SIDS: past, present and future

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Keywords
Bed sharing, Prevention, risk- and protective factors, Sudden infant death syndrome

Abstract
Despite the large reduction in SIDS mortality, which occurred in the early 1990s following the ‘Back to Sleep’ campaigns, SIDS remains the leading cause of death in the postneonatal age group. This paper describes the position in the 1980s, the contribution of the New Zealand Cot Death Study, what should be recommended and the current research priorities.

Conclusion: SIDS is preventable. Application of what we currently know could eliminate SIDS. The challenge is to find ways of implementing our knowledge.

SIDS IN 1980S
In the 1980s, there was considerable concern about SIDS mortality in New Zealand (2). The SIDS mortality rate was higher than that in other countries, furthermore, total postneonatal mortality was higher (3), thus the high rate could not be explained by diagnostic transfer. The non-SIDS mortality rate was similar to other comparable countries, indicating that differences in health care services were unlikely to explain these differences.

Examination of SIDS mortality data showed that there was a male excess, the risk was higher in infants born with low birth weight or preterm, those coming from disadvantaged communities e.g. Maori, and those born to young mothers. Deaths varied by latitude (more prevalent in the higher latitudes), and were more frequent in winter. Furthermore, there was a characteristic age distribution, with few deaths in the first month of life, mortality rates peaking at 2–4 months then becoming

Sudden infant death syndrome (SIDS) has been present since antiquity. Indeed it is described in the Old Testament of the Bible: 1 Kings 3:19 “And this woman’s child died in the night.” It was not until 1965 that a specific International Classification of Diseases (ICD) code was allocated for SIDS (ICD-8 795). The prevalence of SIDS increased largely because of diagnostic transfer, predominantly from respiratory infections, which were often minor. By the 1980s, SIDS mortality was very high in many developed countries. SIDS was described as unpredictable and unpreventable. Indeed even today many reputable organizations subscribe to this view (1). Although SIDS cannot be predicted, I would like to challenge the contention that it cannot be prevented.

This study will describe where we were in the 1980s, the New Zealand Cot Death Study, what should be recommended in 2009, postulated mechanisms and what needs to be done in the future.
increasingly uncommon (2). These characteristics were similar in all countries.

The apnoea hypothesis was the dominant theory for the mechanism of SIDS in the 1970s and 1980s (4). Infants who subsequently died of SIDS were found to have significantly fewer apneic pauses than age-matched control infants, which is in the opposite direction predicted by the apnoea hypothesis (5). Furthermore, the small differences are unable to distinguish those infants who are at risk of SIDS and those who are not. Documented monitoring of cardiorespiratory patterns of infants dying of SIDS is also not consistent with the apnoea hypothesis (6,7). Despite apnoea monitoring programmes, SIDS rates did not decrease. This hypothesis fell into disrepute following the murder conviction (in 1993) of the mother of the multiple cases of ‘SIDS’ in one family in the original case report (8).

In the mid 1980s, the New Zealand Department of Health, now Ministry of Health, established postneonatal mortality review committees. The aims were to (i) identify preventable deaths, and (ii) develop and recommend prevention strategies, thus reducing infant mortality at a local level. I established and chaired the first committee, which covered the Auckland region. After 2 years, we reviewed the findings (9). We concluded that potentially preventable deaths were infrequent (10%). There were 80 cases of SIDS, and ‘notable’ factors were identified, for example co-sleeping and changes in routine and environment, but we could not interpret their importance as we did not know how prevalent these factors were in infants who did not die. The lack of control data led to the development of the New Zealand Cot Death Study.

**THE NEW ZEALAND COT DEATH STUDY**

This was a large nationwide case–control study (10,11). The specific aim was to identify risk factors for SIDS, with a particular emphasis on infant care practices. This research project commenced on 1 November 1987 under my directorship and collected comprehensive information on infants dying from SIDS in the postneonatal age groups in most main centres in New Zealand (covering about 80% of all live births in New Zealand). This study examined 485 SIDS cases and 1800 controls. Very satisfactory completion rates were achieved; obstetric records were examined and parental interviews were completed in 97.5% and 86.9% of subjects respectively. This major study would not have been possible without the skills and enthusiasm of Drs Scragg (epidemiologist), Becroft (pathologist), Taylor, Hassall, Barry, Allen, Roberts and Ford (paediatricians) and Mr Stewart (biostatistician) and the co-operation of the Department of Health Statistics Services.

