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Association between delays to patient admission from the emergency department and all-cause 30-day mortality

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ABSTRACT

Background Delays to timely admission from emergency departments (EDs) are known to harm patients.
Objective To assess and quantify the increased risk of death resulting from delays to inpatient admission from EDs, using Hospital Episode Statistics and Office of National Statistics data in England.
Methods A cross-sectional, retrospective observational study was carried out of patients admitted from every type 1 (major) ED in England between April 2016 and March 2018. The primary outcome was death from all causes within 30 days of admission. Observed mortality was compared with expected mortality, as calculated using a logistic regression model to adjust for sex, age, deprivation, comorbidities, hour of day, month, previous ED attendances/emergency admissions and crowding in the department at the time of the attendance.
Results Between April 2016 and March 2018, 26 738 514 people attended an ED, with 7 472 480 patients admitted relating to 5 249 891 individual patients, who constituted the study's dataset. A total of 433 962 deaths occurred within 30 days. The overall crude 30-day mortality rate was 8.71% (95% CI 8.69% to 8.74%). A statistically significant linear increase in mortality was found from 5 hours after time of arrival at the ED up to 12 hours (when accurate data collection ceased) ($p<0.001$). The greatest change in the 30-day standardised mortality ratio was an 8% increase, occurring in the patient cohort that waited in the ED for more than 6 to 8 hours from the time of arrival.
Conclusions Delays to hospital inpatient admission for patients in excess of 5 hours from time of arrival at the ED are associated with an increase in all-cause 30-day mortality. Between 5 and 12 hours, delays cause a predictable dose–response effect. For every 82 admitted patients whose time to inpatient bed transfer is delayed beyond 6 to 8 hours from time of arrival at the ED, there is one extra death.

Key messages

What is already known on this subject

⇒ Small studies from Canada and Australia have indicated that there is an increased mortality rate among patients who experience delays in admission to an inpatient bed from the emergency department (ED).
⇒ Counterfactual modelling has shown reduced patient mortality as a result of the NHS 4-hour operational standard. The NHS Benchmarking Network found a coefficient of determination (R^2 value) of 0.07 between time greater than 4 hours in the ED and a hospital's Summary Hospital-level Mortality Indicator.

What this study adds

⇒ This study of over five million NHS patients shows an increase in all-cause 30-day mortality that is independently associated with delays to hospital admission from the ED rather than with crowding alone.
⇒ The standardised mortality rate starts to rise from 5 hours after the patient's time of arrival at the ED.
⇒ The increasing effect of long stays in the ED before inpatient admission can be measured and represented as a number needed to harm metric: after 6–8 hours, there is one extra death for every 82 patients delayed.

INTRODUCTION

In England, by the end of the 20th century, demographic changes and reduced numbers of acute hospital beds had resulted in crowded emergency departments (EDs) and long delays for patients. In consequence, the NHS 4-hour operational standard was introduced in 2004 and shortly thereafter, the other nations of the UK and several other countries, such as Canada and Australia, introduced similar standards for ED waiting times.[1–5] (The 4-hour standard is a binary time threshold for discharge, admission or transfer; it starts when the patient arrives at the ED, and time in the ED beyond 4 hours is a 'breach' of the 'target'.)

For more than a decade, the 4-hour standard served both patients and the NHS well but, during the past few years, further increases in the demand for urgent and emergency care have exacerbated long waits for hospital admission.[6] By 2019–2020, over 3.2% of all ED patients waited in the ED for more than 12 hours from their time of arrival.[7] Long ED delays are most often caused by 'exit block' due to a lack of available inpatient beds. This was demonstrated using data collected from all English EDs over a 90-day period by an NHS economics team. They showed that higher inpatient bed occupancy was correlated with longer ED waiting times, but with a non-linear association.[8]

