Primary research

Health Services Management Research
2018, Vol. 31(3) 111–119

DOI: 10.1177/0951484817745064
journals.sagepub.com/home/hsm
SAGE

Investigating consistent patterns of variation in short-notice cancellations of elective operations: The potential for learning and improvement through multi-site evaluations

Nathan C Proudlove[1], Buddhika SW Samarasinghe[2] and Kieran Walshe[1]

Abstract

As part of efforts to increase productivity in healthcare, there is considerable interest in the extent and causes of variation in the performance of provider organisations. In this study, we use publically available data from the English NHS to examine the characteristics of variation in the rates of short-notice cancellations of elective operations due to hospital reasons (e.g. lack of the required resources such as operating theatres and beds). We find that the variation between hospital trusts is very non-random. There is a fourfold difference in the cancellation rates between the top and bottom deciles of performance. Little is known about the causes of this. There is a large and striking consistency in the relative performance of hospital trusts on cancellation rates over the last five years. Thus, the best and worst performers are consistently relatively very good or very poor, so a multi-site comparison of practices, and accounting for confounds like patient demographics, could be very valuable to inform both this knowledge gap and practice in healthcare. Of particular interest is that the cancellation rates could be a symptom of deeper issues with the efficiency of patient flows within hospitals.

Keywords

efficiency, elective admissions, performance indicators, quality improvement, quantitative analysis

Introduction

When examining the performance of providers within healthcare systems, variation in performance outcomes is found to be pervasive and is recognised as a major concern and opportunity for improvement.[1–3] In England, there is a new national programme led by clinicians focusing on identifying variation in care and efficiency across service areas and using the practical learning from this to spread successful practice.[4] Study of variation is also a useful starting point for academic research studies into deeper potential causes.[5]

Cancellation of scheduled operations at short notice reduces the quality of care on clinical outcomes, patient experience and hospital efficiency, that is all dimensions of Berwick's Triple Aim.[6] Our purpose in this paper is to use publically available data to examine the characteristics of variation in rates of short-notice cancellations of elective surgical procedures over five consecutive years in English NHS acute hospital organisations. This is intended to be the starting point for deeper and wider studies to understand drivers and so suggest improvement strategies.

Short-notice cancellations of elective surgical procedures

In the NHS, in common with many other health systems, patients access planned elective surgical procedures via their general practitioner (GP) (cf. family doctor), at primary care level. The general process is as follows. If, in

[1]Alliance Manchester Business School, University of Manchester, Manchester, UK
[2]United Lincolnshire Hospitals NHS Trust, Lincoln, UK

Corresponding author:
Nathan C Proudlove, University of Manchester, Booth Street East, Manchester, M13 9SS, UK.
Email: nathan.proudlove@manchester.ac.uk

discussion of the options with the patient, the GP judges it appropriate, he or she will refer the patient for an appointment with a consultant (e.g. a surgeon), usually at an acute hospital trust, and the patient will join the consultant's waiting list. Then if, again in discussion with the patient, the consultant judges it appropriate, the patient will be put on a waiting list for the surgery. The patient then receives a letter calling him or her to attend hospital on a specified date for the procedure. In England, the funding for this comes from the Department of Health to local Clinical Commissioning Groups, who buy services from providers including GP practices and hospital trusts.

Operations may be cancelled at short notice for a variety of reasons. In the English NHS, these are classified as *clinical reasons* (to do with the condition of the patient and whether they are fit for surgery), *patient reasons* (e.g. failure to attend) or *hospital reasons* (to do with availability of resources such as theatre time, diagnostics, post-operative intensive or critical care beds, etc.). In the NHS, 'short notice' means 'on or after the day of admission' (p. 6).[7] In these cases, the cancellation usually occurs after the patient has been admitted to hospital, and frequently on the day that the procedure was scheduled to take place, and so the patient has already gone through the disruption of personal psychological and logistical preparations. The term 'on the day of operation' cancellations is also commonly used in the NHS.

Every short-notice cancellation can be considered a missed opportunity to achieve high quality in planned care for the patient (outcome and experience), staff (satisfaction and motivation) and provider organisation (cost and productivity). Indeed, the academic literature highlights that cancellations have a considerable impact on the experience of patients and their families,[8–12] may be clinically harmful[13,14] and cause substantial problems for the utilisation of theatres and efficiency of clinical staff[9,12] producing a significant financial loss.[9] Estimating the full costs is very difficult, but prior to 2012 in the English NHS operations cancelled after admission received a specific healthcare resource group code with an associated fixed reimbursement tariff resulting in a cost of nearly £70 million for 2007.[15]

