Lowering levels of bed occupancy is associated with decreased inhospital mortality and improved performance on the 4-hour target in a UK District General Hospital

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▸ Additional material is published online only. To view please visit the journal online (http://dx.doi.org/10.1136/emermed-2014-204479).

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Received 24 November 2014
Revised 22 July 2015
Accepted 23 July 2015
Published Online First 17 September 2015

Linked
▸ http://dx.doi.org/10.1136/emermed-2015-205255

To cite: Boden DG, Agarwal A, Hussain T, *et al*. *Emerg Med J* 2016;**33**:85–90.

ABSTRACT

Objective To evaluate whether there is an association between an intervention to reduce medical bed occupancy and performance on the 4-hour target and hospital mortality.

Methods This before-and-after study was undertaken in a large UK District General Hospital over a 32 month period. A range of interventions were undertaken to reduce medical bed occupancy within the Trust. Performance on the 4-hour target and hospital mortality (hospital standardised mortality ratio (HSMR), summary hospital-level mortality indicator (SHMI) and crude mortality) were compared before, and after, intervention. Daily data on medical bed occupancy and percentage of patients meeting the 4-hour target was collected from hospital records. Segmented regression analysis of interrupted time-series method was used to estimate the changes in levels and trends in average medical bed occupancy, monthly performance on the target and monthly mortality measures (HSMR, SHMI and crude mortality) that followed the intervention.

Results Mean medical bed occupancy decreased significantly from 93.7% to 90.2% (p=0.02). The trend change in target performance, when comparing preintervention and postintervention, revealed a significant improvement (p=0.019). The intervention was associated with a mean reduction in all markers of mortality (range 4.5–4.8%). SHMI (p=0.02) and crude mortality (p=0.018) showed significant trend changes after intervention.

Conclusions Lowering medical bed occupancy is associated with reduced patient mortality and improved ability of the acute Trust to achieve the 95% 4-hour target. Whole system transformation is required to create lower average medical bed occupancy.

Key messages

What is already known on this subject?

Known correlation found in previous studies between high bed occupancy and infection risk.
Minimal international research has found a correlation between Trust bed occupancy and mortality.
No previous studies have looked at bed occupancy and mortality after deliberate intervention to reduce bed occupancy.
No UK studies have shown a correlation between bed occupancy and mortality

What might this study add?

Previous studies have found higher mortality as bed occupancy rises but have not studied the effect on mortality following a deliberate intervention to reduce bed occupancy. This retrospective, single centre study shows that, on intervening to reduce bed occupancy, there appears to be an association with a reduction in mortality and improved performance against the 4-hour target.

INTRODUCTION

Crowding, access block and high workload have been cited as reasons for excess mortality among ED patients.[1–7] The problem of crowding in Emergency Departments (EDs) is recognised by professional bodies around the world as a patient safety issue and, in 2014, this was the principle campaign of the UK Royal College of Emergency Medicine.

Past research has focused on the outcome of ED patients, but less is known about the effect of access block, capacity and performance for the wider group of patients in a hospital. There is increasing evidence of a correlation between Trust bed occupancy and rates of infection, particularly *Clostridium difficile*,[8] which may lead to poor patient outcomes, but there is little published evidence of a correlation between bed occupancy and mortality. A small number of international studies have been published.[9–11] One Danish study showed a 9% increase in mortality rates for inhospital mortality and 30-day mortality when high bed occupancy periods were compared with low bed occupancy periods.

In UK practice the bulk of patients admitted through the ED require acute medical admission. Access block frequently occurs for patients awaiting admission under the general medical teams with a widespread belief that delays and long trolley waits lead to poor departmental performance, poor care and potential harm to patients.

UK emergency departments are required to report the proportion of patients attending who are seen, treated, admitted or discharged within 4 h or arrival against a national standard of 95%.