Delay-related harm in the ED was previously reported by Guttmann *et al* in Canada in 2011.[9] However, their study had a case mix that was substantially different from that of the UK, as the proportion of admitted patients was only 10% of the total, compared with a current NHS average of around 30%. Another smaller study that demonstrated harm both from presentations to a crowded department and longer durations of stay in the ED was confined to admissions at just three hospitals in Australia.[10] A further paper from China in 2019 showed that prolonged length of stay in the ED was independently associated with an increased risk of hospital mortality in patients with sepsis requiring admission to an intensive care unit.[11]

In England, the harm caused by long stays in the ED was modelled by the National Bureau of Economic Research and the Institute of Fiscal Studies in 2018. The researchers asked the counterfactual question of what would have happened if the 4-hour NHS operational standard had not existed between 2011 and 2013. They found that 30-day patient mortality was reduced by 0.4% (or 14% of baseline) as a result of the ED 4-hour standard.[12] The NHS Benchmarking Network looked at data for 2019–2020 and found a coefficient of determination (R^2 value) of 0.07 between ED stays of 4 hours or longer and the Summary Hospital-level Mortality Indicator for a hospital. This suggests that time in ED would explain 7% of the variation in mortality between sites.[13]

This study aimed to use a large NHS database to confirm or disprove an increased risk of death in patients with increasing lengths of stay in the ED before hospital admission and to quantify any such harm that was found to exist.

METHODS

Study design

This was a cross-sectional, comparative, retrospective, observational study of all patients admitted from all type 1 EDs in England between April 2016 and March 2018. (Type 1 EDs are major NHS departments that are open 24 hours a day under the supervision of consultants in emergency medicine.)

Only a patient's first admission in the study period was included because it was considered that there were too many confounders with multiple attendances. Patients attending more than once are known to have poorer outcomes and their inclusion would have increased the overall mortality rates. In addition, to compensate for these factors, a more complicated multilevel logistic regression model would have been required. Patients who waited in the ED for longer than 12 hours were also excluded from the mortality analysis as temporal data were found to be unreliable after this point and the numbers were relatively small.

All times were measured from the patient's arrival at the ED until their transfer to an inpatient bed. NHS data did not allow us to differentiate between treatment time in the ED and non-value-added time while waiting for imaging, a specialist opinion or an available bed on a hospital ward. Thus, the study investigated longer lengths of ED stay, which were often multifactorial in origin. The primary outcome was death from all causes within 30 days of hospital admission.

Patient and public involvement

We received valuable encouragement from the lay group of the Royal College of Emergency Medicine to undertake this research, although the group had no direct involvement or responsibility for our methods and findings.

Box 1 Further information about data handling, inclusion criteria and incomplete records

Hospital Episode Statistics data and Office of National Statistics (ONS) mortality data were linked by NHS Digital before release and provided in tables coupled by a pseudonymised, unique patient identifier. Patient admission data were included when the date of admission, patient identifier, primary diagnosis and admission code were all present. Where patients had multiple emergency department (ED) attendances in a single day, the final attendance of the day was counted. ED data were included when both arrival date and arrival time were recorded. The dataset for use was created by linking admissions to ED presentations by means of the unique patient identifier. ED presentations were linked to the admission when they occurred on the same day as the admission or on the day before. All admissions without a corresponding ED presentation were removed. Thus, during this process, all admissions via the ED were linked to a valid ED presentation in the data, and all admissions had a valid diagnosis and patient identifier. Mortality data from the ONS were then linked to the admission via the patient identifier and the date of death.

Patients with data that could be processed comprised an essential part of the selection criteria for the study. It was of course, impossible not to exclude patients with incomplete or missing admission data or records that could not be matched. The incompleteness and inaccuracy of many records—and the prior cleansing undertaken by NHS Digital—makes an exact estimate of their number very difficult.

At a later stage, 4714 (0.09%) patients out of a total of 5 254 605 individual patients were excluded because of the lack of the key variables of age or gender.

