For discussion

Multiple sudden infant deaths – coincidence or beyond coincidence?

Introduction

On hearing that a family has suffered two, three or even four sudden infant deaths, what should our initial reaction be? Should we view multiple deaths with a great deal more suspicion than an occurrence of just one sudden death in a family?

Of course, there may be, in a particular case, a known and undisputed natural explanation for the deaths or, on the other hand, there may be injuries and overwhelming evidence of child abuse, suggestive of homicide. What we are concerned with in this article are those cases where no natural explanation can be found, nor is there any strong evidence of child abuse. Are such deaths more likely to be cot deaths, that is, natural but unexplained, or are they more likely the result of foul play, such as suffocation or shaking, which has left little in the way of evidence of injury?

In recent years there appears to have been a trend to regard multiple deaths with much more suspicion than single deaths, perhaps inspired by the dictum, known in Britain as Meadow's Law, that 'one cot death is a tragedy, two cot deaths is suspicious and, until the contrary is proved, three cot deaths is murder'. This was propounded by Professor Sir Roy Meadow, an eminent British paediatrician, who has served as an expert prosecution witness in many cases where mothers suffering multiple sudden infant deaths have been accused of murder. In at least some of these cases, it appears that the trigger for the criminal investigation was just the coincidence of the second or third death. In this paper, we consider the question of whether such multiple deaths are likely to be coincidental, or as the prosecution would sometimes have us believe, beyond coincidence.

A first concern with Meadow's Law is that it turns traditional British justice on its head. The normal presumption is that of innocence until proven guilty, and

not the other way round. A recent British case is that of Sally Clark; the death of her first baby was originally recorded as natural cot death, but after the death of her second baby, Clark was tried and convicted of murdering both her babies. Meadow's Law then appeared to hold sway in the sense that the verdict was not quashed until, on second appeal, the defence were able to uncover clear evidence of a natural cause of death. Clark had spent over 3 years in jail for a crime that had not even happened and, it could be argued, she was presumed guilty until her innocence was proved.

A second concern is whether there is any scientific justification for Meadow's Law. It was stated by Sir Roy at Sally Clark's trial that the chances of her having two natural cot deaths were 'one in 73 million', a figure which would rather suggest that such deaths were beyond coincidence. There is little doubt that this figure, condemned by the second appeal court judgement as 'grossly misleading', had a huge impact on the jury. I shall explain later why this figure was both wrong and misleading. But at this point I should just like to add that such figures can have a huge impact not only on jurors, but also on prosecution witnesses in that they can become so convinced, on the basis of mathematical misconceptions, that the accused must be guilty that they become blinded to evidence in support of innocence. This may account (and this is pure speculation on my part) for the 'overlooking' of key evidence by the pathologist in the Sally Clark case.

The main purpose of this article is to estimate various probabilities in order to establish whether Meadow's Law has any scientific substance. First we will look at the definition of sudden infant death syndrome (SIDS), commonly known as cot death in the UK and crib death in the USA; secondly we will consider the relative chances of double cot death or double homicide, the relative chances of triple cot death or triple homicide, and finally we will consider some other relevant aspects such as the legitimacy of taking special known characteristics of the family into account when calculating probabilities, the role of the

Correspondence:
Ray Hill, Professor of Mathematics, University of Salford, Salford, M5 4WT, UK. E-mail: r.hill@salford.ac.uk

Prosecutor's Fallacy in court cases, and the public's preconceptions of how likely coincidences are.

More detailed consideration of some of these issues may be found in my earlier paper,[1] which also largely forms the basis of an excellent paper by Helen Joyce.[2]

Definition of SIDS

The definition of SIDS which is still current was formulated by the American pathologist Beckwith, in 1969, as follows:

> the sudden death of a baby that is unexpected by history and in whom a thorough post-mortem examination fails to demonstrate an adequate cause of death.[3]

This definition allows considerable scope for inconsistency, depending as it does on the pathologist's thoroughness in the autopsy and on his or her interpretation of the findings. Also, pathologists and coroners vary in their readiness to accept SIDS as a registered cause of death, sometimes preferring to use the term 'unascertained'. For example, the term 'unascertained' seems to be increasingly used for a death which meets the Beckwith definition, but for which some factor is present that gives rise to a suspicion that the death might not be natural. The varying interpretations of the definition of SIDS, both geographically and over time, mean that any comparisons of SIDS rates need to be interpreted with caution.