In June 2013, as a result of increasing workload pressures, Derby Teaching Hospitals NHS Foundation Trust introduced a 90% medicine bed occupancy target. A number of interventions were undertaken across the patient journey to facilitate this. These included daily Consultant ward rounds on medical wards, CCG-commissioning of additional community beds and planned utilisation of traditional surgical bed base for medical patients. This permitted a natural experiment to see the effect of this reduction in bed occupancy on 4-h target performance and hospital mortality.

The aim of this study is to evaluate whether there is an association between an intervention to reduce medical bed occupancy and 4-h target performance and hospital mortality in a UK District General Hospital.

METHODS

Study design and setting

We conducted an uncontrolled before-and-after intervention study at Derby Teaching Hospitals NHS Foundation Trust, a large District General Hospital seeing over 140 000 non-elective patients per year. Mortality data were gathered and analysed for the period January 2010–October 2014.

Definitions and patient outcomes

We defined bed occupancy as the number of occupied medical beds as a proportion of the total bed base at midnight. Outliers (medical patients on non-medical wards) were included in the numerator. It is therefore possible to have a derived medical bed occupancy of greater than 100%. Bed occupancy data was gathered from January 2012 to October 2014.

The 4-hour target performance was defined as above. We determined performance against the 4-hour access target on a weekly basis from local data collection.

Table 1 Monthly preintervention and postintervention data (January 2012–October 2014)

Month	Average medical bed occupancy	Monthly HSMR (95% CI)	Monthly SHMI (95% CI)	Crude mortality (%)	Total number of deaths	Trust attendances	Number of non-elective admissions
Preintervention							
January 2012	95.0%	105 (88.5 to 116.7)	114 (100.6 to 128.5)	1.61	194	12 047	2813
February 2012	93.1%	109 (94.9 to 124.5)	114 (100.2 to 128.6)	1.84	211	11 491	2672
March 2012	93.5%	105 (82.9 to 109.3)	109 (96.0 to 123.1)	1.61	199	12 349	2890
April 2012	97.2%	112 (89.7 to 119.3)	109 (95.6 to 123.4)	1.77	189	10 688	2822
May 2012	94.0%	106 (92.9 to 124.2)	109 (95.8 to 124.6)	1.47	182	12 339	2826
June 2012	91.7%	109 (85.1 to 115.8)	101 (87.8 to 115.8)	1.46	160	10 958	2785
July 2012	92.4%	102 (93.7 to 125.7)	105 (91.1 to 119.6)	1.44	176	12 180	2897
August 2012	90.7%	109 (92.1 to 122.9)	106 (92.7 to 120.6)	1.61	185	11 520	2772
September 2012	91.7%	110 (93.8 to 127.6)	112 (97.0 to 127.8)	1.46	164	11 202	2700
October 2012	94.1%	112 (98.7 to 129.9)	120 (105.7 to 135.3)	1.66	207	12 460	2824
November 2012	92.7%	97 (79.4 to 108.3)	101 (88.4 to 115.8)	1.35	160	11 861	2932
December 2012	94.3%	108 (93.6 to 122.9)	114 (100.2 to 128.7)	1.82	205	11 236	3071
January 2013	93.7%	109 (95.5 to 122.9)	119 (105.8 to 132.8)	1.95	237	12 144	2842
February 2013	93.5%	110 (95.4 to 125.3)	115 (101.1 to 129.7)	1.85	212	11 461	2651
March 2013	95.8%	115 (101.5 to 130.8)	113 (99.7 to 126.7)	1.95	233	11 946	3158
April 2013	95.4%	120 (104.3 to 137.5)	111 (98.2 to 125.5)	1.83	206	11 271	2841
May 2013	93.5%	104 (89.9 to 119.7)	106 (93.1 to 119.3)	1.60	191	11 942	3038
June 2013	<7 days data	119 (102.2 to 136.9)	100 (87.5 to 114.4)	1.59	181	11 408	2968
Preintervention Means:	93.7%	109	110	1.66	194	11 695	2986
Postintervention							
July 2013	90.9%	95 (81.1 to 111.1)	97 (83.9 to 110.7)	1.26	153	12 171	3024
August 2013	91.5%	111 (95.5 to 127.2)	112 (98.5 to 127.1)	1.61	180	11 202	3000
September 2013	92.6%	110 (94.2 to 127.1)	111 (97.2 to 126.7)	1.50	170	11 298	2988
October 2013	90.5%	111 (96.3 to 126.9)	113 (99.6 to 127.1)	1.56	195	12 485	3076
November 2013	91.1%	102 (87.7 to 117.0)	116 (102.4 to 130.6)	1.50	182	12 158	2928
December 2013	88.8%	108 (95.0 to 122.9)	111 (98.9 to 125.1)	1.97	232	11 764	3291
January 2014	89.5%	101 (87.9 to 114.6)	107 (94.6 to 120.0)	1.69	212	12 535	3130
February 2014	92.8%	119 (102.8 to 136.3)	112 (98.2 to 127.6)	1.68	188	11 168	2914
March 2014	89.4%	100 (86.9 to 114.0)	115 (101.1 to 129.2)	1.76	217	12 313	3280
April 2014	87.5%	102 (88.8 to 116.7)	102 (89.7 to 115.7)	1.78	211	11 879	2964
May 2014	87.8%	96 (83.1 to 110.6)	104 (91.9 to 117.7)	1.65	197	11 974	3207
June 2014	89.5%	105 (90.1 to 121.0)	96 (83.4 to 109.2)	1.38	161	11 631	3124
July 2014	88.5%	97 (83.8 to 112.0)	94 (81.8 to 105.7)	1.42	180	12 688	3253
August 2014	89.5%	109 (94.0 to 125.1)	104 (91.9 to 118.2)	1.63	186	11 396	3018
September 2014	91.5%	104 (89.7 to 120.0)	101 (89.0 to 114.9)	1.47	180	12 225	2986
October 2014	91.4%	93 (79.6 to 107.4)	92 (80.6 to 104.4)	1.36	179	13 160	3247
Postintervention Means:	90.2%	104	105	1.58	189	12 003	3263
Difference in mean values	−3.5%	−5 (4.6% reduction)	−5 (4.5% reduction)	−0.08 (4.8% reduction)	5 (2.6% reduction)	2.6% increase	9.3% increase