Data sources

This study employed NHS England's Hospital Episode Statistics record of ED attendances (HES AE) linked to the Hospital Episode Statistics admitted patient care record (HES APC) and Office of National Statistics (ONS) population mortality data. HES data include information on a range of clinical, demographic, administrative and geographical variables.[7] The 30-day mortality data were identified by linking HES data to the ONS primary care mortality data file.[14 15] This latter dataset contains details relating to a person's death, including date and cause of death taken from the death certificate. Published reports on HES data quality and the percentage of data linkage show that these data, although incomplete, cover most admissions and 30-day mortality.[16] HES data are supplied already 'cleansed' from their primary source—namely, the Secondary Uses Service secure data warehouse of NHS Digital. Further information about data handing and about the completeness of the data fields used in this study is provided in Box 1.

Statistical analysis

To minimise selection bias for time in the ED (ie, older or sicker patients waiting longer because they take more time to treat), a logistic regression model was used to predict 30-day mortality. Variables included in the model were referenced to patient characteristics, time of attendance and the level of ED crowding. The percentage of 4-hour breaches in the department at the time of the patient's attendance was used as a proxy for ED crowding.

Specifically, the model accounted for:

Table 1 Demographic characteristics of admitted patients and time of arrival at the emergency department

Patient characteristics	Mean	Median (IQR)
Previous emergency admissions	0.94	1 (0–2)
Previous ED attendances	2.22	2 (1–3)
Elixhauser Comorbidity Index (vWs)	2.76	0.5 (0–5)
Age (years)	50.27	55 (25–75)
Time in ED (min)	291	234 (185–342)
Four-hour breach rate in ED at the patient's time of arrival	38%	37% (18%–56%)
	Number	**Percentage**
Male	2 524 541	48%
Female	2 725 350	52%
	Number	**Percentage**
Deprivation decile		
0 (deprivation unknown)	52 384	1%
1 (least deprived)	369 831	7%
2	448 792	9%
3	461 779	9%
4	478 846	9%
5	502 621	10%
6	523 041	10%
7	545 037	10%
8	576 244	11%
9	614 493	12%
10 (most deprived)	676 823	13%
Hour of attendance		
00:00-05:59	611 073	12%
06:00-11:59	1 268 524	24%
12:00-17:59	1 898 281	36%
18:00-23:59	1 472 013	28%
Month of attendance		
January to March	1 485 052	28%
April to June	1 158 860	22%
July to September	1 226 749	23%
October to December	1 379 230	26%
Year of attendance		
2016	1 654 846	32%
2017	2 700 055	51%
2018	894 990	17%

Total number of patients = 5 249 891.
Of a total of 5 254 605 individual patients, 4714 (0.09% of patients) were excluded at this stage because of missing age or gender.
ED, emergency department; vW, summary score developed by van Walraven.[18]