Double SIDS vs. double homicide

Introductory remarks

There is no doubt that the occurrence of two or more SIDS in the same family will be a rare event, just as the occurrence of two or more infant murders in the same family will be a rare event. The point at issue here is: what are the *relative* chances of these occurrences, given that two or more sudden deaths have occurred? Of course, when multiple sudden deaths have occurred, it is not necessarily the case that all were SIDS or that all were homicides. Some or all might be *explained* natural deaths or deaths resulting from accidents. And even if these last two categories can be discounted, there is the possibility that the deaths were a mixture of SIDS and homicides. With this proviso in mind, it still seems to me that the most relevant comparison to make here is that of the chances of multiple SIDS against the chances of multiple homicide, the

reason being that when a case of multiple deaths comes to trial, it is generally the case that the prosecution claims that the deaths are all homicide, while the defence claims that they are all SIDS.

In order to arrive at an estimate in the case where two or more sudden deaths have occurred, it is helpful first to consider the case of just one sudden death.

Single SIDS vs. single homicide

In Britain, the Confidential Enquiry for Stillbirths and Deaths in Infancy (CESDI) studied the deaths of babies in five regions of England from 1993 to 1996.[4] The CESDI study considered a total number of 472 823 live births of which 363 deaths were identified as SIDS. Thus the chances of a random infant suffering a cot death at this time were about 1 in 1300.

According to British national statistics, there are fewer than 30 infant homicides per year among the 650 000 births each year in England and Wales.[4] So the chances of an infant being a homicide victim are about 1 in 21 700.

It follows that an infant is about 17 times more likely to be a SIDS victim than a homicide victim.

Remark

The large sample size of the CESDI study means that the figure of 1 in 1300 can be regarded as highly reliable as a measure of the SIDS rate in England between 1993 and 1996. However, it should be noted that the SIDS rate of the 1980s was almost halved in the 1990s, probably as a result of the *Back to Sleep* campaign of 1991. Moreover, SIDS rates continue to fall as parents receive better advice, and as better diagnosis now allows clear explanations for some deaths which would previously have been recorded as SIDS. So it is important to stress that the 1 in 1300 figure will be highly accurate only when applied to the time period 1993–96. Indeed, this remark serves to reinforce the comment made above that all SIDS statistics should be interpreted with caution.

What is the increased risk of SIDS if there has already been a SIDS in the family?

It is intuitively clear that an infant in a family which has already suffered a SIDS will be at increased risk of SIDS, because many genetic and environmental factors

will be the same. The published data allow us to estimate the actual level of dependency.

According to the CESDI report,[4] among the 323 SIDS families studied, there were 5 previous SIDS, while among the 1288 control families, there were 2 previous SIDS. This suggests a 'dependency factor' of about 10 (given by 5/323 divided by 2/1288). That is, a baby is 10 times more likely to be a SIDS victim if a previous sibling was a SIDS victim than if not.

Remark

The figure of '2' for the number of previous SIDS in the control families is too small to be reliable. We could more accurately replace this figure by E, where E is the *expected* number of previous SIDS in the control families. We already know that the probability of a random baby being a SIDS victim is 1/1300 and so $E = T/1300$, where T is the total number of previous siblings of the control infants. Now $T = 1288A$, where A is the average number of previous siblings per control family, and A was calculated[1] from the CESDI data as 0.923, thus leading to $E = 0.914$. This in turn implies that the dependency factor for second SIDS should be around 22 rather than 10. However, this 'more accurate' argument is counter balanced by the fact that, while the infants in the CESDI study were born in 1993–96, many previous siblings would have been born at a time when the SIDS rate was nearly twice as high, and so the figure of '2' rather than '0.914' might be more accurate after all. So, on balance, I am inclined to regard the dependency factor of 10 as being a reasonable estimate.

