Impact case study (REF3)

Institution: Imperial College London

Unit of Assessment: 10 – Mathematical Sciences

Title of case study: B10-2 Improving the safety and quality of healthcare using statistical analysis of routinely collected data

Period when the underpinning research was undertaken: 2003-2016

Details of staff conducting the underpinning research from the submitting unit:

Name(s):	Role(s) (e.g. job title):	Period(s) employed by submitting HEI:
Professor Alex Bottle Professor Paul Aylin Professor Nicky Best	AB: Professor of Medical Statistics; PA: Professor of Epidemiology and Public Health NB: Professor of Statistics and Epidemiology	AB: since 2001 PA: since 1997 NB: 1996 - 2013

Period when the claimed impact occurred: August 2013 – December 2020

Is this case study continued from a case study submitted in 2014? Y

1. Summary of the impact

A statistical tool for monitoring the quality and safety of hospital care using routine data, developed at Imperial with Dr Foster Ltd and used by managers and clinicians in over half of English NHS hospitals, has improved standards of care and saved lives and continues to do so. The tool was a major factor behind the Francis Inquiry into the high mortality at Mid Staffordshire NHS Trust. The Inquiry led to the 2013 UK Department of Health's Keogh Mortality Review that used Dr Foster data and put 11 high-mortality hospitals into special measures. In 2014, the regulator reviewed how these hospitals responded and noted many improvements in their quality of care. Imperial's 2018 evaluation found that 70% of the tool's alerts identify quality-of-care problems, leading hospitals to change their processes, improving standards, and lower their mortality rates.

2. Underpinning research

Statistical research at Imperial, led by Professors Bottle, Aylin and Best, produced novel statistical methods to monitor variations in quality and safety in healthcare using routinely collected hospital administrative data (Hospital Episode Statistics, HES). Professor Best was submitted as part of the Mathematics Unit of Assessment in the 2014 REF. In initial work **[1]**, the Imperial team assessed the feasibility of setting up a system for the surveillance of patient outcomes (e.g., death) using such data. This work focused on the data requirements and statistical issues involved, especially multiple testing and the between-unit variation that is produced by the net effect of many small unmeasured factors (patient mix, data errors, etc). A more detailed analysis and discussion of the statistical issues in setting up such a system was presented in **[2]**.

One key result of this work **[1,2]** was the identification of log-likelihood cumulative sum control charts as the most useful approach for continuous surveillance; this was based on the comparison of various possible approaches and required adaptations of the methods. These statistical methods had originally been developed for industrial processes, and their use had been suggested in smaller-scale settings, but the statistical research conducted at Imperial demonstrated how they can be used in practice across many hospitals and patient groups.

Based on these developments, and together with a commercial partner (Dr Foster Ltd), Imperial researchers developed a national online surveillance tool using routine administrative data. Designed to monitor hospital outcomes across hundreds of diagnosis and procedure groups, with data updated monthly **[3]**, the tool monitors the outcomes of death, emergency readmission and

long length of stay. The relationship between Dr Foster and Imperial has been ongoing since 2002, with Dr Foster Ltd partially funding the Dr Foster Unit at Imperial, which Profs Bottle and Aylin co-direct.

Another key development of the underpinning statistical research were methods to limit the rate of false alarms caused by the large number of comparisons being made between hospitals and over time. In addition to dealing with this multiple-comparison problem, after creating the monitoring tool in 2007, the Imperial team found it was important to tailor the alerting threshold to the size of each hospital and the expected outcome rate for each patient group. In **[4],** they accounted for these issues both analytically and through simulation studies. The false alarm rate often showed non-linear relations with the threshold, volume, and expected mortality rate. However, **[4]** presented an equation that provided a good approximation to the simulated values, resulting in more appropriate alerting thresholds for each hospital and patient group.

Another challenge in monitoring is how to adjust for patient risk factors such as age, comorbidities etc. to ensure hospitals are compared fairly. The monitoring system does this through logistic regression; due to the hundreds of risk-adjustment regression models, some automation is very desirable, which **[5]** showed was as effective for this purpose as manual model-building. With minor modifications, the methods in **[4]** and **[5]** are still used in the monitoring tool today.