Table 2 Logistic regression model used to predict 30-day mortality

Variable	Number	OR (95% CI)	P value
Previous emergency admissions	5 249 891	1.03 (1.03 to 1.04)	<0.001
Previous emergency admissions^2	5 249 891	1.01 (1.01 to 1.01)	<0.001
Previous ED attendances	5 249 891	1.19 (1.18 to 1.20)	<0.001
Previous ED attendances^2	5 249 891	0.98 (0.98 to 0.98)	<0.001
Elixhauser Comorbidity Index - vWs	5 249 891	1.10 (1.10 to 1.10)	<0.001
Elixhauser Comorbidity Index - vWs^2	5 249 891	1.00 (1.00 to 1.00)	<0.001
Age	5 249 891	1.08 (1.08 to 1.08)	<0.001
Age^2	5 249 891	1.00 (1.00 to 1.00)	<0.001
Four-hour breach rate in ED	5 249 891	1.35 (1.33 to 1.37)	<0.001
Male	2 524 541	Reference	
Female	2 725 350	0.82 (0.81 to 0.82)	<0.001
Deprivation decile			
0 (deprivation unknown)*	52 384	1.06 (1.01 to 1.10)	<0.001
1 (least deprived)	369 831	Reference	
2	448 792	1.04 (1.03 to 1.06)	<0.001
3	461 779	1.09 (1.07 to 1.11)	<0.001
4	478 846	1.12 (1.10 to 1.13)	<0.001
5	502 621	1.13 (1.11 to 1.14)	<0.001
6	523 041	1.15 (1.14 to 1.17)	<0.001
7	545 037	1.20 (1.18 to 1.22)	<0.001
8	576 244	1.23 (1.21 to 1.25)	<0.001
9	614 493	1.27 (1.25 to 1.29)	<0.001
10 (most deprived)	676 823	1.32 (1.30 to 1.34)	<0.001
Hour of attendance			
00:00-05:59	611 073	Reference	
06:00-11:59	1 268 524	0.99 (0.98 to 1.00)	0.075
12:00-17:59	1 898 281	1.01 (1.00 to 1.02)	<0.001
18:00-23:59	1 472 013	0.98 (0.96 to 0.99)	<0.001
Month of attendance			
January to March	1 485 052	Reference	
April to June	1 158 860	0.74 (0.73 to 0.75)	<0.001
July to September	1 226 749	0.63 (0.62 to 0.64)	<0.001
October to December	1 379 230	0.63 (0.63 to 0.64)	<0.001
Year of attendance			
2016	1 654 846	Reference	
2017	2 700 055	0.60 (0.60 to 0.61)	<0.001
2018	894 990	0.27 (0.27 to 0.28)	<0.001
ROC curve statistic=0.862			

Total number of patients = 5 249 891.
^{2}Denotes the use of quadratic terms (ie, the squares of the metrics) that were used in order to account for potential non-linearities in these continuous variables.
*Unknown deprivation includes missing data, overseas visitors, people with no permanent address and those with a new address that had not yet been classified.
ED, emergency department; ROC=receiver operating characteristic; vW, summary score developed by van Walraven.[18]

- Patient characteristics: age, sex, deprivation (using Indices of Multiple Deprivation) and comorbidities (using van Walraven scoring (vWs) for Elixhauser Comorbidity Indices).[17 18] (Comorbidities are a measure of disease complexity but not of patient acuity.)
- Temporal and ED factors: month of any previous ED attendances or emergency admission(s), the time of attendance and level of congestion in the ED at the time of the index attendance.

Time spent in the ED was divided into 15-minute aliquots. To account for potential non-linearities in the continuous variables, quadratic terms (ie, the squares of these numbers) were used. (This is denoted by the superscript following four of the variables in table 2.) To estimate an indirectly standardised mortality rate (SMR) referenced to delay times, the observed number of deaths was summed and then divided by the expected number of deaths. Poisson confidence intervals were determined for the SMR. The SMR was plotted against time in the ED to enable visual inspection of the results and to estimate a p value by fitting a linear model to the graph. An adjusted mortality rate was also calculated by multiplying the SMR by the overall crude mortality rate.