Short-notice cancellation rates exceeding 10% of all scheduled cases have been reported for hospitals in the United States[13,16,17] and in Europe.[18–20] A German study identified that rates varied from 0.8% to 17.9% between hospitals.[21] Studies show that non-clinical reasons predominate in short-notice cancellations.[15] It has been suggested that as much as 60–80% of short-notice cancellations are avoidable.[22]

Little is known about the extent of the overall problem, the root causes and so potential solutions.[15] Single-year studies inside individual NHS trusts provide some estimates of all-reasons short-notice cancellation rates: 5% (with 55% of these for *hospital-reasons*) in one study[9] and 13% (with 34% for *hospital-reasons*) in another.[18] Variation was found between specialties, ranging from 8% in Orthopaedics to 17–18% in General Surgery and Ear, Nose and Throat (ENT) Surgery; the reason for the variation was not investigated.[18] In volume terms the trusts in these studies were small, and the definitions used in the studies differ.

Data and methods

In the English NHS of the three categories of short-notice cancellations, only *hospital-reasons* data are published, defined as operations 'cancelled at the last minute for non-clinical reasons by NHS providers' (p. 2).[7] This is the class of cancellations we analyse in this paper. Although these *hospital-reasons* cancellations do not represent *all* cancellations, the data are potentially particularly interesting as we hypothesise that they are directly influenced by a trust's own policies and practices, and so are potentially indicative of deeper operational efficiency issues (e.g. patient flows) and organisational (e.g. management) culture. The other countries of the UK (Scotland, Wales and Northern Ireland) do not, or no longer, publish these data.[7]

Trust-level *hospital-reasons* cancellations volumes are released quarterly, aggregating inpatient (overnight stays) and day-case operations.[23] Cancellation rates are calculated by dividing this figure by the total elective activity (admissions) of the corresponding NHS unit and time period, released monthly.[24] Both these elective activity and cancellation volume data are part of the statutory data NHS providers in England are required to report to the Department of Health, and published by NHS England on their websites.

Any serious work with NHS data requires careful 'wrangling' of data, usually from several sources. NHS reporting is based on financial years running April–March. We extracted and pre-processed the data for five financial years (2011–2012 to 2015–2016) from the two sources above. We made two small adjustments to the cancellations data: two trusts, each had one quarter with zero cancellations recorded despite continuing large volumes of operations (i.e. a zero cancellation not seen anywhere else in large trusts and so clearly erroneous). In each case, we substituted the value from the corresponding quarter of the previous year.

The admission data downloaded list 322 providers; the cancellation data list 168. These providers include specialist trusts (dedicated orthopaedic, cancer, children's, mental health, etc. hospitals) and some (very low-volume) primary and community-based services. Our interest is in non-specialist acute trusts undertaking substantial volumes of work. Occasionally, a merger or

split results in a major reconfiguration of a trust, and so the number and make-up of the set of hospital trusts change slowly over time. As of July 2017, there were 135 non-specialist acute trusts (together with 17 specialist acutes, 54 mental health, 11 community and 10 ambulance trusts).[25] Table 1 shows the volumes in subsets of our combined dataset. The aggregate cancellation rates calculated are the simple 'NHS-level' results: total of cancellations divided by total elective admissions, not weighted or unweighted means across the 108 individual trust cancellation levels.

Removing 21 specialist trusts, and 15 subject to major reconfigurations, present in the cancellations data left 132 non-specialist acute trusts with several years' data, responsible for nearly 92% of the total admissions and cancellations. The smallest of these dealt with only 790 electives admissions a month, the largest over 12,000; the mean was 4500 per month. To remove smaller trusts, we established a cut-off of 30,000 elective operations undertaken in 2015–2016 (2500 per month), leaving a population of 108 large non-specialist acute hospital trusts for our main analyses. This represents 82% of non-specialist acute hospital trusts, dealing with 92% of this type of trust's elective admissions and cancellations and 85% of all elective admissions and cancellations for NHS England.

With encouragement from Government, some trusts have applied for and been granted 'Foundation' status. This gives them a little more managerial and financial autonomy, and hence might be expected to have some influence on senior management culture and priority setting. By the time of data recording for 2015–2016, 71 of the 108 trusts in our dataset (66%) had attained foundation status. The NHS splits England into four regions (although in recent years formal management at that level has been removed). We coded the data for foundation status and region. Table 1 suggests that, in aggregate, foundation trusts perform better on cancellations, as does the London Region. The number of London trusts in our selected data set is relatively small partly because most of the trusts subject to major reconfigurations (and so excluded) were in this region. There is no statistical pattern between region and foundation status (chi-square test, $p > .05$).

Figure 1 shows the variation in cancellation rates for the last year of the data (financial year 2015–2016). It shows a great deal of variation (the best trusts are many times better than the worst) and an 'outlier', which we see later is a trust with a history of very poor performance. Where the techniques used are not naturally robust to outliers, we analyse the data both with and without this data point.

