

# Murder by Numbers

Lucia, Kevin, José



# Statistics in the Legal Setting

Rutherford: “If you need statistics, you did the wrong experiment”





# Statistics in the Legal Setting

Richard: “If they use statistics, someone will get screwed”



# O J Simpson

- Consider married couples, where the husband physically abuses his wife
  - Most of those husbands don't murder their wives
  - Most of the wives who did get murdered, got murdered by their husbands



# O J Simpson

- Prob ( wife is murdered by husband | husband abused wife & wife is murdered ) is very large
- Prob ( wife is murdered by husband | husband abused wife ) is pretty small





# Kevin Sweeney



- 25% of deaths in house fires are caused by slowly smouldering fires caused by smoking esp. in bed and/or after falling asleep after drinking [US figures; NL similar]
- Forensic fire expert (ex-policeman):  
the idea that fires are caused by smoking in bed is an old wives' tale

14 yrs for murder of wife Susanna by arson at Steensel, nr  
Eindhoven, 1996





# Kevin Sweeney



- Prob ( you die in a house fire | you smoked in bed ) is small
- Prob ( you smoked in bed | you die in a house fire ) is large

14 yrs for murder of wife Susanna by arson at Steensel, nr Eindhoven, 1996



# Kevin Sweeney



- Mother of victim:  
my daughter did not smoke
- Friends of victim:  
Suzanna was a secret smoker
- Policeman: no ash-tray in the room  
(Kevin: I had removed it because my wife was trying to stop smoking)
- Evidence: credit-card payment for pack of cigarettes in local supermarket, day before





# Kevin Sweeney



- Mother of victim: Kevin was a bad man
- Father of victim: Kevin was his daughter's heart's delight

14 yrs for murder of wife Susanna by arson at Steensel, nr  
Eindhoven, 1996



# Kevin Sweeney



- TNO contracted to create “observed” fire damage in bedroom from a fire caused by igniting 5 liters of petrol
- Success, after
  - reinforced steel shutters replace glass
  - brand-new fire-proofed mattress replace ...
  - no bed linen ...

14 yrs for murder of wife Susanna by arson at Steensel, nr Eindhoven, 1996



# Kevin Sweeney



- TNO experiments show that placing a glowing cigarette on the sheet on a bed usually doesn't start fire unless cigarette placed in rather special position
- Experience shows bed fires usually caused when cigarette falls between mattress and headboard (similar for sofa's, armchairs...)

14 yrs for murder of wife Susanna by arson at Steensel, nr Eindhoven, 1996





# José Booij

- Neighbour barrages authorities with warnings that single-mother-to-be will go mad and murder her baby
- Mother (a doctor) driven to distraction by unwanted attentions of social workers
- Baby removed in evening raid by authorities
- Court: kidnapping illegal, immediate return
- Authorities: not in interest of child
- Mother has mental breakdown
- Appeal court: no return till mother proves she's sane



# Lucia de Berk

Juliana Children's Hospital, The Hague

4 September 2001: death baby Amber

17 September 2001: police informed of 20+ deaths and incidents



# Lucia de Berk

Juliana Children's Hospital, The Hague  
2001–2003: the media

- She was a prostitute
- She had depression
- Stolen medicines at home
- Always wanting to care for the most sick babies
- Baby X was in hospital only for the weekend because of “social indication”
- Baby Y was going to home in a couple of days
- Medium care ward, where normally no deaths





# Lucia de Berk

District Court, the Hague (2003)



# Lucia de Berk

District Court, the Hague (2003)

- Life sentence for 4 murders and 3 attempted murders of babies and, earlier, of elderly patients
- Only statistical evidence and report of a co-detainee of conversation with Lucia
- The probability: one in 342 million



# Lucia de Berk

One in 342 million

Shifts	with incident	without incident	Total
with Lucia	9	133	142
without L.	0	887	887
Total	9	1020	1029

JKZ (2nd year only)

Shifts	with incident	without incident	Total
with Lucia	6	52	58
without L.	9	272	281
Total	15	324	339

RKZ-42

Shifts	with incident	without incident	Total
with Lucia	1	0	1
without L.	4	361	365
Total	5	361	366

RKZ-41



# Lucia de Berk

Appeal Court, the Hague (2004)