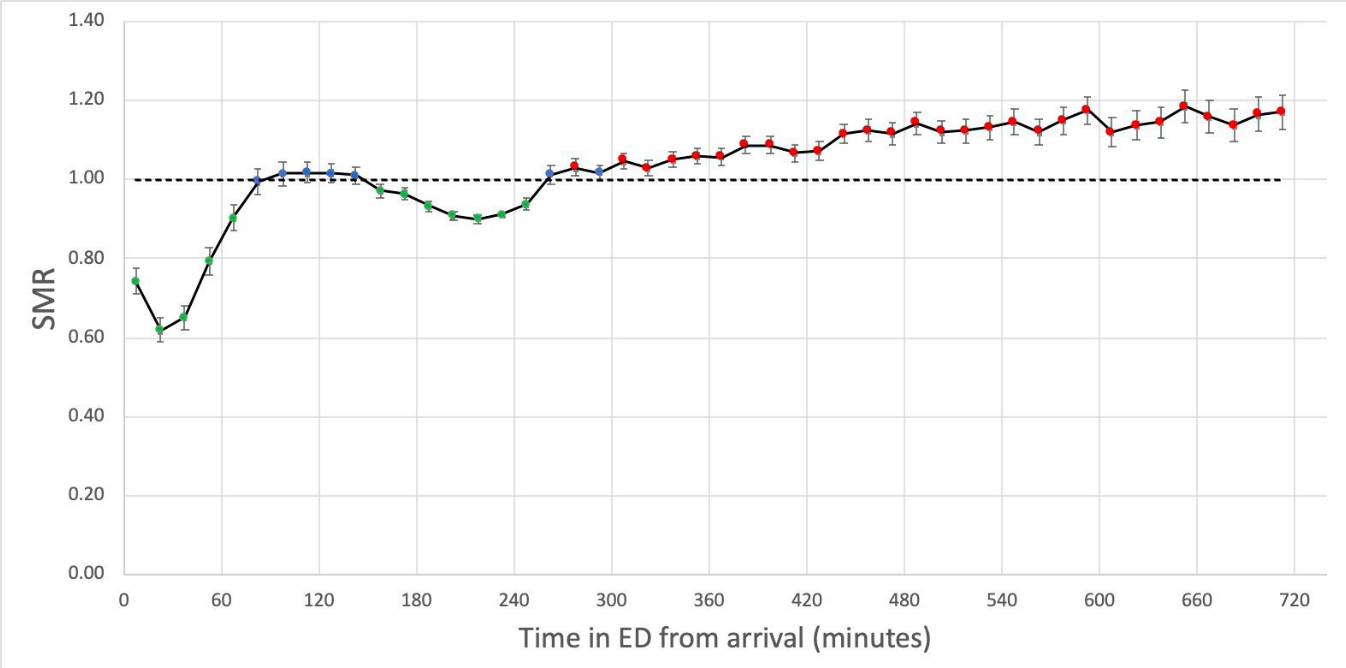

Figure 1 Thirty-day standardised mortality ratio (SMR) referenced to duration in an emergency department (ED) from time of arrival.

RESULTS

Between April 2016 and March 2018, there were 26 738 514 attendances in English type 1 EDs with 7 472 480 matched admissions. Around 30% of ED admissions were patients who had been admitted on at least one other occasion in the previous 2 years; only the first attendance was included in the analysis. This left 5 254 605 individual patients, over 3% of whom waited for more than 12 hours. A further 4714 patients (0.09%) were later excluded owing to missing age and gender data, leaving 5 249 891 patients for inclusion in the logistic regression model.

In this group of admitted patients, there were 433 962 deaths within 30 days. The overall crude 30-day mortality rate was 8.71% (95% CI 8.69% to 8.74%). Table 1 shows the demographic breakdown of admitted patients. The median age of patients admitted to hospital from the ED was 55 years; their comorbidities increased in number with age. Over 1.8 times as many patients were from the highest decile of deprivation as from the least deprived decile. The most frequent time of arrival was between 12:00 and 17:59, with the first 3 months of the year accounting for the biggest proportion of patients. The mean time that a patient spent in the ED was just under 5 hours and 4-hour breach rates in EDs at the patient's time of arrival averaged around 38%.

Table 2 shows the logistic regression model used to estimate the indirectly standardised mortality rate. The risk of death is seen to increase with the number of previous emergency attendances and admissions, Elixhauser Comorbidity Index (vWs) and age. In addition, the likelihood of dying rises with both male sex and increasing deprivation. Patients admitted between April and December had a lower mortality rate than those admitted between January and March. The variable with the largest OR was the 4-hour breach rate, used here to approximate the level of crowding in the ED at the time of the patient's arrival. The area under the receiver operating characteristic curve for this model was 0.862.