HSMR, hospital standardised mortality ratio; SHMI, summary hospital-level mortality indicator.

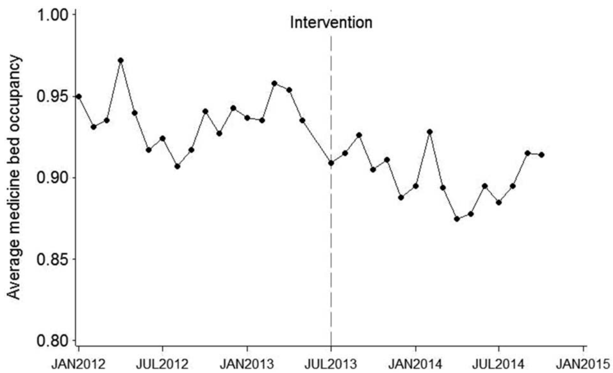

Figure 1 Average monthly medical bed occupancy (January 2012–October 2014).

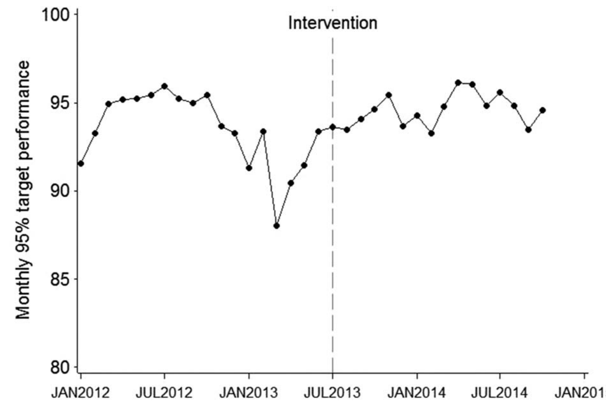

Figure 2 Monthly 95% target performance (January 2012–October 2014).