- Life sentence + “TBR” for 7 murders and 3 attempted murders of babies and, earlier, of elderly patients
- All deaths and incidents shown by incontrovertible medical-scientific evidence to be unnatural
- Deaths occurred in a short period on a ward where normally no deaths occurred
- No statistical probability calculation used



# Lucia de Berk

Appeal Court, the Hague (2004)



- Chain proof: Amber was murdered by Lucia
  - death caused by digoxine poisoning
  - Lucia had opportunity
  - Lucia had motive: secret compulsion
- Other deaths unnatural
- Lucia was present every time
- Lucia couldn't explain her presence

# Lucia de Berk

Supreme Court, the Hague (2006)

- Wrong sentence, but no new facts





# Lucia de Berk

Appeal Court, Amsterdam (2006)

- Life sentence for 7 murders and 3 attempted murders of babies and, earlier, of elderly patients



# Lucia de Berk

Supreme Court, the Hague (2009)

- New facts cast severe doubt on previous verdict:
  - Amber died of exhaustion
  - Lucia did not lie about her actions that night

# Lucia de Berk

Appeal Court, Arnhem (2010)

- All deaths and incidents were natural (up to plentiful errors of medical diagnosis and treatment)
- Nurses' professional behaviour in crisis situations was exemplary
- Newest medical-science insight: when you are old and fatally ill, it is possible that the you suddenly die “without warning”





# Lucia de Berk

2001 – 2010



- Was statistics important?
- Were statisticians important?

# Lucia de Berk

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# Lucia de Berk

Statistician I's evidence: 1 in 342 million

- Three Fisher exact tests
- JKZ: post-hoc Bonferroni:  $\times 26$  (nurses)
- Multiplication of three  $p$ -values
- But: correlation  $\not\Rightarrow$  causation,
  - by way of example, perhaps:
    - Lucia is a bad nurse
    - Lucia has more difficult shifts
    - Lucia has more night shifts
    - Someone is trying to set Lucia up



# Lucia de Berk

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# Lucia de Berk

Statistician I's evidence: 1 in 342 million

- Court: “what is the probability that the coincidence is due to chance?”
- Statistician (frequentist,  $\alpha = 1$  in 10 000):  
“your honour, it was not chance.  
The rest is up to you”

# Lucia de Berk

Statistician II's evidence: 1 in 342 million



- The analysis was correct and state-of-the-art
- The conclusions are robust to errors in the data
- The defendant must explain her presence at so many incidents



# Lucia de Berk

Statisticians for the defence

- There are different probabilities based on different models, paradigms, ...
- The court's question does not have a well-defined answer

# Lucia de Berk

No statistics in the 2004 verdict?

- The incidents at JKZ occurred in a short period on a ward where usually nothing happened
- Lucia was present every time
- A natural cause was ruled out, medically, in every case
- Lucia couldn't explain why she was repeatedly present

# Lucia de Berk

No statistics in the 2004 verdict?

- If the precise time of a death from complex causes can't be predicted, the time of death is inexplicable
- An inexplicable death is suspicious death Lucia is present, and hence probably unnatural
- For every death, a majority of medical experts thought the death was natural; but always one could be found who thought it unnatural
- In two cases, only one expert thought it was unusual; why? Because Lucia was there.



# Lucia de Berk

## Chain proof

- We have a lying murderess who was present at similar medically inexplicable events
- She must explain her presence (statist. II), escape clauses (statist. I) are ruled out by herself
  - Judge: “Were you a bad nurse?”  
Lucia: “No, your honour, my superiors and colleagues ...”
  - Judge: “Did you work more difficult shifts than you colleagues?”  
Lucia: “No your honour, we shared all the work fairly ...”

## Old data

, , JKZ			
	Incident	Normal	
Lucia	9	133	
Others	0	887	

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, , RKZ41			
	Incident	Normal	
Lucia	1	0	
Others	4	361	