How does the dependency factor of 10 derived from the CESDI study compare with that given by other studies? A draft report on the Care of Next Infant (CONI) Programme, a programme which offers a variety of support measures for parents who have had a previous infant's death attributed to SIDS, is based on a survey[5] of over 6000 infants registered on the CONI Programme between 1988 and 1999. The risk of an infant being a SIDS victim was 5.7 times greater if its immediately previous sibling was a SIDS victim. There is not a great discrepancy between the CESDI estimate of 10 and the CONI figure of 5.7. It could be that both figures are accurate and that the smaller figure of 5.7 is a measure of the success of the CONI Programme in reducing the incidence of second SIDS for these particular infants. Or it could just be that the numbers of double SIDS in the two samples are so small that any probabilities

derived from them can be regarded only as rough estimates. Interestingly, a whole population study in Norway[6] gives a dependency factor of 5.8, almost exactly the same as in the CONI study. It should be borne in mind, however, that the Norwegian study, while published in 1996, related to infants born between 1967 and 1988.

In the light of all the data, it seems reasonable to estimate that the risk of SIDS is between 5 and 10 times greater for infants where a sibling has already been a SIDS victim.

Double SIDS vs. double homicide

Given that two sudden infant deaths have occurred in the same family, which is the more likely explanation – double SIDS or double homicide?

The probability that two successive deaths in the same family are both SIDS is given by

$$P = 1/1300 \times x/1300 \qquad (1)$$

where x is the dependency factor for second SIDS, estimated above as lying between 5 and 10.

The probability of double homicide is given by

$$Q = 1/21\,700 \times y/21\,700 \qquad (2)$$

where y is the dependency factor for second homicide, given a first.

We already have a good estimate for x, and so, if we also had an estimate for y, we would immediately reach our goal of getting a comparison of P with Q. The problem is that calculating y from known data is not straightforward. After all, someone who is known to have killed once is generally not at liberty to do so again. However, there is a way around this. We can make an estimate of the ratio P/Q *directly* from data in the CONI study,[5] and then *infer* the value of y from (1) and (2).

A key finding in the CONI study is that of 33 *second* sudden unexpected deaths, 27 were natural and six non-natural, giving an odds ratio in favour of natural deaths of 4.5 to 1. The 27 second deaths recorded as natural were carefully reviewed on the CONI Programme and it is the view of Waite and colleagues[5] that 'although one can never be certain, our reviews indicate that few if any non-natural deaths remained undetected'. They go on to state 'Our finding that this ratio [natural : non-natural] is 4.5 to 1 implies that, when being informed that a family has experienced a second unexpected death, the initial assumption should be

that it is natural and that it should be investigated sympathetically.'

In terms of our quest for an odds ratio of double SIDS to double homicide, the 4.5 to 1 figure is not directly applicable. This is because (a) the 27 cases of natural second deaths included nine cases where at least one of the two deaths was an *explained* natural death, thus leaving 18 which were double SIDS; (b) of the six non-natural second deaths, in only two cases was the parent convicted of the murder of both children. So the double SIDS to double homicide ratio is 18 to 2, that is, 9 to 1.

In order to have confidence in our figure, we should consider whether, in the four cases where the second but not the first death was homicide, there was any *suspicion* that the first death may have also been non-natural. In one of these four cases, the second death was attributed to a juvenile babysitter and so there is presumably no reason to be suspicious of the parents about the first. In another case, the homicide was overt – an assault by the mother causing fractured skull and brain stem injury. So if the first death had been unnatural the cause of death would certainly not have been the same. For the other two cases, no indication is given one way or the other as to whether there are any suspicious circumstances relating to the first death.

So it seems reasonable to conclude that even if our figure of 9 to 1 may be an overestimate, then the correct odds ratio for double SIDS to double homicide probably still lies somewhere between 4.5 to 1 and 9 to 1.

Finally, if we take the CONI figures of $x = 5.7$ and $P/Q = 9$ from above, then we find from (1) and (2) that $y = 176$. So an infant is 176 times more likely to be a homicide victim if its previous sibling was a homicide victim than if not. This is a huge dependency factor, but not surprising, as we would expect it to be the case that a previous killer would be far more likely to kill again than for someone to kill for the first time.