Patient outcomes were determined using hospital standardised mortality ratio (HSMR), summary hospital-level mortality indicator (SHMI) and crude mortality. These have been defined and obtained as documented below:

Hospital standardised mortality ratio

The HSMR is a ratio of the observed number of inhospital deaths at the end of a continuous inpatient spell to the expected number of inhospital deaths (multiplied by 100) for 56 specific clinical classification system groups.

Monthly figures obtained from Dr Foster intelligence.[12]

Summary hospital-level mortality indicator

The ratio between the actual number of patients who die following hospitalisation at the Trust and the number that would be expected to die on the basis of average England figures, given the characteristics of the patients treated there. It covers all deaths reported of patients who were admitted to non-specialist acute Trusts in England and either die while in hospital or within 30 days of discharge.

Monthly figures obtained from internal Trust data.

Monthly crude mortality

The number of deaths that occur in a hospital in any given time period compared with the number of patients admitted for care in that hospital for the same time period. The crude mortality rate has then been set as the number of deaths for every 100 patients admitted.

Monthly figures obtained from internal Trust data.

Statistical analysis

Segmented regression analysis of interrupted time-series method[13 14] was used to estimate the changes in levels and trends in average medicine bed occupancy, monthly 95% four hour target performance (4HTP) and monthly mortality measures (HSMR, SHMI and crude mortality) that followed the intervention.

The model used was $Y_t=\beta_0+\beta_1{*}T1_t+\beta_2{*}I_t+\beta_3{*}T2_t+e_t$

Coefficient β_0 estimated the monthly value of the outcome variable at time 0 (just before the beginning of the observation period, January 2012); β_1 estimated the baseline slope parameter representing change in the outcome variable of interest that occurred every month before the intervention; β_2 was change in the outcome variable of interest immediately after the intervention (intercept changes); β_3 estimated monthly change in outcome variable of interest compared with trend before the intervention (slope changes).

Note that Y_t is the outcome variable in month t; $T1_t$ is a continuous variable indicating time in months at time t from the start of the observation period (T1=1, 2, …, 34); I_t is an indicator variable equal to 0 before the intervention and equal to 1 after the intervention; $T2_t$ represents time after intervention, equal to 0 before the intervention and equal to the number of months after the intervention; the error term e_t represents the random error not explained by the model, consisting of normally distributed random error and an error at time t that may be correlated to errors at preceding time points.

The generalised Durbin-Watson statistic[15] was calculated to test for the serial autocorrelation of the error terms in the regression models. When autocorrelation existed, the stepwise autoregression process was conducted using the Yule-Walker method to correct for autocorrelation. Seasonality was accounted by the inclusion of autocorrelation errors.[16] Initial autoregressive parameters were set to 13 as the data were collected at the monthly level to account for seasonality. The ith order autoregressive error was retained in the model if the term contributed significantly to the fit of the model ($p<0.05$). Using the stepwise

Table 2 Interrupted time-series regression analysis of average medical bed occupancy

	Coefficient	SE	t Statistic	p Value
Intercept (β_0)	0.9344	0.0083	113.15	<0.0001*
Baseline trend (β_1)	0.0002	0.0008	0.30	0.7632
Level change after intervention (β_2)	−0.0283	0.0119	−2.38	0.0238*
Trend change after intervention (β_3)	−0.0013	0.0012	−1.07	0.2941

*Indicates significance at the 0.05 level.

Table 3 Interrupted time-series regression analysis of monthly 95% target performance

	Coefficient	SE	t Statistic	p Value
Intercept (β_0)	142.0124	13.9058	10.21	<0.0001*
Baseline trend (β_1)	−0.2260	0.0646	−3.50	0.0016*
Level change after intervention (β_2)	1.2503	1.0399	1.20	0.2393
Trend change after intervention (β_3)	0.2421	0.0976	2.48	0.0193*

*Indicates significance at the 0.05 level.