---

, , RKZ42			
	Incident	Normal	
Lucia	6	52	
Others	9	272	

## Latest data

, , JKZ			
	Incident	Normal	
Lucia	7	135	
Others	4	883	

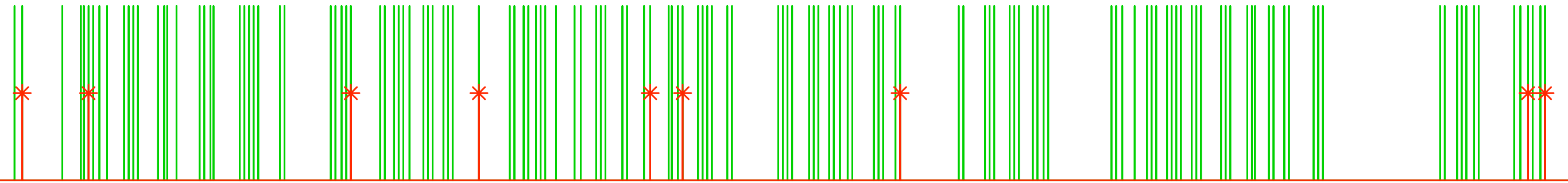
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, , RKZ41			
	Incident	Normal	
Lucia	1	2	
Others	4	359	

---

, , RKZ42			
	Incident	Normal	
Lucia	5	53	
Others	10	271	

## JKZ (2nd year only)



- Three children represent  $7=2+2+3$  of the now 11 incidents (one illegal euthanasia removed)
- Two incidents actually occurred in the shift after Lucia's
- At least two incidents outside of Lucia's shifts are missing (they weren't suspicious incidents)

# Lucia de Berk

New p-values

- Cochran-Mantel-Haenszel test  
JKZ; RKZ-41, -42; & Elffers' post-hoc correction  
1 in 916
- Ultimate stratification  
11 days at JKZ with both incident & Lucia on duty  
1 in 25
- Gamma(1) heterogeneity over Poisson intensity  
JKZ, RKZ pooled  
1 in 25



# Lucia de Berk

## Problems with this analysis

- Post-hoc problem
- Data selection problem
- Information from outside Lucia period,  
total number(s) of incidents  
[Statist. I analyses distribution of incidents *between* nurses, *within* period]
- **Wrong paradigm**

# Lucia de Berk

## The role of the statisticians

- Because statistics was used in the 2003 verdict, there was a public debate about use of statistics in trial, in which statisticians were heavily involved
- 2004–2010: Metta de Noo, Ton Derksen
- From 2006 to 2010 statisticians played a major role in social unrest which culminated in a new fair trial
  - Internet petition, signed by Nobel prize winning physicist and all NL statisticians
  - Articles in *Nature* and in *The Guardian*

# Lucia de Berk

## The aftermath

- The legal profession has learnt a great deal from the case
- The police has learnt a great deal from the police
- Public awareness and public critical attitude greater than ever
- The medical profession believes Lucia did it

# Lucia de Berk

## Recommendations

- Strengthen role and prestige of nursing staff in hospitals
- Scientific-diagnostic reporting by medical experts (“differential diagnostics”) in legal context
- Written scientific expert evidence must be put into public domain (a.f.a.p.), so scientific methodology can be openly discussed in scientific community
- External and independent and confidential medical investigations in Lucia scenarios, before police investigation.
- In Lucia scenario’s, statistician must always question the data and go back to the sources
- Multidisciplinary and in particular statistical and epidemiological analysis should be made of data on medical incidents at JKZ, say 1995–2005
- Investigation to uncover “what really happened”

# Lucia de Berk

## Problems for a real statistical analysis

- Basic empirical research has still not been done to model null hypothesis adequately
  - Hidden confounders cause heterogeneity between nurses, between days
  - $\text{var}(X) = E(\text{var}(X|Y)) + \text{var}(E(X|Y))$
  - Independent uniform random rare events (Statist. I):  
variance  $\approx$  mean
  - Unmeasured heterogeneity:  
variance  $\gg$  mean



# Lucia de Berk

## Problems for a real statistical analysis

- Events are strongly clustered
- Shifts fall in regular patterns
- Variation between nurses  
[a nurses' actions can define when/what is an incident]
- Differently qualified nurses do get different shifts
- A hospital ward is in a non-constant environment  
[winter/summer, changing admissions/discharge policy, opening/closing other wards]
- Multiple incidents concerning same patient

# Forensic statistics

... still in its infancy

- Moves towards *likelihood ratio* paradigm
- Null-hypothesis data, modelling often inadequate
  - How to construct *robust* and *calibrated* likelihood ratio's in non-parametric /  $n \ll p$  situations?
  - Parties must agree on “sampling frame”
  - Who owns the hypotheses?
  - Posthoc hypotheses not allowed
  - The defence isn't obliged to play the game  
(the prosecution must convince the court that, beyond reasonable doubt, ...)

# Lucia, Kevin, José

Murder by Numbers:  
the similarities



# Happy ending