Triple SIDS vs. triple homicide

We have seen that for a single sudden death, SIDS outweighs homicide by about 17 to 1, and that for double sudden death, double SIDS outweighs double homicide by about 9 to 1. There is not a great difference between these figures, and so one might expect that for triple sudden deaths, there would not be much difference again. However, this is not necessarily the case, because hidden behind the closeness of these two figures lie huge differences in the dependency factor for

second SIDS, given a first, and second homicide, given a first. (If the dependency factors had been the same, then double SIDS would have outweighed double homicide by 17×17 to 1, i.e. by 289 to 1).

To date, we have estimated that an infant has:

1 a 1 in 1300 chance of being a SIDS victim, increasing to 1 in 228 ($228 = 1300/5.7$) if a previous sibling was a SIDS victim; and

2 a 1 in 21 700 chance of being a homicide victim, increasing to 1 in 123 ($123 = 21\,700/176$) if a previous sibling was a homicide victim.

In order to estimate an odds ratio of triple SIDS to triple homicide, we need estimates for the chance of a third SIDS given two previous, and for a third homicide given two previous. Any such estimates must be highly speculative. If pressed, I would speculate that reasonable guesses would be that:

1 the chance of a third SIDS, given two previous, might be around 1 in 50; and

2 the chance of a third homicide, given two previous, might be around 1 in 10.

These guesses lead to an odds ratio of $(21\,700 \times 123 \times 10)/(1300 \times 228 \times 50)$ to 1, which is about 2 to 1.

So if my guesses are correct, then triple SIDS is more likely than triple homicide, although not by much. Whether or not my guesses are accurate is not in fact crucial, because if we replace them by other guesses, even ones in which we assume that *every* double killer will become a triple killer, then the odds ratio for triple SIDS against triple homicide would still likely end up somewhere between 5 to 1 in favour of triple SIDS and 5 to 1 in favour of triple homicide. Whatever the actual odds, one would draw the same conclusion, namely that:

> When three sudden deaths have occurred in the same family, the statistics give no strong indication one way or the other as to whether the deaths are more or less likely to be SIDS than homicides.

Remark

As making the above calculation, I have learnt of some further data provided by Professor RG Carpenter, one of the authors of the draft report on the CONI Programme.[5] He was able to draw on information (not given in the report) on *all* deaths of previous siblings in CONI families prior to enrolment on the CONI Programme. Thus, taking account of deaths both before

and after enrolment, Professor Carpenter found that there were in all nine families that suffered three infant deaths. He reports that in eight of the nine cases, all three deaths were natural while just one case was triple homicide. The eight cases of triple natural deaths broke down as: two cases of triple SIDS; three cases of double SIDS combined with one explained or accidental death; two cases of single SIDS combined with two explained deaths; one case of three explained deaths.

It is noteworthy that within this set of nine families, there were precisely two triple SIDS and one triple homicide, thus agreeing exactly with the 2 to 1 ratio of triple SIDS to triple homicide predicted by my mathematical analysis above. The 2 to 1 figure must still be regarded as only a rough estimate, but Professor Carpenter's findings reinforce the conclusion that *when three sudden infant deaths have occurred in a family, there is no initial reason to suppose that they are more likely to be homicide than natural.*

Concluding remarks and related issues

Implications for Meadow's Law

We have estimated that single cot deaths outweigh single homicides by about 17 to 1, double cot deaths outweigh double homicides by about 9 to 1, and triple cot deaths outweigh triple homicides by about 2 to 1.

These figures suggest that with each successive death, there are indeed grounds for slightly increased suspicion, but to nothing like the extent suggested by Meadow's Law. There is certainly no justification for a second or third death in itself being the trigger for a criminal investigation.

My personal view is that the vigour which is currently brought to bear investigating second and subsequent sudden deaths should be applied to *all* cases of sudden unexpected deaths, in order to give parents the best possible chance of learning the true cause of their infant's death. Such investigations should be carried out by a team of various medical and other professionals, but with minimal or no initial police involvement, unless there is clear evidence of foul play. They would be expensive, but should have long-term benefits in gaining knowledge which would help reduce the future incidence of SIDS. And it would surely be a better way of spending money than on expensive criminal trials, possibly producing incorrect verdicts, and which might have been avoided had the first death been fully investigated.