Figure 1 shows the SMR for all-cause 30-day deaths plotted against duration in the ED from time of arrival. It demonstrates an increased SMR for patients admitted to hospital after 5 hours. The SMR increases in an approximately linear fashion from this point until accurate data are unavailable after 12 hours. If a linear model is applied to the data between 240 and 720 minutes, then the SMR is found to increase by about 0.008 (95% CI 0.003 to 0.013) points per minute ($p<0.001$).

The SMR can also be represented as a number needed to harm in order to clarify the magnitude of effect (table 3).

DISCUSSION

The results from this study show that there is a 'dose-dependent' association between time in excess of 5 hours in the ED for

Table 3 Effect on mortality of increasing time from patient arrival to inpatient bed transfer as shown by the standardised mortality ratio and number needed to harm

Hours in the ED	SMR	Percentage change in the SMR	95% lower confidence limit for the SMR	95% upper confidence limit for the SMR	Adjusted absolute mortality rate	Number needed to harm (30-day mortality)
Up to 4 hours	0.94	–6%	0.92	0.95	8.2%	–191
4–6 hours	1.06	6%	1.04	1.08	9.2%	191
6–8 hours	1.14	14%	1.11	1.18	9.9%	82
8–12 hours	1.16	16%	1.12	1.21	10.1%	72

ED, emergency department; vW, summary score developed by van Walraven.[18]

admitted patients and their all-cause 30-day mortality. The data indicate a 10% increase in the SMR within 30 days for admitted patients remaining in the ED between 8 and 12 hours in comparison with those who leave the ED within 6 hours. Moreover, 30-day mortality is a relatively crude metric that does not account for either increases in patient morbidity or for the inevitably worse patient experiences.[19]

ED time targets are popular with patients and politicians alike.[20] This study showed that an increasing 4-hour breach rate in the ED is a strong predictor of higher 30-day mortality. The NHS 4-hour operational standard thus appears to have succeeded in preventing avoidable delay-related patient harm in hospitals where it has been achieved while also reducing additional morbidity and poor patient experiences.

Despite limited supporting evidence,[9–13] there are a number of clinically plausible reasons to accept that there is a temporal association between delayed admission to a hospital inpatient bed and poorer patient outcomes, including:

- Long lengths of stay in the ED are associated with exit block and crowding, which has been shown to increase time to analgesia, time to antibiotics and time to other vital treatments.[21] However, our study attempted to adjust for ED crowding and to investigate an association with delays to hospital admission alone.
- Lack of ED space leads to mitigation processes with patients accommodated in suboptimal areas that make it more difficult for close observation and for the delivery of good care.[22]
- Long periods in the ED usually reduce temporospatial clues (eg, patient unable to see the external environment) with consequent increases in disorientation and precipitation or exacerbation of delirium, especially in elderly patients.[23]
- Long waits in the ED, especially for elderly patients, are correlated with an increase in subsequent hospital length of stay. This, in turn, increases the risk of hospital-acquired infection, iatrogenic harm and physiological and psychological deconditioning.[24]
- Delayed admission (exit block) from the ED is usually related to bed occupancy levels, which are highest in the late afternoon and usually lower around midnight. Thus, a disproportionate number of delayed patients are moved to a ward during night hours when staffing levels are at their lowest.[25]

The methodology in this study attempted to adjust for a wide range of relevant confounding variables, including the ED 4-hour breach rate (at the time of the patient's arrival at hospital) as an imperfect proxy for ED crowding. Selected variables were those that are obtainable from HES and that are potential confounders. However, the reliability of some of the data (such as patient comorbidities) is not sufficiently good to be sure that all variables were completely accounted for by our logistic regression model. Moreover, there might be other confounding variables that are not obtainable from HES. Further limitations include the effect of missing data and of patients removed before the mortality analysis, especially those with multiple attendances and delays longer than 12 hours. Physiological metrics are lacking and thus no estimation can be made of varying patient acuity; staffing and bed occupancy data were also unavailable. Finally, this study was unable to differentiate between the various causes of non-value-added time in the ED. Such delays for patients may have included long ED processing and decision-making times, waiting for investigations or specialist opinions and lack of availability of a suitable inpatient bed.

