Crucial Statistical Concepts for the Judiciary

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Chapter 1

Introduction

Well into the 21st century, data and statistics are becoming increasingly pervasive in our lives, culture, and courtrooms. Traditionally, the courtroom has been a palace of words, not of numbers. The last decade, however, has shown numbers and data showing up in the courtroom with greater frequency and in more substantial ways. The judiciary, however, remains largely ill-equipped to handle increasing use of mathematical and statistical concepts in the courtroom.[1] The aim of this course is to guide judges through statistical concepts that they may see in their courtroom in order to better equip them with the skills necessary for grappling with statistical evidence. The ultimate goal is to improve the mathematical and statistical literacy of the judiciary.

Each chapter of this guidebook will be structured as follows:

1. A brief summary of a case relying on evidence demonstrates a crucial statistical concept will be presented.
2. This will be followed by exposition into the statistical concept and why it is important to get it right.
3. We then discuss how the statistical concept was used in the courtroom:
    a. What did the expert witness present?
    b. Was the expert witness correct?
4. Finally, if the presentation of the statistical concept was not correct, we will describe what should have been done instead.

There is also a glossary at the end containing the key words and phrases we will use throughout the guidebook.

[1] See, for instance "The Supreme Court is Allergic to Math" by Oliver Roeder: "By voicing an unwillingness to engage with data-driven empiricism, justices — and thus the court — are at risk of making decisions without fully grappling with the evidence." Chief Justice Roberts even called methods for quantifying partisan gerrymandering "gobbledygook".

Chapter 2

Sampling

2.1 Case Summary

2.2 Statistical Exposition

2.3 What Was Done?

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Chapter 3

Independence

An important concept in statistics is that of independence. Statistically, independence of two events, call them A and B, is defined as

$$P(A \cap B) = P(A) \cdot P(B). \tag{3.1}$$

In words, this says that the probability of the two events ocurring together is equal to the product of the probabilities of them occurring individually. This means that the occurrence of A does not affect the chance that event B will occur, and vice versa.

The concept of independence is crucial for determining the likelihood of simultaneous or subsequent events. When events are *not* independent, but are treated as independent in the courts, catastrophic results have occurred, as we will describe in Section 3.1.

3.1 Case Summary

On November 9, 1999, a UK mother, Sally Clark, was convicted of murdering her two infant children. Sally and her husband Steve had their first child on September 22, 1996, a boy named Christopher. Christopher passed away less than three months later, on December 13, 1996, the cause of which was determined to be an infection in the lungs, and his death was treated as a case of Sudden Infant Death Syndrome (SIDS). After the death of her first son, Sally soon became pregnant again, and gave birth to a second son, Harry, on November 29, 1997. Harry also passed away in his first months of life, on January 26, 1998. The autopsy, performed by the same doctor, found that Harry died as a result of "non-accidental injury, consistent with shaking on several occasions over several days" (Henry, 2000)[1].

Steve and Sally Clark were both arrested for murder and released on bail. Steve was later exonerated on both charges, while Sally was brought to trial for the murder of both sons. The prosecution relied primarily on medical expert witnesses to demonstrate that the causes of death of both sons were not natural. The Prosecution's witnesses were:

[1] Link to decision in first appeal: http://www.bailii.org/ew/cases/EWCA/Crim/2000/54.html

- Dr. Williams, a consultant histopathologist and very experienced forensic pathologist who conducted the post mortems
- Professor Sir Roy Meadow, Emeritus Professor of Paediatrics and Child Health at St James' University Hospital in Leeds
- Professor Green, a consultant pathologist
- Dr. Keeling, a consultant pediatric pathologist.
- Dr. Christine Smith, a consultant neuropathologist,

Unusual findings by the medical experts for the prosecution are summarized below for each child.

- Christopher's symptoms. Prosecution witnesses testified these were consistent with smothering
  - bleeding in the lungs
  - torn frenulum
  - bruising
- Harry's symptoms. Prosecution witnesses testified these were consistent with shaking
  - hypoxic damage to the brain
  - small brain hemorrhages which, although not diagnostic, were consistent with smothering before death and which appear straightaway
  - petechial hemorrhages on the eyelid
  - haemorrhages on the back of the eyes which, if present, were consistent with asphyxia
  - an old fracture of the second rib
  - a dislocated first rib, which was unlikely to have been a resuscitation injury and was more likely to have been caused by abuse
  - spinal bleeding and a swollen cord, which, if confirmed, must have resulted from some trauma
- Meadow testified that the probability of two SIDS death in one family similar to the Clarks was 1 in 73 million.

The defense also brought medical expert witnesses:

- Professor Berry, a pediatric pathologist specialising in sudden and unexpected infant deaths
- Dr. Rushton, a consultant pediatric and perinatal pathologist
- Professor David, a consultant pediatrician
- Dr. Whitwell, a senior lecturer and forensic pathologist
- Professor Luthert, a pathologist specialising in eyes

The defense expert witnesses refuted the prosecution's witnesses as follows:

- Christopher:
  - Bruising: Visual diagnosis of bruises could be mistaken. The photographs were poor quality and no microscopic sections had been taken to confirm the existence or age of any bruising. The bruises had also not been seen at the hospital.
  - Torn frenulum: the tear had not been confirmed histologically
  - Bleeding in the lungs: hemorrhage in the lungs was a marker for, but not diagnostic of, the possibility of asphyxiation
  - Professor Berry and Dr. Rushton would have given the cause of death as unascertained
- Harry:
  - Spinal injuries: Doubted the interpretation of the photographs as showing a swollen cord. Many

of the findings had either been shown not to exist or had been misinterpreted. Bleeding in the epidural space was commonly found in post mortems of babies and was not significant. The old bleeding was not in an area where one would have expected to see trauma and was more consistent with a birth injury than a shaking injury.

- Brain injuries: hemorrhages were a common finding consistent with almost any cause of death and they might have been birth related, although the small haemorrhages were consistent with smothering.
- Eye injuries: Concluded there were no intra-retinal haemorrhages. The blood could have got into the eyes after death and was not significant. Blood found on the surface of the backs of both Harry's eyes was not a classic sign of shaking and was not associated with any particular disease
- Petechial hemorrhages: difficult to say if the two petechiae had any significance
- Rib fracture: the fracture of the second right rib had not been confirmed and the process of new bone formation could also occur if there was a bruise. The evidence pointed to the dislocation being a post mortem injury and although unusual, he could not exclude the possibility it had occurred in resuscitation.
- The conclusion was that the causes of death were inconclusive.

Sally Clark's first appeal Sally Clark's second appeal

3.2 Statistical Exposition

The numbers used to arrive at the 1 in 73 million chance of two SIDS deaths in a family came from a draft report of the Confidential Enquiry into Stillbirths and Deaths in Infancy (CESDI). The study examined three key risk factors: having a smoker in the household, no waged income in the household, and a mother aged 26 or younger. The table presented in court containing a summary of the study's findings is reproduced below.

Overall rate in the study population: 1 in 1303

Rate for groups with different factors

Risk Factor	Odds if present	Odds if absent
Smoker in household	1 in 737	1 in 5,041
No waged income	1 in 486	1 in 2,088
Mother 26 or younger	1 in 567	1 in 1,882
All 3 factors	1 in 214	1 in 8,542
2/3 factors	1 in 596	1 in 1,616

3.3 What Was Done?

3.4 What Should Have Been Done?

Chapter 4

Conditional Probability

4.1 Case Summary

People v Collins

4.2 Statistical Exposition

4.3 What Was Done?

4.4 What Should Have Been Done?

Bibliography

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