Taking account of particular risk factors

Before I had studied the published research into cot deaths, I had naively assumed that, because such deaths were unexplained, they therefore somehow struck families at random and that my children were at just as much risk as anyone else's. This is far from the case, as research such as the CESDI study shows that there are many factors which can place a baby at substantially greater risk of SIDS. These include gender (boys are at greater risk than girls), smoking of parents, baby sleeping on front rather than back, and various indicators of social deprivation.

When a cot death mother is accused of murder, the prosecution sometimes employs a tactic such as the following. If the parents are affluent, in a stable relationship and non-smoking, the prosecution will claim that the chances of the death being natural are greatly reduced, and by implication that the chances of the death being homicide are greatly increased. But this implication is totally false, because the very same factors which make a family low risk for cot death also make it low risk for murder.

Why was the '73 million to one' figure wrong in the Sally Clark case?

The answer to this question has been considered at length[1] (and unpublished manuscript Hill 2002, 'Why Sally Clark is, probably, innocent'). Let me here just summarise the three primary objections to the use of this figure. First, note that it was derived by claiming that, for a family like Sally Clark's (non-smoking and affluent), the chances of a single cot death were 1 in 8543 and that therefore the chances of two cot deaths were 1 in 8543×8543, that is, about 1 in 73 million.

Objection 1

We saw above that, on average, the chances of a cot death are 1 in 1300. So why did the prosecution witness, Sir Roy Meadow, claim the chances were as low as 1 in 8543 for each of Sally Clark's babies? Well, he adopted the tactic described in the previous subsection, taking account of three key characteristics possessed by the Clark family, all of which make cot death less likely (he conveniently ignored factors such as both the Clark babies being boys – which make cot death more likely!). He thus used a probability which applies only to a certain subpopulation. The objection

is that just as this subpopulation is atypical for cot death, so also is it atypical for murder, and so the *relative* chance of cot death as opposed to murder is not necessarily lower.

Objection 2

This concerns the infamous squaring of 8543 to get 73 million. Squaring would have been a correct step if the two deaths could have been regarded as independent events. But, as we saw above, after a first cot death the chances of a second become greatly increased. Incidentally, Sir Roy went on to make a further calculation in his evidence at the Clark trial. He claimed that the 1 in 73 million figure translated into such a double death occurring once every hundred years. This calculation was endorsed by the Appeal Court judges at Clark's first (failed) appeal as being 'a straight mathematical calculation to anyone who knew that the birthrate over England, Scotland and Wales was approximately 700 000 a year'. Far from being a straight mathematical calculation, the deduction is in fact complete nonsense, because the figure of 1 in 8543, used by Sir Roy to get the 73 million, is not applicable to the whole population, but only to the much smaller subpopulation having the three special characteristics.

Objection 3

Did the jury fall victim to the so-called 'Prosecutor's fallacy'? That is, did they mistakenly regard the 1 in 73 million figure as meaning the chances of Sally Clark being innocent? I have previously discussed (Hill 2002, unpublished manuscript) not only why I believe the jury were misled in this way, but also why the first appeal court failed fully to realise the significance of this. We have already seen that second cot deaths occur with more regularity than the 73 million to 1 figure would imply, perhaps four or five times a year in the UK. When such a tragic double-death does occur, there is no statistical basis for inferring guilt of the parent, just as no-one argues that the three or four (on average) British lottery jackpot winners each week must be fraudulent because each of them has individually overcome odds of 14 million to 1.

Statistics in the courtroom

What role should probabilities and statistics play in our courtrooms? The Royal Statistical Society, in a press release issued after Sally Clark's first appeal failed, advocated that statistical evidence should be given only by statistical experts, just as medical evidence can be given only by medical experts. Others might argue that it would be better to avoid statistics altogether. The danger with the latter approach is that jurors may well draw incorrect conclusions for themselves, believing that occurrences of very rare events are somehow beyond coincidence. One wonders whether the Clark jury would have convicted if, instead of being given the 'once in a hundred years figure', they had been told that second cot deaths occur around four or five times a year and indeed happen rather more frequently than second infant murders in the same family.