Future research could examine multiple attendances and non-admitted patients and attempt to address some of the limitations detailed above. Although these limitations could obviously be overcome by a prospective randomised controlled trial, this would never be ethically acceptable. Instead, we believe that future researchers could use the approach of Arpino and Cannas to propensity score matching to develop a causation model of the effect of ED delays on patient outcomes.[26]

CONCLUSIONS

Time in the ED for an individual patient requiring hospital admission should be of therapeutic benefit. Delays to inpatient admission from any cause are of no value to the patient and may also impede timely care for new ED arrivals. This study demonstrates a time-associated linear increase in all-cause 30-day mortality for patients who remain in the ED for more than 5 hours from their time of arrival. One extra death occurs for every 82 patients who are delayed for more than 6 to 8 hours. This study confirms that healthcare policy makers should continue to mandate timely admission from the ED in order to protect patients from hospital-associated harm.

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Contributors This study was conceived by SB, SS and PM, following conversations with CMo and CMa. RO and NM undertook data preparation and SJ led the statistical analysis with support from RO and PM. CMo and CMa informed study design, supported interpretation and assessed the likely clinical impact. CMo and SJ drafted the paper. All authors contributed their time free of charge; no funding was provided. SJ is the guarantor of this study.

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Competing interests All authors have completed the Unified Competing Interest form (available on request from the corresponding author). The authors who work for Methods Analytics declare the paragraph given below: Methods Analytics has undertaken work previously on behalf of NHS England, NHS Improvement, CCGs, trusts and local authorities investigating apparent issues with mortality rates as well as analysis pertaining to service redesign within emergency and urgent care settings. Methods Analytics have also undertaken analytical work for NHS England's "Getting It Right First Time" programme (GIRFT) to develop the emergency medicine provider level data pack, which includes metrics concerning hospital mortality.

Patient consent for publication Not applicable.

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Data availability statement All data relevant to the study are included in the article or uploaded as supplementary information. The study involved secondary analysis of an existing data set of anonymised data. HES data were made available by NHS Digital (©2018, reused with the permission of NHS Digital. All rights reserved). Publicly-available ONS data were also used.

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REFERENCES

1 Department of Health. *The NHS plan*. London: HMSO, 2000. http://www.dh.gov.uk/en/Publicationsandstatistics/Publications/PublicationsPolicyAndGuidance/DH_4002960
2 Department of Health. *Clinical exceptions to the four-hour emergency care target*. London: DH, 2003. https://webarchive.nationalarchives.gov.uk/20120106101107/http:/www.dh.gov.uk/prod_consum_dh/groups/dh_digitalassets/@dh/@en/documen