3. References to the research

[1] Aylin P, Best N, Bottle A, Marshall C. Following Shipman: a pilot system for monitoring mortality rates in primary care. Lancet 2003;362:485-491, doi:10.1016/S0140-6736(03)14077-9.
[2] Marshall C, Best N, Bottle A, Aylin P. Statistical issues in the prospective monitoring of health outcomes across multiple units. J Royal Statist Soc A 2004;167:541-559, doi:10.1111/j.1467-985X.2004.apm10.x.
[3] Bottle A, Aylin P. Intelligent information: a national system for monitoring clinical performance. Health Serv Res 2008;43(1 Pt 1):10-31, doi:10.1111/j.1475-6773.2007.00742.x.
[4] Bottle A, Aylin P. Predicting the false alarm rate in multi-institution mortality monitoring. J Operational Res Soc 2011;62(9):1711-1718, doi:10.1057/jors.2010.121.
[5] Jen MH, Bottle A, Kirkwood G, Johnston R, Aylin P. The performance of automated case-mix adjustment regression model building methods in a health outcome prediction setting. Health Care Manag Sci 2011;14(3):267-78, doi:10.1007/s10729-011-9159-6.

Grant
Evaluation of a national surveillance system for mortality alerts, 2014-16, £627,000. National Institute for Health Research HS&DR project 12/178/22. Aylin P (PI), Vincent C, Benn J, Bottle A.

4. Details of the impact

The creation of a monitoring tool using the underpinning statistical research with the commercial partner Dr Foster Ltd has helped the NHS improve care and save lives since 2007. This case study describes the impact since 1 August 2013, but we first give some important background.

Before the current REF impact period, our hospital monitoring system identified high mortality at Mid Staffordshire NHS Trust. The alert letters sent by Imperial to the trust and the national regulator, the CQC, helped trigger CQC inspections, which led to a public inquiry (Francis Inquiry). The resulting report **[A],** published in February 2013, notes Imperial's and Dr Foster's contribution: *"There is no doubt that, without the work of the Dr Foster Unit and Dr Foster [Ltd], comparative mortality statistics would not have been published as quickly, or as fully, as they now are.*" One of the consequences of the Francis Inquiry was the investigation of other high mortality hospitals, which led to the Keogh Mortality Review **[B],** published in July 2013. The Review used in part our monitoring tool's HSMRs (measures of hospital death rates) to spot high-mortality hospitals, and 11 out of 14 high-mortality hospital trusts were put into special measures. In 2013, the 11 trusts had 570,000 admissions and 21,000 deaths.

This resulted in improvements in the quality of care, mostly in the period after August 2013. The CQC assessed the 11 hospital trusts in August 2014 and found many improvements **[C]**. For example, one of those hospitals, Sherwood Forest, put in place regular audits and sufficient handover time between shift changes. With higher-than-expected mortality in 2014, they proceeded to transform sepsis care as a direct response to our mortality figures. Improvements continued over the coming years – see Dr Foster online case study **[D]**: "*The Trust has seen a significant reduction in its mortality rates, with deaths below the expected level since April 2016....for the first time since 2010*". They have around 50,000 admissions and nearly 2,000 deaths each year; NHS Digital's SHMI web pages report their relative risk (the risk-adjusted rate compared with the national average, known as the SHMI) as 1.10 for Jan-Dec 2012, falling to 0.95 for Jan-Dec 2016.

To investigate the impact of the monitoring system beyond those 11 trusts, in 2018 Imperial staff evaluated the monitoring tool in a peer-reviewed report to NIHR **[E]**, including interviews with and quotes from staff at site visits plus a national survey. Although the study time period straddled August 2013, it provides a robust summary of the monitoring system. The study included 532 alerts sent to 139 hospital trusts; 71 trusts responded to the survey, and 11 hospitals were visited as case studies. The evaluation found:
- Quality of care was cited as a factor in 70% of investigations into the alerts
- On average, the relative risk of death fell by 58% during the 9-month period immediately following an alert and then levelled to a slow decline
- Full action plans were created in 77% of trusts investigated, and several hospitals reported positive changes in culture. The tool changed how some hospitals respond to information such as death rates, leading to changes in their processes. For example, before receiving our alert regarding heart attacks, one site reported poor communication, and one doctor had been disciplined for speaking out about poor care. As a direct response to our alert letter, a new mortality committee was set up, reviewing every death. A chest pain pathway was introduced across the trust, and new coronary care facilities and more consultants were approved.

