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Variation in quality of acute stroke care by day and time of admission: prospective cohort study of weekday and weekend centralised hyperacute stroke unit care and non-centralised services

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3 TITLE: Variation in quality of acute stroke care by day and time of admission: prospective cohort
4 study of weekday and weekend centralised hyperacute stroke unit care and non-centralised
5 services
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ABSTRACT

Objective: To investigate variations in quality of acute stroke care and outcomes by day and time of admission in London hyperacute stroke units compared with the rest of England.

Design: Prospective cohort study using anonymised patient-level data from the Sentinel Stroke National Audit Programme.

Setting: Acute stroke services in London hyperacute stroke units compared with the rest of England.

Participants: 68 239 patients with a primary diagnosis of stroke admitted between January and December 2014.

Interventions: Hub-and-spoke model for care of suspected acute stroke patients in London with performance standards designed to deliver uniform access to high-quality hyperacute stroke unit care across the week.

Main outcome measures: 16 indicators of quality of acute stroke care, mortality at three days after admission, disability at the end of the inpatient spell, length of stay.

Results: There was no variation in quality of care by day and time of admission across the week in terms of stroke nursing assessment, brain scanning, and thrombolysis in London hyperacute stroke units, nor was there variation in three-day mortality or disability at hospital discharge (all p-values>0.05). Other quality of care measures significantly varied by day and time of admission across the week in London (all p-values<0.01). In the rest of England there was variation in all measures by day and time of admission across the week (all p-values<0.01), except for mortality at three days (p-value>0.05).

Conclusions:

The London hyperacute stroke unit model achieved performance standards for “front door” stroke care across the week. The same benefits were not achieved by other models of care in the rest of England. There was no weekend effect for mortality in London or the rest of the

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3 England. Other aspects of care were not constant across the week in London hyperacute stroke
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5 units, indicating some performance standards were perceived to be more important than others.
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7 ***Strengths and limitations of this study***

- 9 • The main strength of our study is the large national dataset we have used containing
10 detailed information on quality of care, outcomes, and patient characteristics.
 - 11 • We have examined whether time of admission was related to quality of care using a
12 comprehensive set of indicators from across the acute stroke care pathway.
 - 13 • The rich set of patient characteristics in the dataset meant we could control for patient
14 factors likely to affect quality of care and outcomes that vary by day and time of
15 admission across the week and between London and the rest of England.
 - 16 • One limitation of our study is that, while case ascertainment in SSNAP was 90% during
17 the time period of our study, these data might not be representative of all stroke patients.
18 Also, in SSNAP data are inputted voluntarily by hospitals and we cannot exclude the
19 possibility of inaccurate or selective reporting.
 - 20 • Another limitation is that we were unable to measure long-term outcomes as these were
21 not available in SSNAP.
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INTRODUCTION

There is conflicting evidence as to whether or not patients presenting with acute stroke symptoms receive lower quality of care and have worse outcomes if admitted to hospital outside of normal weekday working hours or at weekends (the “weekend effect”). Some studies have shown that acute stroke patients admitted at weekends have lower quality of care[1,2] and higher mortality[1–10], while others have shown the opposite[11–14]. Evaluation of these studies is further complicated by recent evidence that stroke incidence reporting at the weekend may be unreliable in older studies[15]. Recent work based upon data from the Stroke Sentinel National Audit Programme (SSNAP) dataset further shows that care quality and outcomes in acute stroke vary across the week, and concluded that binary comparisons of weekend versus weekday or in-hours versus out-of-hours processes and effects oversimplify more likely variations by day of week and time of day [16]. Further, no studies have investigated the impact of time of admission on disability following a stroke.

If there is lower quality of care and there are worse outcomes at the weekend these could be linked to reduced staffing levels[17]; for acute stroke care, nurse staffing levels at weekends has been shown to be a significant predictor of mortality[18], while evidence from the United States suggests that specialised stroke units, with round-the-clock availability of specialist stroke teams and rapid access to imaging and thrombolysis, reduce variation in quality of care and outcomes across the week[19–21].

In 2010 London centralised its acute stroke services using a hub-and-spoke network model [22] [23,24]. Out of 34 hospitals that had historically provided acute stroke care [25], 8 were selected as host sites for Hyperacute Stroke Units (HASUs). The HASU model involved the London Ambulance Service taking all patients with suspected stroke symptom onset within 48 hours to one of the eight HASUs[26]. HASUs receive patients with suspected stroke and routinely provide immediate assessment by specialised stroke assessment teams, access to immediate brain imaging, and the immediate delivery of intravenous thrombolysis where appropriate. Acute

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3 stroke patients seen at other medical facilities were similarly transferred as an emergency to a
4 HASU. The aim of the HASUs was to provide specialised care for all acute stroke patients
5 during the first 72 hours after onset of stroke. After 72 hours, patients requiring ongoing
6 inpatient treatment are transferred to one of the twenty-four Acute Stroke Units in London linked
7 to HASUs. Eight of these were in the same hospital trust as a HASU[27].

