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Distribution of incidents of resuscitation and death in the Juliana Kinderziekenhuis [Juliana Children's Hospital] and the Rode Kruisziekenhuis [Red Cross Hospital]

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Point at issue and method employed

This memo deals with the question as to whether it may have been coincidence that a particular nurse, hereafter referred to as Mrs. V., was faced very frequently indeed with situations requiring patients to be resuscitated, whether or not successfully, during her shifts at a particular Medium Care Unit of the Juliana Kinderziekenhuis (JKZ) and at wards '41' and '42' of the Rode Kruis Ziekenhuis (RKZ).

Below, I will use the term 'incidents' by way of abbreviation of the phrase 'situations requiring patients to be resuscitated, whether or not successfully'.

To answer the question, two approaches are possible.
The first method, which I will refer to as the epidemiological method, attempts to compare the occurrence of incidents on the wards in question with data about the occurrence of incidents in similar patients in other hospitals.
The second method, which I will refer to as the conditional method, investigates the *distribution* of the occurrence of incidents on those wards between the employees working there.

In answering the above question, my preference lies with the conditional method, for the following reason. The use of the epidemiological method requires the availability of data relating to "similar patients". Straightaway, we are presented with a problem, for who are these "similar patients"? One might, of course, gather the mortality and resuscitation figures for the children's wards of other Dutch hospitals and for their medium care units in particular, insofar as these are of an even remotely similar nature as the units at the JKZ. Equally, for the sake of comparison one might collect data about deaths on wards that resemble those of the RKZ. Yet the comparison would not be reliable. After all, we cannot assume, *a priori,* an equal risk of death or resuscitation requirement in the various kinds of care given by different hospitals, nor an identical quality of medical or nursing care. Actually, it is an established fact that the incidence of deaths in The Netherlands is not uniformly distributed between towns and villages. How this affects the mortality on the kinds of wards on which Mrs. V. worked is not clear. It follows that the epidemiological method would leave many questions unanswered, all the more so because the actual number of deaths on medium care children's wards is negligible to begin with - no children at acute risk are present on such wards. Thus, the potential of such a comparison to differentiate between hospitals will necessarily be small. Moreover, the accuracy of the results will decrease with a non-uniform distribution of the mortality risk dependent on a diverging intake of patients. I consider the epidemiological method to be unsuited to the matter in hand.[1]

The conditional method, then, rather than compare the hospitals in question with others, focuses on the resuscitation cases on a particular ward. The method poses the question whether it is possible, *given the total number of incidents on that ward*, that the distribution of those incidents between the employees involved can be explained by chance. The method is called conditional because it is only effective on condition that the number of incidents is given. It is not hampered by a greater or lesser mortality rate or resuscitation requirement on the particular ward than is experienced at other hospitals. The core of the method is the premise that, where exactly nine incidents take place, which would not be related to a particular nurse on duty, involvement in exactly 0, 1, 2, …, 9 incidents may be calculated on the basis of probability theory, given the number of shifts during which a particular employee was or was not on duty. On this assumption, that number has the hypergeometric distribution[2].

I will apply the conditional method to the below, first in respect of the period during which Mrs. V. worked at the JKZ, then of the period during which she worked at the RKZ. I will then work the data into a combined result.

Analysis of data for the Juliana Kinderziekenhuis

To apply the method, we need access to the duty roster of the person in question, Mrs. V., for the period at issue. The team of detectives on the case placed at my disposal an excerpt from the timetable worked by Mrs. V. from September 2nd, 1999 until the date of being suspended on September 10th, 2001. Subsequently, Mrs. V. was suspended and/or dismissed. I have also been informed that during Mrs. V.'s presence at the MCU-1, she experienced nine incidents among her patients and that over the same period of time, no other incidents occurred on the ward.

We must first determine the period most suited to the analysis. Here, I have selected the period from October 1st, 2000 until September 9th, 2001. In October 2000, Mrs. V. achieved the Specialist Nurse in Child Care diploma and was employed as a fully-qualified children's nurse on the MCU-1 ward. Prior to that date, she did not hold the diploma and required the assistance of another employee to carry out particular duties. V. had

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1 For the sake of argument: it goes without saying that, in themselves, epidemiological data can be relevant. For the kind of analysis I propose to undertake, however, the data in question are insufficiently accurate.