In the next section, we further analyse these data using standard techniques for statistical visualisation and analysis of variation: a funnel plot, which compares trusts' cancellation rates with the range of what would be expected if the cancellation rate in each trust deviated from the global mean merely due to random variation (using confidence interval limits based on binomial distributions)[26,27] and standard boxplots (box-whiskers diagrams).[28] We are particularly interested in how persistent the relative performance of trusts is from year to year, since persistence would suggest the potential to research underlying drivers. Therefore we also trace the trajectories of the best and worst recent performers on top of the boxplots and supplement this with calculations of rank (ordinal) correlations across years.

Table 1. Overview of dataset: The data analysed are the 108 large non-specialist acute hospital trusts.

		Data for financial year 2015–2016				
	Providers	Admissions	% of total	Cancellations	% of total	Aggregate cancellation rate, %
Elective admissions data	322	7,809,838	100.00	–	–	–
Cancellations data	168	7,759,095	99.40	73,941	100.00	0.95
Exclusions (specialist and merged trusts)	36	601,471	7.70	6,178	8.40	1.03
Non-specialist acute trusts, with several years' data	132	7,157,624	91.60	67,763	91.60	0.95
Large non-specialist acute trusts, with several years' data	108	6,596,156	84.50	62,443	84.40	0.95
Foundation trusts	71	4,257,861	54.50	36,390	49.20	0.85
Non-foundation trusts	37	2,338,295	29.90	26,053	35.20	1.11
London region	10	703,232	9.00	6,174	8.30	0.88
Midlands and East region	33	1,947,489	24.90	19,144	25.90	0.98
North region	38	2,318,807	29.70	21,098	28.50	0.91
South region	27	1,626,628	20.80	16,027	21.70	0.99

Note: Activity for the financial year 2015–2016.

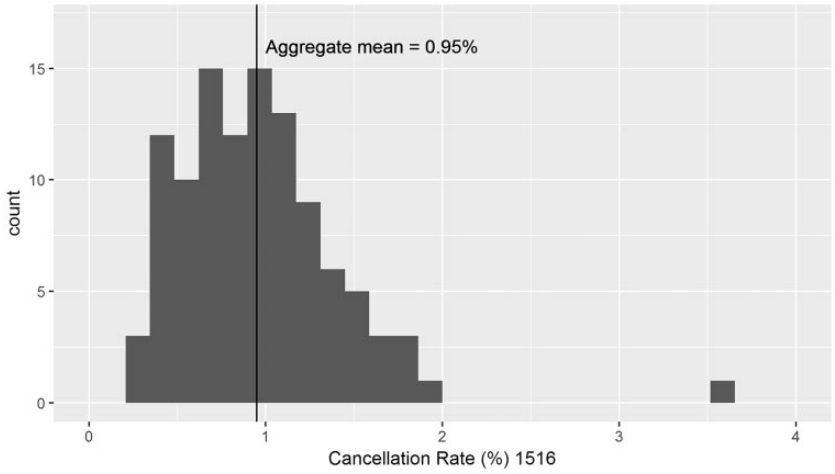

Figure 1. Histogram showing variation in cancellation rates for financial year 2015–2016 (108 trusts).

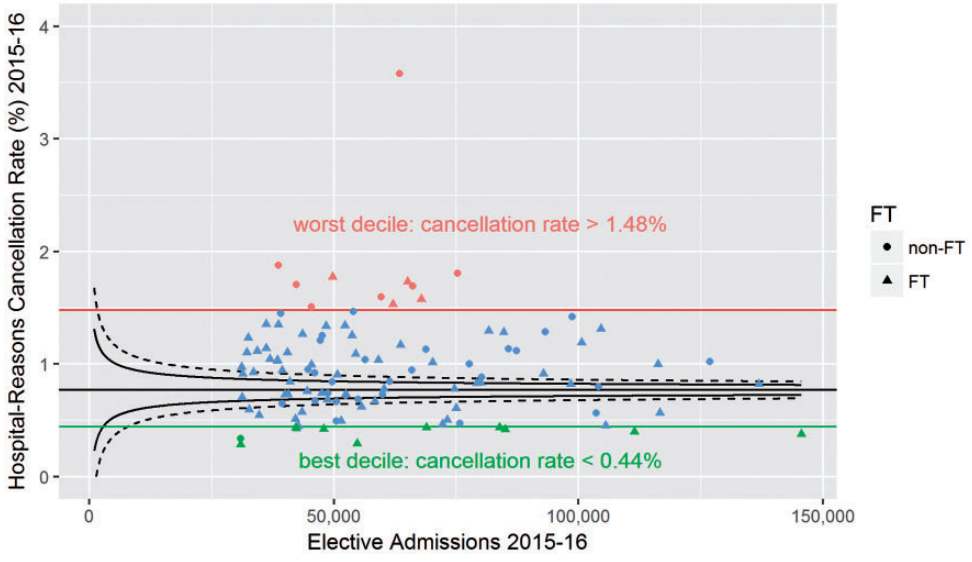

Figure 2. Funnel plot of short-notice hospital-reasons cancellations rates vs. elective admissions for 2015–2016, 108 trusts.

