jaw, for example if the mother, or other person, unknowingly pressed their body or limb against the baby's chin. Alternatively, if baby was sleeping with the adult's arm under its head or if baby was placed higher up on

the bed with its head on a pillow, there could be pressure from the pillow that would tend to flex baby's head forward, again leading to pressure on the jaw. In New Zealand as in much of the developed world adult beds are often markedly softer than infant cots—the weight of the adult will cause depressions in a bed where a baby may be forced into a flexed position.

This hypothesis is consistent with the known epidemiology of SIDS in general, and particularly of that described above with SIDS during co-sleeping. First, the youngest infants, with the least mature temporo-mandibular joints, are at highest risk. Second, not all cases are associated with apparent drug use or alcohol intake; even in those cases, the danger may be not from overt overlaying but from the adult being less responsive to direct contact with baby or to movement by the baby. Next, it is noteworthy that backwards displacement of the jaw leads to obstruction of the pharynx, and thus to reduced air flow, and so no sounds can be made. This is consistent with the lack of reported outcry by infants who die of SIDS.[12]

What other factors could be involved?

Smoking is highly prevalent in cases of SIDS and occurred in the majority of cases in the UK Avon case-control study.[6] Nicotine exposure reduces hypoxic arousal,[22] and so speculatively might augment susceptibility due to underlying brainstem abnormalities.[11] Critically, however, it may be argued that without blocking of the airway the babies would not have needed to respond in the first place. Consistent with this, the association between co-sleeping and SIDS remains after controlling for maternal smoking.[23]

Unusual sleeping circumstances such as shared sleeping on a couch are associated with a high rate of SIDS.[23] However, in absolute terms this is still rather uncommon and the great majority of co-sleeping SIDS cases both internationally and in New Zealand occur in the family bed.[23] We also cannot rule out a possible role for other factors such as covering of the head by bedding, which is also highly associated with SIDS.[3]

In one study, covering appeared to precede death, as shown by sweat on the face of the infant, and so may well be causally related to the death,[3] presumably due to obstruction of the external airway leading to hypoxia and rebreathing (carbon dioxide build up). However, the infants in that study were older than average, which is not consistent with the known younger age in infants who die of SIDS while co-sleeping.[6]

Why weren't these cases sleeping separately?

The most likely reasons for co-sleeping in the SIDS cases reported in New Zealand include: a lack of appreciation of the importance of sleeping baby on a separate sleep surface, a cultural preference for co-sleeping, and an association with financial deprivation of families that makes purchase of a cot for only a few months' use challenging for parents.

The message that young babies should sleep in the same room as their parents but on a separate sleep surface has been weakened by advocacy for bed-sharing to promote bonding and breastfeeding.[24] Since breastfeeding is associated with many positive benefits, this is an important issue. Nevertheless, before giving advice we must be

mindful that there is no compelling evidence that it is ever possible for a young infant to share its bed with a sleeping adult in absolute safety.

Thus, in New Zealand it is recommended that baby should sleep in its own space, beside the parents' bed.[5] There are now programmes that lend cradles to parents, from SIDS New Zealand, Pregnancy Help, Moe Ora, and some maternity hospitals. Although further research is clearly needed, anecdotally, the authors believe that with the assistance of these initiatives effective breastfeeding can be achieved without baby being left to sleep with the adult, in the adult bed.

Alternatively, one proposed option to help baby sleep safely next to mother is the *wahakura* (flax cradle) developed by Dr David Tipene-Leach that can be placed on the parents' bed. The wahakura may help provide a safe sleeping place with easy access for breastfeeding, while at the same time baby would be protected from any pressure on the face. The wahakura have not yet been the subject of research to confirm their safety, and the relative effect of these different strategies on breastfeeding success is not known.

Summary

The safest way for an infant to sleep is on its back, on its own sleep surface, but in the same room as its parent. There must be no head flexion, covering of the face, or pressure on the lower jaw.

Competing interests: None known.

Author information: Christine G McIntosh, General Practice Senior Registrar, Depts of Physiology and General Practice, The University of Auckland; Shirley L Tonkin, Emeritus Member, New Zealand Cot Death Association, Auckland; Alistair J Gunn, Professor, Depts of Physiology and Paediatrics, Faculty of Medical and Health Sciences, The University of Auckland

Acknowledgements: We thank the HB Williams Turanga Trust, the Child Health Research Foundation, the Auckland Medical Research Foundation and the Health Research Foundation of New Zealand for their support.