Because of public and health professional concern about SIDS, we analysed some of the data from the first year of the study (10). As expected many risk factors for SIDS were confirmed including:

- Socioeconomic factors: (unmarried, manual occupation and younger age mother left school),
- Pregnancy (younger age of mother at first pregnancy, younger age of mother at infant’s birth, more than 4 months pregnant when first attended antenatal clinic, non-attendance at antenatal education classes and increasing number of previous pregnancies),
- Infant: (Maori ethnicity, male, low birth weight and preterm birth) and
- Postnatal factors: (age of infant, time of day, season, region and infant admission to a neonatal unit).

In addition, however, we identified risk factors, which were potentially amenable to modification. These were:

- prone sleeping position of baby,
- maternal smoking and
- not breastfeeding.

After controlling for all the above variables, the relative risks associated with prone sleeping position, maternal smoking and not breast feeding were still statistically significant. Population attributable risk calculations suggested that these three risk factors accounted for 79% of deaths from SIDS in New Zealand. The SIDS rate could theoretically be reduced from 4/1000 live births to 1/1000 live births if infants were not placed prone to sleep, mothers did not smoke and babies were breastfed.

At my instigation a group comprising of the Plunket Society, Department of Health, New Zealand Cot Death Association, Area Health Boards, Maori representatives, the Commissioner for Children and the research group met to devise strategies to produce these changes in infant care practices. The New Zealand Cot Death Prevention Programme was launched on 27 February 1991 (11), although the prevalence of prone sleeping position was decreasing before the launch (12). Figure 1 shows the first poster used in the national prevention campaign in 1991. Note at this time, the message was ‘side or back’ sleeping position, as the increased risk with side sleeping was not firmly established. This subsequently was changed to ‘back or side’, then ‘back only’.

![Figure 1](https://example.com/figure1.png) The first poster in the New Zealand Cot Death Prevention Campaign in 1991.
A fourth risk factor, namely infants sharing a bed with another person, was added to the prevention programme in 1992 (13). The prevention programme has been spectacularly successful (Fig. 2).

The New Zealand Cot Death Study has identified many new risk factors, including smoking by the father (14), postnatal depression (15), interaction between smoking and bed sharing (16), the protective effect of pacifiers (17) and the protective effect of sleeping in the same bedroom as the parents (18). We also showed that the increased risk in Maori was explained by higher prevalence of maternal smoking and co-sleeping with infant (19). The data have confirmed the importance of thermal insulation (20), duration and degree of breastfeeding (21) and symptoms of illness (22). It has excluded a causal relationship between SIDS and immunizations (23), types of nappies and how they are cleaned (24) and travel and changes in routine in the preceding 2 days (25). We also described the epidemiology of intrathoracic petechial haemorrhages and intrapulmonary haemorrhage in SIDS for the first time (26,27).

WHAT SHOULD BE RECOMMENDED?

Table 1 summarizes the major modifiable risk and protective factors for SIDS.

<table>
<thead>
<tr>
<th>Risk factors</th>
<th>Protective factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prone and side sleeping position</td>
<td>Sleeping in the parental bedroom</td>
</tr>
<tr>
<td>Maternal smoking in pregnancy</td>
<td>Breastfeeding</td>
</tr>
<tr>
<td>Bed sharing for infants of mothers who smoked</td>
<td>Pacifier use</td>
</tr>
<tr>
<td>Head covering</td>
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</table>

Sleep position

The risk of SIDS with prone sleeping position is well established (28) and has been largely eliminated and thus will not be discussed further. We were the first group to report an increased risk of SIDS with the side sleeping position (10,13). A meta-analysis of 10 studies examining side sleeping position reported a pooled odds ratio (OR) of 2.0 [95% confidence interval (CI) = 1.7–2.4] (29). Infants placed supine (back) to sleep are at the lowest risk of SIDS, which supports the recommendation that this is the preferred sleeping position of healthy infants. The prevalence of side sleeping position is declining but in New Zealand is still about 26.3% (30).

Smoking

There were 52 studies before the ‘Back to Sleep’ campaigns and these showed an increased risk of SIDS with maternal smoking [pooled OR = 2.9 (2.8–3.0)] (31). Since the ‘Back to Sleep’ campaign, there have been at least 17 studies. All showed an increased risk [pooled OR = 3.9 (3.8–4.1)]. However, it is difficult to disentangle the effect of maternal smoking in pregnancy from smoking by the mother after the birth, as few mothers change their smoking behaviour in such a short period of time. One way of establishing the importance of environmental tobacco smoking is to examine the risk of SIDS with smoking by the father where the mother is a non-smoker. There have been seven such studies [pooled OR = 1.5 (95% CI = 1.2–1.8)]. Although this is statistically significant, the effect of environmental tobacco smoking is small. We have argued that the relationship between maternal smoking in pregnancy and SIDS is causal. From a biological perspective, it is likely that the predominant effect from maternal smoking is likely to be in utero exposure of the foetus (31).