We use the high-level programming language *R* for data analysis and visualisation. The library package *ggplot2*[29] is particularly useful for constructing the graphs overlaying the best and worst trusts' trajectories (line graphs) on top of the boxplots (Figures 3 and 4), as it conceives of graphs as layers of information and allows almost complete customisation.

Analysis of variation

Figure 2 shows a funnel plot of the cancellation rates for 2015–2016. The bottom layer of the graph is formed by the black lines. These represent the weighted mean for all trusts (horizontal black line) and the expectations (curved lines) for the distribution of data points (trusts) *if* the departures of individual trusts' rates from this mean are purely due to random variation. The solid curved lines are the 95% confidence interval and the dotted curved lines are the 99.9% confidence interval. If the departures from the mean in the data were generated by purely random processes, only 5 in 100 points (trusts) would be expected to lie outside the 95% confidence interval and 1 in 1000 outside the 99.9% interval. The higher the number of elective operations for a trust (X axis), the lower the relative expected variation around the mean. Consider the possible likelihood of obtaining a very high or low mean score from throwing two dice relative to that from throwing 20 dice. This gives the characteristic curved funnel shape of the confidence intervals.

The next layer is the overlay of the 108 points showing the actual data for the trusts for the year 2015–2016.

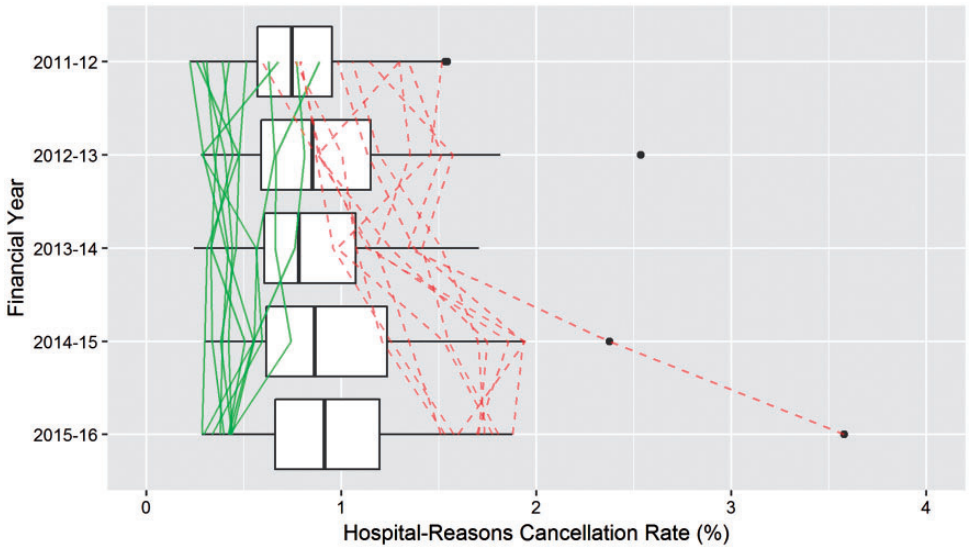

Figure 3. Boxplots of short-notice hospital-reasons cancellations rates over the last five financial years. Green/solid paths are the best decile trusts in 2015–2016; red/dashed are the worst decile, 108 trusts.