This impact had significant reach between August 2013 and December 2020: we sent out 1,312 alert letters to hospitals, covering nearly 41,000 deaths during this period.

Many hospitals report the HSMR for specific patient groups in their annual Quality Accounts and set targets for the following years: the source of these figures is our monitoring tool. An example is sepsis at Oxford University Hospital in 2017/8, with reports of improvements in both care processes and the HSMR for sepsis in 2018/19 **[F]**: the trust had 1,503 inpatients with sepsis in 2018/19.

Besides the public health impact, there are financial impacts. Dr Foster benefit financially from the underpinning research, which they sell, together with further analysis and support undertaken by their staff, to NHS organisations and others: in June 2018, their annual turnover was £6.5m, with 67 employees **[G]**. Telstra Health acquired them in 2015, a deal reportedly worth 25-30 million Australian dollars **[I]**; the monitoring system developed with Imperial and the expertise provided by the Imperial unit were important elements of that deal **[H]**. Dr Foster were the first organisation worldwide to publish hospital-level death data (as HSMRs) in national newspapers, working with hospitals to understand and improve their performance. As UK pioneers of healthcare analytics, Dr Foster Ltd led the way in the use of HES data and statistical methods, which was then followed by competitors such as CHKS and HED and helped create a market now worth $2.7bn in Europe alone **[J]**.

5. Sources to corroborate the impact

[A] Francis Report from the Mid Staffs Public Inquiry. Quote is in paragraph 5.237. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/279115/0898_i.pdf (Archived here)
[B] Keogh Mortality Review of Jul 2013: https://www.nhs.uk/nhsengland/bruce-keogh-review/documents/outcomes/keogh-review-final-report.pdf (Archived here)

[C] CQC report "Special measures: one year on" on hospitals flagged as high mortality that were put into special measures and what improvements they made
https://www.cqc.org.uk/publications/evaluation/special-measures-one-year (Archived here): mortality rates are shown in Table 2 on page 12, which also shows the HSMRs from Dr Foster.

[D] Dr Foster case study of how Sherwood Forest Hospitals used mortality data from our tool to transform their processes and sepsis care: https://drfoster.com/case-studies/how-sherwood-forest-hospitals-used-dr-foster-data-to-tackle-high-mortality-and-become-an-exemplar-of-improvement/ (Archived here)

[E] Our HS&DR report's case studies: Appendix 12 has interviews and quotes from hospitals e.g. the first one (p232) had AMI alert and changed its processes despite history of bullying culture [this example is cited above]: Aylin P, Bottle A, Burnett S, Cecil E, Charles KL, Dawson P, D'Lima D, Esmail A, Vincent C, Wilkinson S, Benn J. Evaluation of a national surveillance system for mortality alerts: a mixed-methods study. Health Serv Delivery Res 2018;6(7), doi:10.3310/hsdr06070. Available from URL https://pubmed.ncbi.nlm.nih.gov/29481031/ (Archived here)

[F] Quality Accounts of Oxford University Hospital for 2017/8 and 2018/19:
https://www.ouh.nhs.uk/about/publications/documents/quality-account-2018.pdf (Archived here) and https://www.ouh.nhs.uk/about/publications/documents/quality-report-2019.pdf (Archived here)

[G] Dr Foster Limited's size as a company:
https://suite.endole.co.uk/insight/company/03812015-dr-foster-limited gives figures for the year ending June 2019 (Archived here)

[H] Statement by Director of Strategy and Analytics, Dr Foster

[I] Article by the Herald Sun on 27 March 2015 about the purchase of Dr Foster by Telstra. https://www.heraldsun.com.au/business/breaking-news/telstras-ehealth-push-continues-with-dr-foster-buy/news-story/dd7ffe0eccf0b4bd785247407d413472 (Archived here)

[J] European Healthcare market size estimate by Market Data forecast
https://www.marketdataforecast.com/market-reports/europe-healthcare-analytics-market (Archived here)