Correspondence: Alistair J Gunn, Dept of Physiology, University of Auckland, Private Bag 92019, Auckland 1023, New Zealand. Fax: +64 (0)9 3737499; email: aj.gunn@auckland.ac.nz

References:

1. Haines L, NZPA. Baby deaths spark call for better bedsharing warnings. New Zealand Herald 2008 Dec 10.
2. Evans GL. Report of the Coroners court held at Wellington on 9 December 2008. Wellington, New Zealand: Coroners Court; 2009.
3. Mitchell EA, Thompson JM, Becroft DM, et al. Head covering and the risk for SIDS: findings from the New Zealand and German SIDS case-control studies. Pediatrics 2008;121:e1478-83.
4. Vennemann MM, Bajanowski T, Brinkmann B, et al. Sleep environment risk factors for sudden infant death syndrome: the German Sudden Infant Death Syndrome Study. Pediatrics 2009;123:1162-70.
5. The Ministry of Health, Child and Youth Mortality Review Committee. Preventing sudden unexpected death in infancy. http://www.moh.govt.nz/moh.nsf/indexmh/preventing-sudi-health-practitioner-info-apr08. In. Wellington; 2008.

6. Blair PS, Sidebotham P, Berry PJ, et al. Major epidemiological changes in sudden infant death syndrome: a 20-year population-based study in the UK. Lancet 2006;367:314-9.
7. McGarvey C, McDonnell M, Hamilton K, et al. An 8 year study of risk factors for SIDS: bed-sharing versus non-bed-sharing. Arch Dis Child 2006;91:318-23.
8. Auckland Coroner. Office of the Auckland Coroners Annual Report. Auckland: Ministry of Justice; 2005.
9. Gunn AJ, Gunn TR, Mitchell EA. Is changing the sleep environment enough? Current recommendations for SIDS. Sleep Med. Rev. 2000;4:453-69.
10. Naeye RL, Fisher R, Rubin HR, et al. Selected hormone levels in victims of the sudden infant death syndrome. Pediatrics 1980;65:1134-6.
11. Kinney HC, Richerson GB, Dymecki SM, et al. The brainstem and serotonin in the sudden infant death syndrome. Annu Rev Pathol 2009;4:517-50.
12. Tonkin SL, Gunn TR, Bennet L, et al. A review of the anatomy of the upper airway in early infancy and its possible relevance to SIDS. Early Hum Dev 2002;66:107-21.
13. Stark AR, Thach BT. Mechanisms of airway obstruction leading to apnea in newborn infants. J Pediatr 1976;89:982-5.
14. Thach BT, Stark AR. Spontaneous neck flexion and airway obstruction during apneic spells in preterm infants. J Pediatr 1979;94:275-81.
15. American Academy of Pediatrics. Safe transportation of premature infants. Pediatrics 1991;87:120-2.
16. Tonkin SL, McIntosh CG, Hadden W, et al. Simple car seat insert to prevent upper airway narrowing in preterm infants: A pilot study. Pediatrics 2003;112:907-13.
17. Merchant JR, Worwa C, Porter S, et al. Respiratory instability of term and near-term healthy newborn infants in car safety seats. Pediatrics 2001;108:647-52.
18. Kinane TB, Murphy J, Bass JL, et al. Comparison of respiratory physiologic features when infants are placed in car safety seats or car beds. Pediatrics 2006;118:522-7.
19. Tonkin SL, Vogel SA, Bennet L, et al. Apparent life-threatening events in infant car safety seats. BMJ 2006;333:1205-6.
20. Tonkin SL, McIntosh CG, Nixon G, et al. Can we reduce episodes of haemoglobin desaturation in full-term babies restrained in car seats? Acta Paediatr 2008;97:105-11.
21. Tonkin SL, Vogel S, Bennet L, et al. Positional upper airways narrowing and an apparent life threatening event. N Z Med J 2002;115:193-4.
22. Cohen G, Roux JC, Grailhe R, et al. Perinatal exposure to nicotine causes deficits associated with a loss of nicotinic receptor function. Proc Natl Acad Sci U S A 2005;102:3817-21.
23. Tappin D, Ecob R, Brooke H. Bedsharing, roomsharing, and sudden infant death syndrome in Scotland: a case-control study. J Pediatr 2005;147:32-7.
24. Hauck FR, Kemp JS. Bedsharing promotes breastfeeding and AAP Task Force on Infant Positioning and SIDS. Pediatrics 1998;102:662-4.