Bed sharing

In 1992, we reported the association of bed sharing with SIDS (11). The following year my colleague Dr Robert Scragg showed that the association was predominantly among infants of mothers who smoked (16). This has been confirmed in many studies (32–34). We showed that duration of bed sharing was important, with infants spending the whole night in bed with their parents being at higher risk of SIDS than those spending less than 2 h (16). Bed sharing infants who are placed back in their own beds are not at increased risk (33). However, mothers may intend to place their infant back in their own cot, but fall asleep. This may account for why tired mothers and SIDS cases accustomed to bed sharing appear to be at higher risk. This provides strong evidence that bed sharing is the problem, and not just the characteristics of the families that bed share.

The risk of SIDS with bed sharing is higher in younger infants. Carpenter et al. showed that even in infants whose mothers did not smoke there is an increased risk of SIDS in infants up to 3 months of age (32,33). Co-sleeping on a sofa or couch has been identified as a risk for SIDS (33,36). Infants sharing a bed with older siblings are at increased risk (16,37), although there are no data to state whether...
co-bedding of twins is a risk or not. There is no evidence that bed sharing is protective against SIDS in any group. The epidemiological evidence is summarized in Table 2.

When an interaction is present, removal of either factor will achieve the same effect. Although stopping smoking is desirable, this is difficult to achieve. The emphasis on stopping the co-sleeper from smoking rather than stopping the smoker from co-sleeping is not addressing the problem.

Bed sharing is fine for cuddles and breastfeeding, but baby should be in its own bed when parents go to sleep. In 1994, we recommended a cot beside the parent bed for the first 6 months of life (38). This approach has been followed by United Kingdom Department of Health (39) and the American Academy of Pediatrics (40).

What is the down side of advising that infants should not bed share? The major concern is that this will impact on breastfeeding (41). Bed sharing increases the frequency and duration of suckling (42,43). Although bed sharing is associated with a longer duration of breastfeeding, the effect is quite small. The other concern is that parents will reject this advice and with it other SIDS prevention messages. I believe that parents have a right to know what risks they are exposing their infants to and that health professionals should advise parents that the safest place for an infant to sleep is in a cot beside the parental bed in the first 6 months of life.

Head covering
A recent meta-analysis has been reported (44). There were 10 studies with control data. The prevalence of head covering in SIDS cases was 24.6% vs. 3.2% in controls [pooled unadjusted OR = 9.6 (95% CI = 7.9–11.7) and the pooled adjusted OR = 16.9 (95% CI = 12.6–22.7)]. Population attributable risk was 27.1%.

In UK the ‘Feet to foot’ campaign advised parents to place the feet of the infant at the foot of the cot to prevent head covering (45). This advice was endorsed by the American Academy of Pediatrics (46). Although intuitively sensible, there is no evidence that it reduces risk of head covering or lowers risk of SIDS.

Pacifiers
The New Zealand Cot Death Study was the first to examine the association between pacifier use and a reduced risk of SIDS (17). There are now seven further studies. Two meta-analyses both concluded that pacifier use was associated with a reduced risk of SIDS and that the evidence is consistent and moderately strong (47,48). The American Academy of Pediatrics task force recommended the use of a pacifier throughout the first year of life according to the following procedures (40):

- The pacifier should be used when placing the infant down for sleep and not be reinserted once the infant falls asleep. If the infant refuses the pacifier, he or she should not be forced to take it.
- Pacifiers should not be coated in any sweet solution.
- Pacifiers should be cleaned often and replaced regularly.
- For breastfed infants, delay pacifier introduction until 1 month of age to ensure that breastfeeding is firmly established.

However, the potential disadvantages were dismissed, particularly a reduced duration of breastfeeding (49) and increase in otitis media (50).

The approach we have taken in New Zealand is that the possible detrimental effects have to be balanced against the low risk of SIDS. We recommend that pacifiers should no longer be discouraged, but not specifically encouraged.

Room sharing
In 1996, our group was first to show the protective effect of sleeping in the parental bedroom (18). There have been several other studies, which have reported similar findings (Table 3) (32,33,37,38,51). Room sharing providing the infant is not bed sharing decreases 3-fold the risk of SIDS. This supports the recommendation that baby should sleep in the same room as the parents for the first 6 months of life.

