

Statistical Case Studies 2024/25 Semester 2

Examining the relationship between insulin and c-peptide.

1 Background

Deadline: 14 February 16:00

1.1 Lucy Letby

In August 2023 a nurse called Lucy Letby who worked in the neonatal ward at the Countess of Chester Hospital was found guilty of seven counts of murder and seven counts of attempted murder of infants. In July 2024 she was re-tried and found guilty of one further count of attempted murder. She has been unsuccessful in appealing both verdicts.

Since July 2024, when the reporting restrictions on the case were lifted, there has been much public criticism by statisticians of the way in which statistical issues associated with the case were presented.

[Optional] For more details on the case itself, there have been many newspaper articles, TV programs, and podcasts published. Some that I would recommend, which include discussion of the statistical issues, are:

- Tortoise podcast: <https://www.tortoisemedia.com/listen/the-slow-newscast/lucy-letby-the-expert-witness>
- New Yorker article (the first published article criticising the statistics - note this was banned in the UK at the time): <https://web.archive.org/web/20240513112618/https://www.newyorker.com/magazine/2024/05/20/lucy-letby-was-found-guilty-of-killing-seven-babies-did-she-do-it>
- Channel five episode: <https://www.channel5.com/show/lucy-letby-the-new-evidence>
- Telegraph articles featuring statistical analysis by John O'Quigley and Peter Elston (note these are behind a paywall and so not linked).

1.2 The insulin cases

In two of the cases of attempted murder, Letby was accused of having added insulin into the feed bags of two premature infants (child F, August 2015 and child L, April 2016). Blood samples had been taken from the two infants and at the time and sent for immunoassay blood tests. The results of these tests were:

- Child F - 4,657 pmol/L insulin, 169 pmol/L C-peptide.
- Child L - 1,099 pmol/L insulin, 264 pmol/L C-peptide.

It is known that the results of immunoassay tests are affected by interference in the sample between 0.4% and 4% of the time. This inference will result in errors in the reported values and hence false positive and false negative results in diagnoses based on the tests. When the tests were taken (including after receiving the test results) there was no suspicion that the babies had been attacked. As such, more accurate follow-up

tests were not carried out because the babies had recovered. The unusual results of these blood tests were noted by medical experts involved in the police investigation against Letby over a year later.

One of the arguments made at trial was that the results from the immunoassay blood tests were indicative of insulin poisoning. The argument made was that the C-peptide value should be around 5-10 times that of the recorded insulin value. In fact, both babies had insulin levels that were much higher than their C-peptide readings and experts testified that this suggested that the insulin cannot have been naturally produced.

Details of the arguments made in court can be seen in court reporting of the evidence ¹. In particular, the following two comments were made:

- Dr John Gibbs, a consultant at the Countess of Chester Hospital: ‘The [...] C-peptide reading [for child F] should, for natural insulin, [...] be even higher [than 4,657] in this context, Dr Gibbs explains, but it is ‘very low’. The ratio of C-peptide/insulin is marked as ‘0.0’, when it should be ‘5.0-10.0’. Dr Gibbs says the [...] c-peptide reading should be at 20,000-40,000 to correlate with the insulin reading in this test. The doctor says this insulin result showed Child F had been given a pharmaceutical form of insulin administered, and he ‘should have never received it’.
- An unnamed doctor at the hospital: ‘The doctor says the cortisol reading was ‘normal’, the insulin at a reading of 4,657 was “too high for a baby who has a low blood sugar”. The doctor says it would be expected, with a baby in low blood sugar, for insulin to stop being produced, so that would also be low. The [...] c-peptide reading of ‘less than 169’ does not correlate with the insulin reading. The insulin and [C-peptide] readings would be ‘proportionate’ with each other. The doctor says it was likely insulin was given as a drug or medicine, rather than being produced by Child F, to account for this insulin reading.’

2 Task

You have been approached by the lawyer of Lucy Letby to give expert statistical advice on the case. The lawyer wants you to produce an expert witness report giving your opinion on:

- the argument made in the case that when no exogenous insulin has been taken, the C-peptide measurement should be around 5.0-10.0 times higher than insulin.
- whether there is an alternative relationship between insulin and C-peptide.
- whether the insulin and C-peptide measurements for babies F and L are unusual.

Expert witnesses should only testify in relation to matters within their knowledge, so you must comment only on statistical issues in your report. You should also stick to commenting on the insulin question above, and not on the wider statistical issues in the case.

There are several ways you could approach the analysis but I suggest that you start by fitting a linear regression model with C-peptide as the response variable, to study how C-peptide varies with insulin.

The lawyer does not have access to datasets from the Countess of Chester Hospital, or from the labs that carry out the immunoassay tests. They have given you a dataset from a Freedom of Information request sent to the Liverpool University Hospitals NHS Foundation Trust (https://www.whatdotheyknow.com/request/blood_test_records_for_insulin_a). The data have also been provided in csv format. As part of your task you should comment on the appropriateness of this dataset for answering the questions that the lawyer has asked as well as detailing any limitations of your analysis.

2.1 Format

You should submit a written report detailing your findings. Your report must contain no more than 1000 words (not including references, tables, figures and their captions). Please state the word count under the title of your report. You can structure your report however you like but I would expect to see:

¹<https://www.chesterstandard.co.uk/news/23146323.recap-lucy-letby-trial-thursday-november-24/>

- A short executive summary at the start summarising your key findings, that can be understood by a lawyer.
- A description of the datasets you have been given. You should assume that the lawyer is not familiar with the dataset.
- Detail on the methods you have used for the analysis.
- Detail on model fit and the limitations of your analysis.
- Your conclusions.

You should also submit well-documented R code, either plain or as markdown so that your analysis is reproducible.

The work must be completed in your group of 3, which you must have arranged and registered on Learn. If you have any difficulties with this or have not managed to find yourself a group, please email me or speak to me in the workshops. The first paragraph of your report must list your names with university user names. Contributions from different team members never end up completely equal, but you should aim for rough equality, with team members each making sure to 'pull their weight', as well as not unfairly dominating.

3 Mark Scheme

There is no single correct analysis for this type of project, so you will not be marked on the basis of how close you get to some particular model answer. The marks are not subdivided, but will be allocated on a combination of statistical approach and justification, interpretation of results in context and presentation.

- 80 – 100% A report that could be presented to the client or collaborator with little or no revision. Analysis is sound so that conclusions are well-supported statistically. Interpretation is reasonably mature. The project should demonstrate a clear overview of the work, without getting lost in details, and be free of all but minor statistical errors. The work is to a publishable standard.
- 70-79% A report that could be presented to the client or collaborator with little or no revision. Analysis is sound so that conclusions are well-supported statistically. Interpretation is reasonably mature. The project should demonstrate a clear overview of the work, without getting lost in details, and be free of all but minor statistical errors.
- 60 – 69% A project that could be presented after a round of revision, but without having to re-do much of the actual analysis. Some flaws in the analysis or presentation (or minor flaws in both), but basically sound. A good grasp of the statistics and context, so that interpretation is reasonable.
- 50 - 59% Major re-working required before the project could be presented, but containing some sound statistics demonstrating understanding of statistical modelling and its application. Reasonable presentation and organisation.
- 40 – 49% Major flaws in analysis and presentation, but demonstrating some understanding of statistics, and a reasonable attempt to present the results.
- Fail (below 40%) Flawed analysis demonstrating little or no understanding of statistics, and/or incomprehensible or very badly organised presentation.