2 The hypergeometric distribution is a method of apportioning probability. It describes the occurrence of incidents for a particular person involved, dependent on the total number of incidents and shifts worked. Should a particular person fail to experience an incident A times and experience an incident B times while no incidents take place during C shifts where that person was absent and incidents do take place during D shifts where that person was also absent, the probability of that person experiencing exactly B incidents, given the total number of shifts during which (s)he was or was not present as well as the total number of incidents, is expressed by the formula

$$\{ (A+B)!\,(C+D)!\,(A+C)!\,(B+D)! \} / \{(A+B+C+D)!\,A!\,B!\,C!\,D! \}$$

A! (A factorial) refers to the product $A \cdot (A-1) \cdot (A-2) \cdot \ldots \cdot 3 \cdot 2 \cdot 1$

Also see, for example, W.Feller, *An introduction to probability theory and its applications*,vol I, 3rd edition, ch.II.6, New York etc.: Wiley, 1968).

previously also worked at the JKZ, in part on wards such as ICN, MCU-2 and MCU-3. We will not take these periods into consideration. Although following September 10th, 2001, the date on which Mrs. V. was suspended, no more incidents took place, I consider it inappropriate to incorporate these figures into the analysis. After all, Mrs. V was not in a position at that time, of working shifts during which incidents did or did not occur.[3] The analysis covers a period of 343 days.

During a day in unit MCU-1, Mrs. V's place of work, nursing staff cover three shifts of approximately 8 hours each.[4]. Therefore, we investigate 1029 shifts in total. During this period, Mrs. V worked 142 nurse's shifts on the ward, and was absent from the ward on 201 days (not timetabled, ill, training, holiday).

Over the period under investigation, 9 incidents took place in which resuscitation was required. In five of the nine cases, the resuscitation failed and the child in question died. All nine resuscitation attempts occurred while Mrs. V was on duty. Thus, she was involved in incidents in 6% of her shifts worked. When Mrs. V was not on duty, no resuscitation procedures or deaths took place.

We are now able to represent the shifts in the table below:

Table 1: *JKZ-MCU-1, 1 Oct 2000 – 9 Sept 2001*	no incident	an incident	total
number of shifts where V was present	133	9	142
number of shifts where V was absent	887	0	887
total number of shifts	1020	9	1029

Conditional on the total number of shifts during which Mrs. V did or did not work, and on the number of incidents, we can calculate the probability of Mrs. V having experienced exactly 0, 1, 2, …, 9 incidents in a scenario of random distribution of the incidents between the shifts, using the formula for hypergeometric distribution set out in footnote 2.

Figure 1 (page 4) shows the probability. Clearly, the chance of being present by sheer coincidence at more than four incidents is already minute; the likelihood of experiencing nine incidents, as is the case here, is infinitesimal: 0.000000014512.[5]

It is customary for the above argument to be formalized into a statistical investigation, exploring the hypothesis of a uniform distribution of incidents over V's presences and absences or, stated differently, of a coincidental distribution of the occurrence of incidents, applying the alternative hypothesis that incidents are more likely to occur should V be

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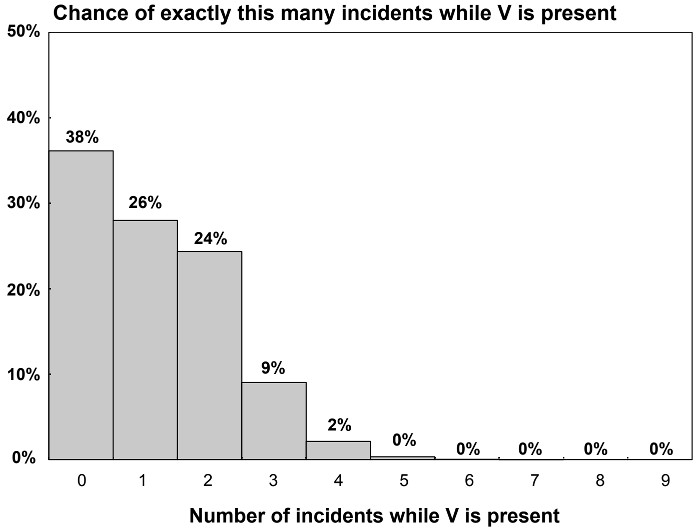
3 Incidentally, neither an analysis that takes the period of suspension into consideration nor one that incorporates the period before October 1st, 2000 into the calculations yields results that deviate significantly from the analysis presented here.