Breastfeeding
Most studies have shown that SIDS is lower in breast fed infants (52), but as breastfeeding in most developed countries is associated with socioeconomic advantage, adjustment for socioeconomic factors results in a reduced level of protection. Some studies have concluded there is no decreased risk from breastfeeding (53,54). However, others, including us, have argued for a protective effect (21,55,56).

Table 2: Summary of the risk of sudden unexpected death in infancy and sudden infant death syndrome with bed sharing
| The risk of SIDS with bed sharing is high when the mother smokes or smoked in pregnancy |
| The risk of SIDS with bed sharing is higher in younger infants |
| There is a small increased risk with bed sharing when the mother does not smoke in infants less than 3 months of age |
| Bed sharing infants placed back in their cot are not at increased risk of SIDS |
| The longer the infant bed shares during the night the greater the risk of SIDS |
| The risk of SIDS with bed sharing is higher if the adult has been drinking, taking drugs or medications that might impair their awareness of the infant or if the adult is obese or if the baby was preterm or low birth weight |
| Co-sleeping on a couch or sofa is associated with a high risk of SIDS, although the number of infants exposed to this risk is small |
| Infants bed sharing with older siblings are at increased risk, although there are no data either way for twins sharing (sometimes referred to as co-bedding) |
| There is no evidence that bed sharing is protective against SIDS in any group |

Table 3: Studies showing reduced risk of SIDS with room sharing
<table>
<thead>
<tr>
<th>Author</th>
<th>Ref</th>
<th>Country</th>
<th>Percent exposed</th>
<th>Control OR</th>
<th>Univariate OR</th>
<th>Multivariate OR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scragg (1996)</td>
<td>(18)</td>
<td>New Zealand</td>
<td>20.7</td>
<td>37.1</td>
<td>0.44</td>
<td>0.25</td>
</tr>
<tr>
<td>Blair (1999)</td>
<td>(33)</td>
<td>England</td>
<td>25.3</td>
<td>39.0</td>
<td>0.53</td>
<td>0.51</td>
</tr>
<tr>
<td>Hauck (2003)</td>
<td>(37)</td>
<td>United States</td>
<td>20.8</td>
<td>28.1</td>
<td>0.67</td>
<td>Not reported</td>
</tr>
<tr>
<td>Carpenter (2004)</td>
<td>(32)</td>
<td>Europe</td>
<td>28.0</td>
<td>44.5</td>
<td>0.49</td>
<td>0.32</td>
</tr>
<tr>
<td>Tappin (2005)</td>
<td>(51)</td>
<td>Scotland</td>
<td>35.8</td>
<td>63.5</td>
<td>0.32</td>
<td>0.31</td>
</tr>
</tbody>
</table>
POSTULATED MECHANISMS
A large number of mechanisms for SIDS have been proposed, although most such as poisoning by immunizations or toxic gases are unsubstantiated.

The ‘triple risk hypothesis’ has been proposed by a number of authors (57–59). This hypothesis proposes that there is an underlying vulnerability of the infant, an age-related developmental stage and precipitating factor or stressors (Fig. 3). Factors producing a vulnerable infant include genetic, abnormalities of serotonin (5-HT) neurones and pregnancy related factors. Genetic studies have identified several ways that SIDS cases differ from healthy infants. Polymorphisms include cardiac ion channelopathies, serotonin transporter gene, autonomic nervous system development, complement C4 gene and interleukin-10 cytokine (60,61). 5-HT neurons in the medulla oblongata regulate multiple aspects of brainstem-mediated control of respiratory and autonomic function (62,63). Failure of ‘protective’ reflexes would place the infant at risk for sudden death during normal life stresses that may occur in sleep such as hypoxia, rebreathing or airway obstruction. Detailed studies of the brainstem show that some SIDS infants have a developmental abnormality in the medullary network (63). Pregnancy related factors include low birth weight, preterm birth and maternal smoking. Maternal smoking causes foetal growth retardation (64), reduction in lung growth and elasticity (65), and alters the neural control of autonomic, behavioural and homeostatic function (62,66). Maternal smoking during pregnancy alters cardiovascular function in the weeks after birth (67). This might lead to failure of the homeostatic cardiovascular responses resulting in substantial loss of blood pressure, bradycardia and death (68).

Precipitating factors or stressors include sleep position, bed sharing, thermal stress, head covering, infection, etc. The risk of SIDS associated with the prone sleeping position is greater in winter (69), at higher latitudes (70) and altitudes (71), with excess thermal insulation (20,72) and with illness (22,72). This suggests that the mechanism by which prone sleeping position causes SIDS is in some way related to temperature (73). Bed sharing and head covering might cause thermal stress, airway obstruction or rebreathing of expired gases.