3 Department of Health. *Revision to the operating framework for the NHS in England 2010/11*. London: HMSO, 2010. http://data.parliament.uk/DepositedPapers/Files/DEP2010-1328/DEP2010-1328.pdf
4 Welsh Assembly Government. *Designed for life: creating world class health and social care for Wales in the 21st century*. Cardiff: Department of Health and Social Care, 2005. https://www.wales.nhs.uk/documents/designed-for-life-e.pdf
5 Northern Ireland Audit Office. *Transforming emergency care in Northern Ireland*. Belfast: NIAO, 2008. https://www.niauditoffice.gov.uk/publications/transforming-emergency-care-northern-ireland
6 Blunt I. *Focus on: A&E attendances (Research report*. London: Nuffield Trust, 2014. https://www.nuffieldtrust.org.uk/research/focus-on-a-e-attendances
7 NHS Digital. *Hospital episode statistics data dictionary*. NHSD, 2020. https://digital.nhs.uk/data-and-information/data-tools-and-services/data-services/hospital-episode-statistics
8 Paling S, Lambert J, Clouting J, *et al*. Waiting times in emergency departments: exploring the factors associated with longer patient waits for emergency care in England using routinely collected daily data. *Emerg Med J* 2020;37:781–6.
9 Guttmann A, Schull MJ, Vermeulen MJ, *et al*. Association between waiting times and short term mortality and hospital admission after departure from emergency department: population based cohort study from Ontario, Canada. *BMJ* 2011;342:d2983.
10 Sprivulis PC, Da Silva J-A, Jacobs IG, *et al*. The association between hospital overcrowding and mortality among patients admitted via Western Australian emergency departments. *Med J Aust* 2006;184:208–12.
11 Zhang Z, Bokhari F, Guo Y, *et al*. Prolonged length of stay in the emergency department and increased risk of hospital mortality in patients with sepsis requiring ICU admission. *Emerg Med J* 2019;36:82–8.
12 Gruber J, Hoe TP, Stoye G. *Saving lives by tying hands: the unexpected effects of constraining health care providers*. National Bureau of Economic Research and Institute of Fiscal Studies, 2018. http://www.nber.org/papers/w24445
13 NHS Benchmarking Network. *Acute Hospital bed stock analysis: a review of bed numbers and hospital KPIs between 2010/11 and 2019/20*. Manchester: NHSBN, 2021.
14 NHS Digital. *Primary care mortality database*. NHSD, 2018. https://digital.nhs.uk/services/primary-care-mortality-database
15 NHS Digital. *Linked HES-ONS mortality data*. NHSD, 2020. https://digital.nhs.uk/data-and-information/data-tools-and-services/dataservices/linked-hes-ons-mortality-data
16 NHS Digital. *The processing cycle and HES data quality*. NHSD, 2019. https://digital.nhs.uk/data-and-information/data-tools-and-services/data-services/hospital-episode-statistics/the-processing-cycle-and-hes-data-quality
17 Office of National Statistics. *English indices of deprivation*. ONS, 2015. https://www.gov.uk/government/statistics/english-indices-of-deprivation-2015
18 van Walraven C, Austin PC, Jennings A, *et al*. A modification of the Elixhauser comorbidity measures into a point system for hospital death using administrative data. *Med Care* 2009;47:626–33.
19 Pines JM, Iyer S, Disbot M, *et al*. The effect of emergency department crowding on patient satisfaction for admitted patients. *Acad Emerg Med* 2008;15:825–31.
20 Healthwatch. *People's views on A&E waiting times*, 2019. https://www.healthwatch.co.uk/report/2019-03-11/peoples-views-ae-waiting-times
21 Fee C, Weber EJ, Maak CA, *et al*. Effect of emergency department crowding on time to antibiotics in patients admitted with community-acquired pneumonia. *Ann Emerg Med* 2007;50:501–9.
22 Moskop JC, Sklar DP, Geiderman JM, *et al*. Emergency department crowding, part 1--concept, causes, and moral consequences. *Ann Emerg Med* 2009;53:605–11.
23 Bauernfreund Y, Butler M, Ragavan S, *et al*. Time to think about delirium: improving detection and management on the acute medical unit. *BMJ Open Qual* 2018;7:e000200.
24 Rutberg H, Borgstedt Risberg M, Sjödahl R, *et al*. Characterisations of adverse events detected in a university hospital: a 4-year study using the global trigger tool method. *BMJ Open* 2014;4:e004879.
25 Ewbank L, Thompson J, McKenna H. *NHS Hospital bed numbers: past, present, future*. London: The King's Fund, 2020. https://www.kingsfund.org.uk/publications/nhs-hospital-bed-numbers
26 Arpino B, Cannas M. Propensity score matching with clustered data. An application to the estimation of the impact of caesarean section on the Apgar score. *Stat Med* 2016;35:2074–91.