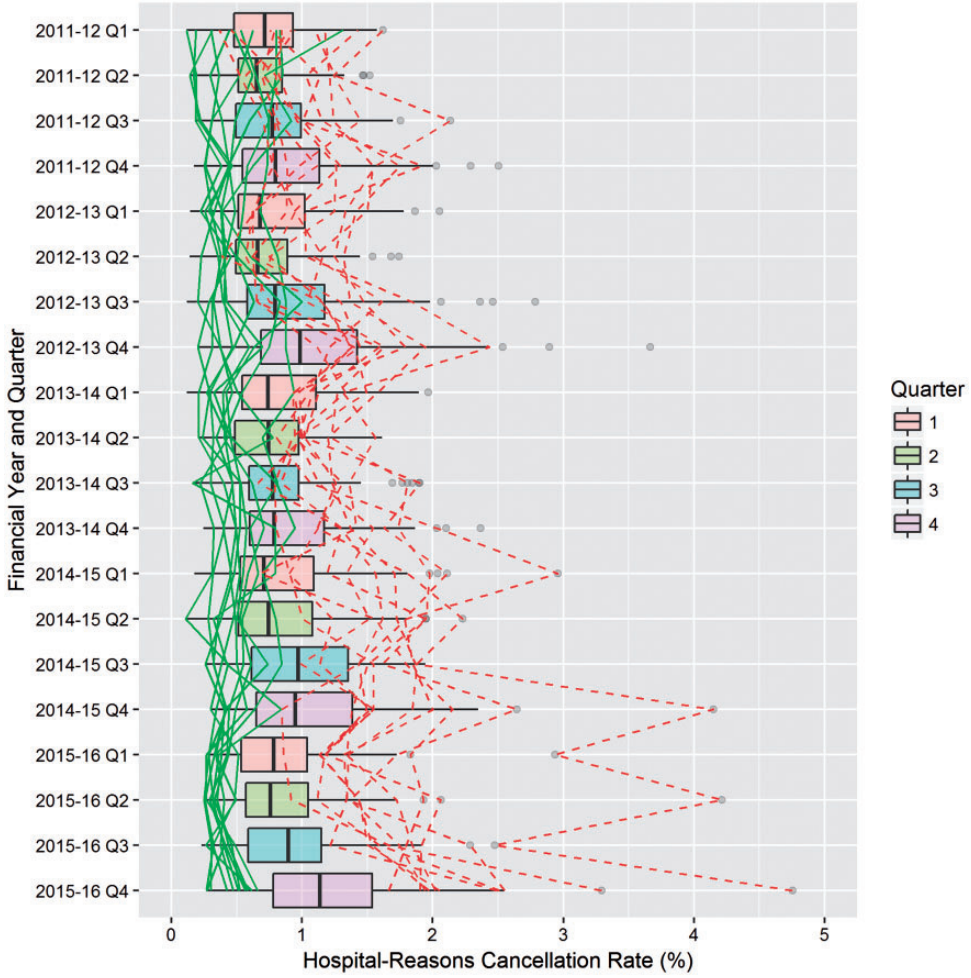

Figure 4. Short-notice hospital-reasons cancellations rates over the last five financial years, by quarter. Green/solid paths are the best decile trusts in 2015–2016; red/dashed are the worst decile, 108 trusts.

Here, the majority of the trusts lie outside the 99.9% confidence interval: the data are highly over-dispersed. The sizes of the populations of electives are so large that departures from the mean rate are *very* highly non-random. The shape of the symbol used (circle or triangle) shows the foundation-trust status for each trust.

The final layer of information is the red, blue and green colouring. The red and green horizontal lines (above and below the line of the mean respectively) have been added to pick out the best and worst deciles of performance (with 11 trusts in each). The data points for these worst and best trusts have been correspondingly coloured red and green, with the remainder blue. The best span the range of size (admissions volumes), but the worst are towards the smaller end.

Foundation trusts (triangle symbol) dominate the set of the best performers (10 out of 11), and overall foundation trusts tend to perform materially better. The presence of so many foundation trusts in this best set randomly is clearly unlikely, but not sufficient to be statistically significant. (The probability of seeing 10 or 11 foundation trusts due to random variation from a binomial distribution with individual probability of 71/108 is $p = .06$).

Multivariate analysis of the 2015–2016 cancellation rate data by foundation-trust status and NHS region reveals that the foundation-trust status is significant ($p = .03$) but region and the interaction between foundation-trust status and region are not significant. The figures in Table 1 indicate the difference that foundation-trust status makes, in aggregate 0.85% for foundation trusts versus 1.11% for others.

Having established that there is substantial and non-random variation between trusts, we are particularly interested in whether trusts' relative performance is persistent over time. One possibility is strong seasonal cycles affecting the NHS. Another possibility is fairly stable differences between trusts reflecting persistent differences in underlying structures and/or management culture, which might be investigated subsequently by very-much-more-extensive data collection and perhaps intensive fieldwork. We investigate persistence of performance in Figures 3 and 4 looking at all five years of our data.

Figure 3 contains two layers of information. The bottom layer, in black, shows boxplots. For each year, the central box (white shaded) shows the middle 50% of the data, containing the thick black line denoting the median cancellation rate. On either side of the box, the whiskers show the top and bottom quartiles. The dots to the right of the upper (worst) quartile whiskers show outliers, considered by the standard algorithm to be unusually far from the rest of the data: beyond the third quartile $+ 1.5 \times$ (third quartile $-$ first quartile). There are no outliers on the left (low cancellation-rate) side. These boxplots show that the extent of the variation is consistent over the years.