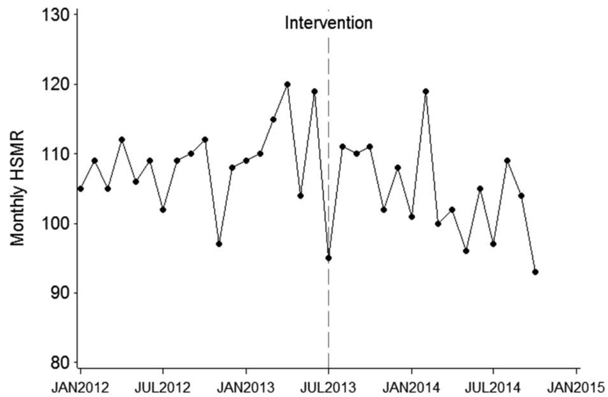

Figure 3 Monthly hospital standardised mortality ratio (HSMR) (January 2012–October 2014).

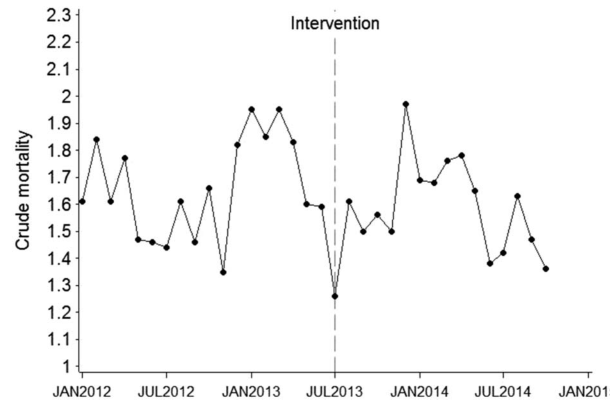

Figure 5 Monthly crude mortality (January 2012–October 2014).

autoregression process, the following autoregressive errors were retained: medical bed occupancy (no autoregressive error retained), 4 h target performance (no autoregressive error retained), HSMR (a 3rd order autoregressive error retained), SHMI (a 7th order autoregressive error retained), crude mortality (a 7th order and an 11th order autoregressive errors retained). The statistical package SAS V.9.3[17] was used for all analyses. A p value less than 0.05 was considered statistically significant.

RESULTS

Preintervention and postintervention data from January 2012 to October 2014 is summarised in table 1 below.

Total Trust attendances during this period were 210 510. Attendances increased, with a monthly mean of 11 695 attendances before the intervention and 12 003 following the intervention. Non-elective admissions also increased with a mean of 2986 preintervention compared with 3263 postintervention.

Medical bed occupancy

Following the planned intervention in July 2013 mean medical bed occupancy decreased from a preintervention mean of 93.7% to a postintervention mean of 90.2%, (see table 1).

A statistically significant level change (p=0.02) in bed occupancy was noted. However, due to a slight rise in occupancy levels in September and October 2014, there was a resultant non-significant trend change after intervention (p=0.29) (figure 1, table 2).

Four-hour target performance

Four-hour target performance was compared with midnight bed occupancy in medicine. Following intervention performance on the target improved with the Trust achieving a 95% or greater performance in 37/72 (51.4%) weeks as compared with the preintervention period where the standard was achieved in 24/72 (33.3%) weeks (see online supplementary appendix 1)

The trend change in target performance when comparing preintervention and postintervention revealed a statistically significant improvement (p=0.019) (figure 2, table 3).

Medical bed occupancy and mortality

With respect to the relationship between medical bed occupancy and mortality before and after intervention, table 1 shows data on monthly average medical bed occupancy, HSMR, SHMI and crude mortality with accompanying relevant CIs. Total Trust attendances, number of deaths and non-elective admissions are also included to illustrate the total deaths in relation to number of admissions and attendances.