Parents frequently report that their babies had minor symptoms of infection, especially respiratory tract symptoms, in the days immediately before the death (22,74). These infections are not thought to cause the death. Immunoglobulin levels (IgG) in the first year of life are high in the first month of life due to passive transfer from the mother in utero. The levels then decrease and are lowest at 2–4 months of age, but then gradually increase as the infants produce their own IgG. The levels are a mirror image of the age distribution of SIDS cases. Blackwell et al. have postulated that some SIDS deaths are caused by uncontrollable inflammatory reaction to infectious agents (especially pyrogenic toxins of Staphylococcus aureus) (75,76). The pro-inflammatory cytokines induced by the infections can cause respiratory and cardiac dysfunction, pyrexia, shock and arousal defects. Prone sleeping position increases pooling of nasal secretions resulting in an increase in bacterial colonization (77). Staphylococcus aureus may produce pyrogenic toxins, but only when the temperature is between 37 and 40°C (76). The nasopharynx is usually below this, but prone position and a viral infection may increase the temperature in the nasopharynx (78).

THE FUTURE
SIDS can be prevented and the application of what we already know has the potential to further reduce SIDS. The evidence supporting these risk and protective factors is strong, as I have described, and should be included in SIDS prevention campaigns. Antenatal and neonatal services have an important role. Nursing care plans should be developed to establish these infant care practices as the norm. The biggest influence is what is performed on the postnatal wards in the first few days of life. If a midwife/nurse places a baby on the back to sleep, then this sleeping position will be continued by the mother following discharge home. Neonatal Intensive Care Unit graduates should be placed supine prior to discharge home. The UNICEF-WHO Baby Friendly Hospital Initiative is applicable to developed as well as developing countries (79).

In New Zealand in 2004, there were 45 SIDS cases (ICD-10 R95); many were described as being in an unsafe sleeping environment (80). In addition, there were eight deaths certified as ‘other ill defined’ (ICD-10 R99), which include ‘unascertained’. In many of these cases the coroner was unable to determine whether the death was due to SIDS or accidental suffocation in bed. Worryingly, there were 16 deaths resulting from accidental suffocation and strangulation in bed (W75). In Wellington, New Zealand over a 10-year period 54% of sudden unexpected deaths in infancy occurred while co-sleeping (81). Thus the biggest gain in New Zealand would come from stopping bed sharing.

There are two innovative interventions – Cribs for Kids (82), which is a cradle loan scheme, and the wahakura safe bed-sharing project, which is a Maori initiative in New Zealand.
Zealand (83). Wahakura is a flax woven basket in which baby sleeps and the basket can be taken into the parental bed (Fig. 4). The families are also taught about the dangers of bed sharing with their infant. Although these interventions have yet to be evaluated, it is pleasing to see new approaches to establishing a safe sleeping environment for infants.

The major research need is educational research, in particular how to produce behavioural change. The major questions are how to avoid head covering and how to bed share safely, as we know that some parents will choose to continue bed sharing despite the evidence of the risk.

Until we understand the mechanism of SIDS, there will always be concerns that the risk factors are associations and not part of the causal mechanisms. Genetic studies offer a way forward, and I expect that in the next decade there will be considerable advances in this area. It is likely that the list of polymorphisms will expand rapidly once genome wide association studies for SIDS are reported. The next major advance will come from studies examining the interaction between genetic and environmental risk factors.

CONCLUSIONS

SIDS is preventable. Application of what we currently know could eliminate SIDS. The challenge is to find ways of implementing our knowledge.

ACKNOWLEDGEMENTS

This paper is based on the Nils Rosen von Rosenstein Award Lecture given on 24 April 2009 in Uppsala, Sweden. The award honours the recipient and all members of the New Zealand Cot Death Study Group, which comprised Robert Scragg, David Becroft, Alistair Stewart, Carol Everard, John Thompson, Liz Allen, David Barry, Ian Hassall, Alison Roberts, Rodney Ford, Barry Taylor and Sheila Williams. The New Zealand Cot Death Study was funded by the Medical Research Council of New Zealand and Hawkes Bay Medical Research Foundation. Ed Mitchell is supported by the Child Health Research Foundation.

DEDICATION

This study is dedicated to the parents of both cases and controls who so willingly shared information with our research team. Without their contribution we would not have made the advances that have resulted in a reduction of infant mortality in New Zealand and many other countries.

References