Figure 3 highlights that although the average short-notice *hospital-reasons* cancellation rates may appear small (0.95% overall for 2015–2016, see Table 1), the extent of the variation is very considerable. Trusts in the worst-performing decile have rates about four times worse than the best decile (around 1.6% vs. 0.4%) for 2015–2016. For 2015–2016, the best quartile performance is 0.66%. If the average performance moved from its current value (0.95%) to this best quartile performance, then around 19,000 cancellations (around 30%) could have been avoided. This gives us a reasonable 'size of the prize' target for improvement.

The medians indicate the problem is getting a little worse over time. There is a statistically significant year-on-year increase in cancellation rates, but this is small (0.04 percentage points per year).

Plotted on top of the boxplots are lines running top to bottom. These trace the trajectories over the five years of the trusts that end up in the best and worst deciles in 2015–2016. Looking at 2015–2016, the green solid lines pick out the cancellation rates of the 11 trusts with the best (lowest) cancellation rates in 2015–2016. Following the lines upwards, they connect to the trusts' cancellation rates in the previous year (2014–2015) and on back over earlier years to 2011–2012 at the top. The red dotted lines do the same for the 11 trusts with the worst (highest) cancellation rates in 2015–2016.

This highlights a great deal of persistence in the relative performance, i.e. the trusts that are best/worst in 2015–2016 were also very good/poor the previous year and earlier. Of the 22 trusts, over the four previous years a trust only ever appears on the other side of the median in three cases and these are back in 2011–2012, four years before the selection of the best and worst performers.

Table 2 shows this persistence is also the case for the whole set of trusts. The year-on-year rank correlations are very large (a correlation greater than .5 is generally considered 'large'[28]) and are very highly statistically significant. A year-on-year correlation of .86 means that 74% of the variance in the relative positions (ranks) of trusts can be 'explained' by the ranks the previous year.

Table 2. Year-to-year Spearman rank correlations.

	2011–2012	2012–2013	2013–2014	2014–2015
2011–2012				
2012–2013	.79			
2013–2014	.63	.77		
2014–2015	.58	.66	.81	
2015–2016	.46	.54	.68	.86

Note: 106–108 pairs of trusts; all $p < .001$.

Figure 4 elaborates Figure 3 to consider seasonality. The colours of the central boxes of the boxplots indicate the quarter of each financial year. It shows there is a material seasonal impact on cancellation rates, with the fourth quarters (January–March) being consistently the worst. In 2015–2016, 31% of cancellations occurred in quarter 4, in which the mean cancellation rate was 1.2%. With later data showing 2016–2017 quarter 3 at 1.1%, winters have been particularly difficult and are potentially getting worse. Although the trajectories of the top and bottom performers in 2015–2016 are of course noisier in Figure 4, a very large amount of consistency can still be observed.

Discussion

This study found considerable and non-random variation in hospital-reasons cancellation rates between large non-specialist hospital trusts in the English NHS. This corresponds to findings on cancellations in other health systems,[21] and more generally on a wide range of healthcare performance metrics.[1–5] Understanding the causes of variation is a central task in system improvement.[30]

There is some systematic variation in cancellation rates over the course of a year corresponding to quarters of the year (Figure 4), with winters being worst.[31] In the UK, emergency demand peaks in winters, and hence this suggests that there is impact from interaction with emergency flows which can compete with electives for operating theatres and post-operative recovery beds. 'Winter pressures' are compounded by loss of capacity through staff illness and infection in wards. However, there is very little seasonality in elective admissions volumes. This suggests that there may be improvement potential from better forecasting and planning of emergency demand.[32,33] Figure 4 shows, however, that the overall variation between trusts is very much greater than the effects of seasonality.

The most interesting finding from this study is that the relative performance of trusts is remarkably persistent (Figures 3 and 4 and Table 2). This suggests that performance is influenced by local context and/or policies and culture. As noted earlier, there is very little known about the extent and causes of short-notice cancellations in the NHS.[15] The magnitude of the difference in performance between the best and worst decile of trusts, together with the very great persistent of this, highlighted in Figure 3, suggests that there could be considerable value in a comparative study of good versus poor performers. Econometric studies are starting to suggest that, on top of context such as patient demographics and trust structure, differences in management culture between NHS trusts might have a significant and material effect on performance.[5]

The data presented in this study suggest that foundation-trust status seems to make a difference, with rates significantly and materially lower in these. This is consistent with a previous statistical cross-sectional study of overall short-notice cancellation rates in the English NHS, but the reason for this better performance is not known: patient demographics were found to have an influence but were not considered to be the major factor.[15] This foundation-trust effect is despite a suggestion that in recent years the increasing need for bailouts from Department of Health funds (with oversight attached) has eroded their autonomy and the distinction between foundation and non-foundation trusts.[34] It could be a result of continuing greater autonomy, or it may be a signal of trusts that are generally better organised or led. After accounting for foundation-trust status, geography (NHS region) is not found to be significant.