How good is our intuition regarding coincidences?

The phrase 'lightning doesn't strike twice' does seem to reflect our perceptions in that almost everyone underestimates the true chances of coincidence. Here is how I demonstrated this to an audience of medical professionals in a conference talk. There were 22 persons in the audience. I asked each of them to choose a random number from the range 1 to 100. I asked each person also to estimate the probability that some two of the 22 persons will have chosen the same number, giving this probability as one of the percentage ranges 0–10%, 11–20%, and so on up to 91–100%. Before reading on, you might wish to pause and have a guess yourself as to which is the correct range.

On this occasion, shows of hands revealed that four persons thought the probability would lie in the range 0–10%, nine persons thought 11–20%, six thought 21–30%, two thought 31–40%, and one thought 41–50%. Not one person thought the chances of a matching pair to be greater than 50%.

The correct range is actually the top one, the probability of a matching pair being 92%. To see this, we first calculate the probability p that all 22 chosen numbers are different. The probability that the second number differs from the first is $99/100$, the probability that the third differs from the first two is $98/100$, and so on, giving $p = 0.99 \times 0.98 \times \ldots \times 0.79 = 0.08$. (It is perhaps surprising, but true, that this product of 21 numbers all close to 1 ends up being so small.) Finally, the probability of at least one matching pair is $1 - p = 0.92$.

On the occasion referred to, it did not take long to go round the room checking numbers to find not only a double but a triple match. This demonstration is a

variation of the well known 'birthdays paradox', that you need have only 23 persons in a gathering to have a better than evens chance of two having the same birthday.

I have used the same demonstration with audiences of mathematicians, and they perform only slightly better than the medics in their estimate of the probability. Our intuition really does play tricks with us. Given this predisposition to underestimate the chances of coincidence, it is all the more important to be on one's guard against fallacious arguments which further raise those chances – to the point where 'coincidence' becomes 'beyond coincidence'.

References

1 Hill R. Cot death or murder – weighing the probabilities. Paper presented to the Developmental Physiology Conference, June 2002. Available from the author.

2 Joyce H. Beyond reasonable doubt. *Plus Magazine*, September 2002, http://www.plus.maths.org/issue21.

3 Beckwith JB. Discussion of terminology and definition of the sudden infant death syndrome. In: *Proceedings of the Second International Conference on Causes of Sudden Death in Infants*. Editors: Bergman, JB, Ray, CG. Seattle: University of Washington Press, 1970; pp. 14–22.

4 Fleming P, Bacon C, Blair P, Berry PJ (eds). *Sudden Unexpected Deaths in Infancy, The CESDI Studies 1993-1996.* London: The Stationery Office, 2000.

5 Waite A, Coombs RC, Daman-Willems C, McKenzie A, Huber J, Carpenter RG, *et al.* Repeat sudden infant deaths in families enrolled on to a support programme. Draft manuscript, November 2002.

6 Oyen N, Skjaerven R, Igens LM. Population-based recurrence risk of sudden infant death syndrome compared with other infant and fetal deaths. *American Journal of Epidemiology* 1996; **144**:300–305.

7 Di Maio DJ, Di Maio VJM. *Forensic Pathology*. New York: Elsevier, 1989; p. 291.

Editor's note

Whilst 'Meadow's Law' is quoted frequently in the UK, I am grateful to Dr Glynn Walters for pointing out the following:

> 'Professor Meadow did not originate the law. It appears to be attributable to D.J. and V.J.M. Di Maio, two American pathologists who state in their book:[7] *It is the authors' opinion that while a second SIDS death from a mother is improbable, it is possible and she should be given the benefit of the doubt. A third case, in our opinion, is not possible and is a case of homicide.*
> It is clear that the statement is the authors' *opinion*. It is not a *conclusion* reached by analysis of their observations; no supportive data are presented and there are no illustrative case histories, or references to earlier publications. This is in striking contrast with the rest of the book which is replete with illustrative case histories and cites many references throughout. A recent examination of Meadow's own contributions to the medical literature has likewise failed to uncover supportive pathological evidence or references to it.'

<div align="right">

RAY HILL
University of Salford, Salford, UK

</div>