4 The duty roster actually encompasses 6 separate shifts, all covering a period of close to 8 hours.

5 Translator's note: the first two bars in this figure should be 28%, 36% instead of 38%, 26%.

present. The hypothesis may be tested using Fisher's exact test[6], which is based on the hypergeometric distribution of variable X, being the number of incidents experienced by V.

Figure 1: conditional probability distribution of incidents



The hypothesis tested must be rejected as the chance of exceeding the value observed of X = 9 on the right hand side equals 0.00000001451. This means that the chance of V having coincidentally been present at this number of incidents, while no incidents took place during her absences, is smaller than 1 in 68 million. In keeping with conventional statistical practice, this entails our rejection of the notion that the case in hand may be explained by a random distribution of the incidents.[7,8]

We must apply an adjustment to the above calculation, however, as we did not plan the analysis before looking at any data. We only embarked on exploring the chance of V being present at this many incidents *once* we had been alerted to V experiencing a large number of incidents. Thus, it would be more appropriate to investigate the chance of someone, anyone at all, experiencing this many incidents by coincidence in the kind of work carried out by Mrs. V. What is the actual likelihood of any random member of the nursing staff of the Medium Care Unit-1 being involved in all incidents when 142 shifts are worked out of a total of 1029? To calculate the probability, one needs to obtain further detail about the

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6 Where the contingency table contains small numbers, Fisher's exact test is preferable to the commonly applied Chi-square test, which may be seen as an approach to the exact test (also see, for example, §15.2 of *Social Statistics* by H.M. Blalock jr., 2nd ed.Tokyo etc.; McGraw-Hill, of L.Sachs, *Angewandte Statistik*. Berlin: Springer-Verlag, 1974, p. 288). The exact test calculates the probability using the formula supplied in footnote 2.

7 We repeated the above analysis using only the 5 incidents that resulted in the death of a patient. A likelihood of 0.00004706 of Mrs. V being present coincidentally at all five incidents then results.

8 We considered the inclusion of more detail into the analysis. In fact, the nursing staff on duty at the MCU-1 arrange the care of the patients on the ward amongst themselves. So, two nurses working a night shift will each attend to half of the patients. In this manner, a shift actually consists of two or more subshifts. Reworking table 1 to incorporate the subshifts, with Mrs. V attending each time to the patients requiring a resuscitation procedure, would yield a likelihood of the value being exceeded that is much smaller still. We decided against such an exercise, however, because of the varying numbers of nursing staff on duty during each shift. Moreover, nurses working subshifts self-evidently would be in the vicinity of one another's patients.

ward. I have been informed that, to run the Medium Care Unit-1, a maximum of 27 nurses is required, 21 of whom would be qualified and 6 would be trainees. The chance of any one of the 27 employees becoming involved in all 9 incidents during 142 out of 1029 shifts, were those incidents to be spread out over the shifts by coincidence[9], clearly is somewhat greater than the chance of this happening to a single nurse. It remains a very small chance indeed, however - 0.00000039 or approximately 1 in 2½ million. I shall refer to the adjustment applied in this recalculation as the post-hoc adjustment[10].

Analysis of data in respect of the Rode Kruisziekenhuis

The team of detectives on the case has provided me with the following details about deaths at the RKZ. Mrs. V worked on ward '42' of the Rode Kruisziekenhuis throughout the period August 6th, 1997 to November 26th, 1997. This period comprises 113 days of three shifts each, equalling 339 shifts. V worked 58 of these, during which 6 patients died. In other words, patients died in 10% of V's shifts. During the other shifts, numbering 281, 9 patients died – i.e. in 3% of those shifts.

Table 2: RKZ, ward 42, 6th August to 26th November 1997	no incident	an incident	total
number of shifts where V was present	52	6	58
number of shifts where V was absent	272	9	281
total number of shifts	324	15	339

As with table 1, we carry out the test of uniform distribution of the deaths over the times of V's presence or absence for table 2, applying the alternative hypothesis of V's increased chance of involvement in patients' deaths. The hypothesis of uniform distribution is rejected because of a chance of exceeding the value observed of 0.02771536. In other words, given the number of shifts, the probability of V coincidentally experiencing *6 or more of the 15* incidents is smaller than 1 in 36.