There is much evidence for process changes to reduce cancellations for *patient-reasons*, for example through reminder letters, and for *clinical-reasons* cancellations, for example through improving pre-assessment. However, many *hospital-reasons* cancellations can tend to be regarded as unavoidable, particularly when these appear to be a result of displacement of elective work by emergency or urgent demand.[9,35] A study in a small NHS trust in 2012 revealed lack of beds and lack of theatre time being the cause of 22% and 17%, respectively, of all cancellations.[9] Much less work has been done on studying these deeper patient-flow issues. A study of all-reasons short-notice cancellations found that day of admission was statistically significant, with Mondays being the worst for cancellation rates and weekends the best.[15] This suggests that patient-flow issues may be important, including the interaction with emergency flows in general as well as particularly in winters.

Therefore, a hypothesis worth investigating across a set of persistently good and poor performers is that short-notice *hospital-reasons* cancellations of operations are signs of deeper causes involving poor operational management of patient flows. This includes investigating the extent to which elective flows are impacted by emergency flows (including delayed transfers of care to post-acute provision). Despite the importance of this area, we have found that most published work on this subject focuses on single providers. The main drawback of such single-centre studies is that local contextual factors like specific administrative procedures or planning processes might profoundly influence performance and improvement outcomes.

NHS England uses rates of short-notice *hospital-reasons* cancellations as a performance indicator. Considering this category alone for performance management can introduce limitations, as each NHS trust

can interpret these categories in different ways. Competition for resource between planned elective work and unplanned urgent or emergency demand makes *some* short-notice cancellations inevitable. However, it is possible that some NHS providers facing intense emergency-demand pressures may cancel elective patients a day or more earlier to avoid the performance-management implications of reporting them as short notice. Thus, there is a dilemma in identifying what is an 'appropriate' short-notice cancellation rate.

It is worth noting that the trusts highlighted in Figure 3 as persistently high performing are achieving this while facing the same environment of constrained budgets and rising emergency-care pressures as others, and regardless of other changes in the NHS. Our findings of highly persistent performance over many years among the best and worst performers provide a useful research opportunity to conduct multi-provider studies to identify what these trusts are doing differently. For wider health management, this would also create a great opportunity for NHS trusts to work together, sharing knowledge and learning from each other.

To extend the single-provider work in the English NHS,[9,18] we suggest intensive multi-provider research studies could be very fruitful to provide generalisable, evidence-based knowledge on reduction of short-notice cancellations, and so recommendations for planned care providers. This has the potential to improve patient experience and safety, and increase productivity in elective care to help to reduce the current very substantial financial 'waste' to the NHS and other health systems. There is also the potential to investigate interactions between seasonal patterns observed in data and to apply econometric approaches to the sort of longitudinal (panel) data used in this study to search for associations with a wider set of contextual and performance variables.

Declaration of conflicting interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