The intervention resulted in mean reductions in all markers of mortality (range 4.5–4.8%). SHMI (p=0.02) and crude mortality (p=0.018) resulted in significant trend changes after intervention (figures 3–5, tables 4–6).

DISCUSSION

After the introduction of relevant interventions to reduce bed occupancy in medicine, our principle findings are statistically significant differences in medical bed occupancy (level change), 4 h target performance and SHMI and crude mortality. Where this study differs from previously published research is that the association of bed occupancy on mortality has been studied after specific interventions were undertaken to reduce bed occupancy. This has not previously been studied and is potentially reproducible by other hospitals and Trusts.

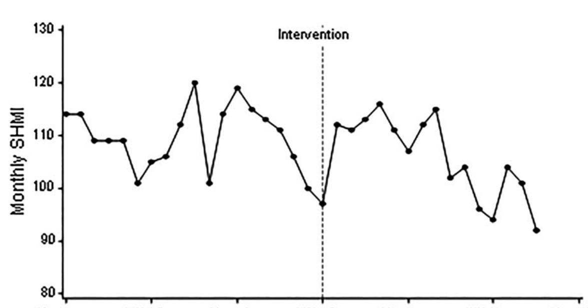

Figure 4 Monthly summary hospital-level mortality indicator (SHMI) (January 2012–October 2014).

Table 4 Interrupted time-series regression analysis of monthly HSMR

	Coefficient	SE	t Statistic	p Value
Intercept (β_0)	−6.2176	48.7828	−0.13	0.8995
Baseline trend (β_1)	0.1783	0.1966	0.91	0.3724
Level change after intervention (β_2)	1.8449	3.2282	0.57	0.5724
Trend change after intervention (β_3)	−0.5681	0.2925	−1.94	0.0626

HSMR, hospital standardised mortality ratio.

Table 5 Interrupted time-series regression analysis of monthly SHMI

	Coefficient	SE	t Statistic	p Value
Intercept (β_0)	62.5537	60.9786	1.03	0.3141
Baseline trend (β_1)	0.1198	0.2762	0.43	0.6679
Level change after intervention (β_2)	3.1627	4.6711	0.68	0.5041
Trend change after intervention (β_3)	−0.9593	0.3887	−2.47	0.0202*

*Indicates significance at the 0.05 level.
SHMI, summary hospital-level mortality indicator.

Table 6 Interrupted time-series regression analysis of crude mortality

	Coefficient	SE	t Statistic	p Value
Intercept (β_0)	4.1112	1.6098	2.55	0.0169*
Baseline trend (β_1)	0.0151	0.0059	2.56	0.0168*
Level change after intervention (β_2)	−0.1937	0.0973	−1.99	0.0571
Trend change after intervention (β_3)	−0.0227	0.0090	−2.52	0.0183*

*Indicates significance at the 0.05 level.

The data in this before-and-after study shows an association between these factors but we must be cautious in the interpretation of such data as association does not equate to causality.

First, the limitations of any before-and-after study design must be noted. Undertaking such a study type runs the risk of conclusions being made that actually result from secular/temporal trends, of regression to the mean, of potential for influence from the Hawthorne effect and challenges with regards to sustainability and generalisability.

In addition a number of confounding factors may influence the findings and these are detailed in table 7.

We feel it is important to highlight these other variables that may have contributed to the reduction in mortality that we have found in this study. This is because, at present, it remains difficult to disentangle these (and other) confounders from the results. By doing this we hope to open debate as to the potential role that all of these may have played. This, in turn, should increase our knowledge and understanding in a vitally important area of Emergency Medicine.

Even accounting for the challenges posed by confounders, we believe that the negative patient and system outcomes associated with high bed occupancy pass face validity and deserve further consideration and research.

In 2014 the Royal College of Emergency Medicine published a paper titled '*Crowding in the Emergency Department*'.[19] Within this document they state that an Emergency Department is crowded if "ambulances cannot offload, there are long delays for high acuity patients to see a doctor, there are high rates of patients with a 'Left Without Being Seen' Code, there are more trolley patients in the ED than there are cubicle spaces, or if patients are waiting more than 2 hours for an inpatient bed after a decision to admit has been made".