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13 Performance standards for HASUs, linked to payments, were initially set by Healthcare for
14 London[30] and subsequently the London Strategic Clinical Networks to maintain high quality of
15 care across the HASU stay. Some standards were set to provide rapid access to time-critical
16 “front door” measures, e.g., dysphagia screen within four hours of admission, brain scans within
17 one hour, administration of thrombolysis to eligible patients[26] within 60 minutes). Other
18 standards were set with less stringent time constraints (e.g., stroke specialist consultant
19 physician assessment within 24 hours, physiotherapist assessment within 72 hours).

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28 On average across all patients, the quality of acute stroke care in London increased as a result
29 of the centralisation and was significantly higher than elsewhere in England on all measures
30 analysed [28], and mortality decreased[29]. Following these findings, the aim of this study was
31 to investigate variations in the quality of acute stroke care and outcomes by day and time of
32 admission in London HASUs and the rest of England. We used national audit data for all
33 patients in England who had a stroke during a 12-month period recorded by the Sentinel Stroke
34 National Audit Programme (SSNAP)[31]. We hypothesised were that there would be less
35 variation across the week in care quality measures in London HASUs compared with the rest of
36 England, and that this would also translate into less variation in outcomes in London HASUs.

52 53 **METHODS**

Data and measures

We obtained anonymised patient-level data from the Sentinel Stroke National Clinical Audit Programme (SSNAP)[31], for all patients in England with a primary diagnosis of stroke (ischaemic stroke or primary intracerebral haemorrhage) between 1 January and 31 December 2014. SSNAP collects data on clinical characteristics, care quality (from the time of admission up to 6 months after stroke) and outcomes for all stroke patients admitted to acute care hospitals in England[32–34]. During our study period the case ascertainment in the SSNAP, which is calculated as the proportion of all acute stroke patients admitted to hospitals, for England was estimated to be 90%. We excluded patients treated at hospitals in Wales from our analysis because for Wales the case ascertainment was estimated to be 60%[33].

The following quality of care indicators were measured from time of hospital admission (or onset of stroke symptoms for those who were already in hospital): brain scan within one hour and within 12 hours; dysphagia screen within four hours; assessment by a nurse trained in stroke management within 24 hours; administration of intravenous thrombolysis to eligible patients; door-to-needle time within one hour in patients receiving thrombolysis; assessment by a stroke specialist consultant physician within 12 hours* and within 24 hours; admission to a stroke unit within four hours; assessments by a Physiotherapist, Occupational Therapist, and Speech and Language Therapist within 24 hours* and within 72 hours. These measures are quality indicators routinely reported by SSNAP; we also included measures (marked with a *) with more stringent time constraints to reflect the time-critical nature of acute stroke care. Outcomes were measured as whether or not the patient died within three days and disability using the modified Rankin Scale (mRS) score 0-2 versus 3-6 (moderate, moderately severe or severe disability or death) at the end of the inpatient stay. We also analysed mRS score 0-2 versus 3-5 at the end of the inpatient spell, excluding patients who died. Mortality data beyond hospital discharge were not available in SSNAP; we therefore measured mortality up to three days after admission

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3 to minimise the number of missed deaths. We analysed length of stay (LOS) in the HASU (in
4 London only) and length of stay in hospital. The denominators used for each measure were
5 consistent with the SSNAP key indicators[35]. Most outcomes were measured for all patients,
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7 but there were exceptions: patients who were medically unwell or refused to be screened were
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9 excluded from the dysphagia screen measure; only patients with ischaemic stroke who met the
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11 RCP guideline minimum threshold for thrombolysis were included in the thrombolysis rate; door-
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13 to-needle times included only those who received thrombolysis with a final diagnosis of stroke;
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15 patients who were persistently medically unwell, declined to be assessed or had no relevant
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17 deficit were excluded from the therapy performance measures.
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22 To examine variations across the week we initially used a flexible specification of time of
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24 admission, measured in six four-hour periods from 00:00 to 03:59, 04:00 to 07:59, 08:00 to
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26 11:59, 12:00 to 15:59, 16:00 to 19:59, 20:00 to 23:59 for every day of the week (42 periods). We
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28 also created a more restrictive measure to examine broad trends across the week: Monday to
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30 Friday 08:00 to 19:59; Monday to Friday 20:00 to 07.59; Saturday and Sunday 08:00 to 19:59;
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32 Saturday and Sunday 20:00 to 07.59(four periods) following Bray et al.[16] who found variations
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34 across the week with both specifications.
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39 **Statistical analysis**