References

1. Carter P. *Operational productivity and performance in English NHS acute hospitals: Unwarranted variations*. Department of Health, www.gov.uk/government/publications/productivity-in-nhs-hospitals (2016, accessed 10 August 2017).
2. Chandra A, Finkelstein A, Sacarny A, et al. Productivity dispersion in medicine and manufacturing. *Am Econ Rev* 2016; 106: 99–103.
3. Castelli A, Street A, Verzulli R, et al. Examining variations in hospital productivity in the English NHS. *Eur J Health Econ* 2015; 16: 243–254.
4. Abercrombie J. *GIRFT Programme national specialty report: general surgery*. 2017. http://gettingitrightfirsttime.co.uk/wp-content/uploads/2017/07/GIRFT-GeneralSurgeryReport-Aug17v1.pdf (accessed 10 August 2017).
5. Ali M, Salehnejad R and Mansur M. Hospital heterogeneity: what drives the quality of health care. *Eur J Health Econ* 2017; online first. DOI: 10.1007/s10198-017-0891-9.
6. Berwick DM, Nolan TW and Whittington J. The triple aim: care, health, and cost. *Health Aff (Millwood)* 2008; 27: 759–769.
7. England NHS. NHS cancelled elective operations: quarter ending March 2016, www.england.nhs.uk/statistics/wp-content/uploads/sites/2/2013/04/NHS-cancelled-elective-operations-commentary-Q4-2015-16.pdf (2016, accessed 10 August 2017).
8. Hovlid E, von Plessen C, Haug K, et al. Patient experiences with interventions to reduce surgery cancellations: a qualitative study. *BMC Surg* 2013; 13: 30.
9. Dimitriadis PA, Iyer S and Evgeniou E. The challenge of cancellations on the day of surgery. *Int J Surg* 2013; 11: 1126–1130.
10. Tait AR, Voepel-Lewis T, Munro HM, et al. Cancellation of pediatric outpatient surgery: economic and emotional implications for patients and their families. *J Clin Anesth* 1997; 9: 213–219.
11. Ivarsson B, Larsson S and Sjöberg T. Postponed or cancelled heart operations from the patient's perspective. *J Nurs Manag* 2004; 12: 28–36.
12. Schofield WN, Rubin GL, Piza M, et al. Cancellation of operations on the day of intended surgery at a major Australian referral hospital. *Med J Aust* 2005; 182: 612–615.
13. Argo JL, Vick CC, Graham LA, et al. Elective surgical case cancellation in the Veterans Health Administration system: identifying areas for improvement. *Am J Surg* 2009; 198: 600–606.
14. Ivarsson B, Kimblad PO, Sjöberg T, et al. Patient reactions to cancelled or postponed heart operations. *J Nurs Manag* 2002; 10: 75–81.
15. McIntosh B, Cookson G and Jones S. Cancelled surgeries and payment by results in the English National Health Service. *J Health Serv Res Policy* 2012; 17: 79–86.
16. Lacqua M and Evans J. Cancelled elective surgery: an evaluation. *Am Surg* 1994; 60: 809–811.
17. Hand R, Levin P and Stanziola A. The causes of cancelled elective surgery. *Qual Assur Util Rev* 1990; 5: 2–6.
18. Sanjay P, Dodds A, Miller E, et al. Cancelled elective operations: an observational study from a district general hospital. *J Health Org Manag* 2007; 21: 54–58.
19. Mangan JL, Walsh C, Kernohan WG, et al. Total joint replacement: implication of cancelled operations for hospital costs and waiting list management. *Qual Saf Health Care* 1992; 1: 34–37.

20. Seim AR, Fagerhaug T, Ryen SM, et al. Causes of cancellations on the day of surgery at two major university hospitals. *Surg Innov* 2009; 16: 173–180.
21. Schuster M, Neumann C, Neumann K, et al. The effect of hospital size and surgical service on case cancellation in elective surgery: results from a prospective multicenter study. *Anesth Analg* 2011; 113: 578–585.
22. Rymaruk S. A retrospective observational study of patient cancellations on the day of surgery in the general surgical directorate. *J Perioper Pract* 2011; 21: 337–341.
23. NHS England. Cancelled elective operations data, www.england.nhs.uk/statistics/statistical-work-areas/cancelled-elective-operations/cancelled-ops-data/ (accessed 17 January 2017).
24. NHS England. Monthly hospital activity data, www.england.nhs.uk/statistics/statistical-work-areas/hospital-activity/monthly-hospital-activity/mar-data (accessed 17 January 2017).
25. The NHS Confederation. Key statistics on the NHS (14 July 2017), http://www.nhsconfed.org/resources/key-statistics-on-the-nhs (accessed 10 August 2017).
26. Spiegelhalter DJ. Funnel plots for comparing institutional performance. *Stat Med* 2005; 24: 1185–1202.
27. Ieva F and Paganoni AM. Detecting and visualizing outliers in provider profiling via funnel plots and mixed effect models. *Health Care Manag Sci* 2014; 18: 166–172.
28. Field A, Miles J and Field Z. *Discovering statistics using R*. London: SAGE, 2012.
29. Wickham H. *ggplot2: elegant graphics for data analysis*. New York: Springer-Verlag, 2009.
30. Boaden R, Harvey G, Moxham C, et al. *Quality improvement: theory and practice in healthcare*. Coventry: NHS Institute for Innovation and Improvement, www.institute.nhs.uk/service_transformation/quality_improvement/quality_improvement%3a_theory_and_practice_in_healthcare.html (2008, accessed 1 April 2016).
31. Proudlove NC, Gordon K and Boaden R. Can good bed management solve the overcrowding in A &E? *Emerg Med J* 2003; 20: 149–155.
32. Proudlove NC and Brown C. Winter planning: seasonal cycles. *Health Serv J* 2002; 112: 24–25.
33. Proudlove NC, Black S and Fletcher A. OR and the challenge to improve the NHS: modelling for insight and improvement in in-patient flows. *J Oper Res Soc* 2007; 58: 145–158. DOI: 10.1057/palgrave.jors.2602252.
34. Collins B. The foundation trust model: death by a thousand cuts, www.kingsfund.org.uk/blog/2016/02/foundation-trust-model (2016, accessed 10 August 2017).
35. Basson MD, Butler TW and Verma H. Predicting patient nonappearance for surgery as a scheduling strategy to optimize operating room utilization in a Veterans' Administration hospital. *Anesthesiology* 2006; 104: 826–834.