In addition, on November 27th, 1997, V worked a single shift on ward '41'. A patient died during this shift. The time span covering Mrs. V's work on '41' being so short, an analysis such as carried out in tables 1 and 2 is not feasible – there are no comparative data. The records relating to ward '41' for the months of August to November 1997 show that 5 incidents occurred on the ward during 366 shifts. The chance of Mrs. V having been

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9 The method for calculating the probability is as follows, whereby p is the chance of a random individual experiencing such a sequence of incidents. The chance of a person *not* experiencing such a sequence then is (1-p), meaning that the chance of none of the 27 nursing staff experiencing the sequence equals $(1\text{-}p)^{27}$. Therefore, the chance of this happening to at least one of the 27 is $1–(1–p)^{27}$. Substituting the value of 0.000000014512 for p yields 0.00000039.

10 Also including trainees either on trial or on a work placement, the maximum number of staff working at the MCU-1 consists of 32 people. Post-hoc adjustment then yields a probability of 0.00000046, less than 1 in 2.1 million.

present *by coincidence* at one of the five deaths while being on duty on the ward just once is 5/366 = 0.013661, or 1 in 73.

Please note that there is no need to apply the post-hoc adjustment to the RKZ data. After all, the purpose of the analysis in this case is not so much to determine whether an (indeterminate) nurse can be involved disproportionately frequently in the deaths of patients but whether Mrs. V., whose identity was already revealed by the JKZ analysis, may have been involved coincidentally.

Conclusion

We will conclude the analysis by combining the probability of Mrs. V.'s coincidental presence at so many deaths as established in the three separate analyses.

The chance of

- a nurse becoming involved in all nine incidents on the MCU-1 during the period of time under consideration and given the number of shifts she worked at the JKZ;
- and *the same* nurse becoming involved in at least 6 of the 15 deaths on ward 42 of the RKZ, given the number of shifts she worked;
- and *the same* nurse becoming involved in one of the five deaths on ward 41 at the RKZ, during her only shift worked on that ward,

under the conditions described, equals the product of the separate chances as calculated in the three cases, being

$$0.00000039 * 0.027715 * 0.013661 = 0.00000000015 \qquad (x)$$

which is less than 1 in 6 billion[11].

In accordance with standard arguments in the field of statistics, we therefore reject the hypothesis that the distribution of incidents observed is consistent with any notion of coincidence.

We must assume a relationship between Mrs. V's work and the occurrence of incidents.

[11] Carrying out the analysis on the basis of the 5 actual deaths at the JKZ, rather than of the 9 cases of resuscitation procedures including those resulting in death, and using the same data for the RKZ as set out above, the equivalent calculation yields the following result. The equivalent of table 1 provides a chance of exceeding the value observed of 0.00004706, resulting in 0.0012698 after post hoc adjustment. Substituting this figure into formula (x) yields a chance of 0.00000048, i.e. less than 1 in 2 million.

Discussion

We have demonstrated that coincidence is firmly ruled out. For completeness's sake, I point out that the above does not, in itself, demonstrate that Mrs. V *caused* the incidents. Obviously, other correlations between V's presence and the occurrence of deaths are possible.

Apart from the hypothesis of Mrs. V having caused the incidents, by way of example I here mention five hypotheses one might put forward so as to explain the demonstrated relationship between V and the occurrence of incidents.

- V prefers to work together with W. It is W who causes the incidents;
- V often works night shifts. At night, there is a smaller chance of life threatening situations being observed on time;
- V is a poor nurse, who is tardy in recognizing critical situations;
- V habitually volunteers to handle the most difficult cases – ones that carry an increased risk of death;
- someone bears a grudge against V and attempts to discredit her.

Whether one might consider these hypotheses to present credible explanations for Mrs. V's involvement in incidents that is beyond coincidence, must be examined by means other than the above-analysed figures. The first two hypotheses may be investigated through careful inspection of the duty rosters, whereas the merit of the latter three cannot be assessed in this way and ought, therefore, to be explored further through other considerations.

Drawn up on May 8th, 2002 at Leiden

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