Studies in a number of different countries demonstrate increasing evidence of the importance of ED crowding and its detriment to patient care including:

- Evidence of an association between crowding and mortality.[3–5]
- Reduction in the quality of patient care received.[20]
- Increased length of stay for non-elective admissions.[21]
- Cancellation/postponement of hospital elective activity[22]

All these factors are likely to reduce patient experience and outcome. This paper provides statistical evidence to support the beliefs and experiences of UK and international physicians. The tagline that 'crowding kills' is emotive, but important. If our access systems fail and patient harm results then we have a responsibility to monitor and report the data that demonstrates potential causes and associations such that the profession, healthcare systems and patients can explore, understand and improve care.

This study represents the experience of one Trust over a relatively short time period. We suggest that further research should be conducted in other centres of different size and location to ascertain whether these findings are generalisable to a UK, or even international, population.

CONCLUSION

Lowering medical bed occupancy is associated with reduced patient mortality and improved ability of the acute Trust to achieve the 95% 4 h target. Whole system transformation is required to create lower average medical bed occupancy.

Table 7 Confounders and their potential influence

Confounder	Risk
HSMR/SHMI	HSMR and SHMI are derived comparative measures where changes in patient outcomes for other Trusts can have a large impact on our own scores.
Mild winter 2013/2014 and seasonal variation	Winter 2013/2014 was a milder winter which may have positively influenced the ability of the Trust to maintain 90% occupancy in medicine as well as potentially lowering mortality.
National hospital mortality reduction	Hospital mortality is dropping as a trend.[18] It should be noted though that this was not the case at Derby Teaching Hospitals NHS Trust.
Increased non-elective admissions	An increase in non-elective admissions has contributed to the postintervention crude mortality reduction by increasing the denominator. However, even accounting for a rise in attendances (mean 308/month), the number of Trust deaths actually reduced by a mean of 5 deaths per month following intervention.
Less seriously ill patients admitted	Increased bed availability potentially resulted in proportionately less seriously ill patients being admitted hence reducing overall mortality.
Elective care	The winter plan 2013/2014 relied on using surgical beds to maintain 90% bed occupancy for non-elective patients admitted under medicine. This may lead to a reduction in other hospital activities such as complex surgery, thus leading to a reduction in HSMR/SHMI.
Staffing changes	Staffing in the Emergency Department for nursing and middle grade numbers was increased during 2013/2014.
Progress in other areas of care	Mortality is influenced by other factors and concurrent service improvements in 2013/2014 such as increased thromboprophylaxis, sepsis management and pneumonia and kidney injury care bundles may have contributed to the reduction in mortality.

HSMR, hospital standardised mortality ratio; SHMI, summary hospital-level mortality indicator.

Contributors The concept of the potential association between medicine bed occupancy and mortality and the 95% target was conceived by DGB (Emergency Medicine Consultant). Other contributions have been made, in alphabetical order, by AA (Workstream Four—facilitating ward discharge in the Acute Trust), TH (Workstream Two Lead—Medical Assessment Unit), SJM (Divisional Director for Medicine and winter planning team member), NR (Head of Operations—coordinated winter planning), MSR (Emergency Medicine Consultant—Cardiac arrest data), KS (Emergency Medicine Trainee—Cardiac arrest data), YS (Statistician), AT (Trust Mortality data) and CIW (Respiratory Consultant and Workstream Three Lead—coordinating uniformed working on medical base wards). DGB is the nominated guarantor of the article.

Competing interests None declared.

Provenance and peer review Not commissioned; externally peer reviewed.

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Lowering levels of bed occupancy is associated with decreased inhospital mortality and improved performance on the 4-hour target in a UK District General Hospital

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Emerg Med J 2016 33: 85-90 originally published online September 17, 2015
doi: 10.1136/emermed-2014-204479