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41 We ran patient-level logistic regressions, regressing each measure against time period of
42
43 admission. For LOS we used parametric survival models (modelled as time to event of
44
45 discharge) assuming a lognormal survival distribution. We ran separate models for London and
46
47 the rest of England. In every model we controlled for sex, age (continuous variable), ethnic
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49 group (six categories), type of stroke (infarction or primary intracerebral haemorrhage),
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51 comorbidities prior to admission (five options), mRS before stroke (0 to 2, 3 to 5), level of
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53 consciousness on arrival at the hospital (four categories), method of admission to the hospital
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55 (three categories), time from onset of stroke symptoms to admission (four categories), month of
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3 admission (12 categories), and hospital Trust. When analysing mRS scores 0-2 versus 3-5 at
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5 the end of the inpatient spell we additionally controlled for the number of days after admission at
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7 which the mRS score was measured. We were unable to do this for the analysis of mRS score
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9 0-2 versus 3-6 as date of death was not available. We tested for statistically significant
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11 variations across the week using Wald tests and reported the results as joint p-values under the
12
13 null hypothesis that the regression coefficients for every time period relative to the omitted time
14
15 period were zero. We calculated the average predicted probability of each outcome (predicted
16
17 median LOS in the case of the LOS variables) in each time period controlling for the covariates.
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19 Patients admitted with a diagnosis of acute stroke in London who were not treated in a HASU
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21 were excluded (6% all London patients in our dataset were not treated in a HASU). P-
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23 values < 0.05 were considered to be statistically significant. Data on National Institutes of Health
24
25 Stroke Scale (NIHSS) score, a validated measure of stroke severity on a scale from 0 (no stroke
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27 symptoms) to 42 (severe stroke), were available for 93% patients in London HASUs and 77%
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29 patients in the rest of England. Due to the extent of missing NIHSS data, in our main analysis
30
31 we controlled for stroke severity using level of consciousness on arrival at the hospital (one
32
33 component of NIHSS); we then reran all analyses controlling for NIHSS on arrival at the hospital
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35 on the smaller sample instead of level of consciousness on arrival. The findings using NIHSS
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37 score on arrival were qualitatively the same and are presented in the Data Supplement.
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43 **Patient and public involvement**

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45 Two stroke patient representatives contributed to our study protocol and research questions;
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47 they also contributed to discussions of interim findings presented at steering committee
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49 meetings in June 2015 and July 2016, raising issues related to variation in quality of care and
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51 mortality, which we incorporated into our analysis.
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53 **Results**

The study cohort comprised 68 239 patients (7094 from London HASUs, 61 145 from the rest of England) from 208 hospitals (eight London HASUs, 200 hospitals from the rest of England). The number of admissions varied across the week, with similar trends for London HASUs and the rest of England: there were more admissions during the day than at night; more admissions in the day during the week compared with during the day at the weekend; similar numbers of admissions during the night each day; and the highest number of admissions was during the day on Monday (Figure 1). In London HASUs the total number of admissions across all hospitals during the 12-month period ranged from 47-297 across the 42 time periods; in the rest of England it ranged from 398-2709. There was slightly higher proportion of men than women in London compared with the rest of England, the mean age was slightly lower, and patients were less likely to be white (all p-values<0.01; Table 1). There were also differences in the pattern of pre-existing comorbidities (all p-values<0.01), mRS before stroke (<0.01), level of consciousness on arrival at the hospital (<0.05), method of admission to the hospital (<0.01), and time from onset of stroke symptoms to admission (<0.01).

Table 1. Patient characteristics

	London HASUs (n=7094)	Rest of England (n=61 145)	P-value
Sex			<0.01
Male	3719 (52%)	30 536 (50%)	
Female	3375 (48%)	30 609 (50%)	
Age, years (mean (std.dev.))	72 (15)	75 (13)	<0.01
Ethnic group			<0.01
White	4332 (61%)	56 221 (92%)	
Mixed	72 (1%)	141 (<1%)	
Black	650 (9%)	1272 (2%)	

Asian	505 (7%)	362 (<1%)	
Other	526 (7%)	358 (<1%)	
Not available	1009 (14%)	2791 (5%)	
Type of stroke			0.06
Infarction	6252 (88%)	54 355 (89%)	
Primary Intracerebral Haemorrhage	842 (12%)	6790 (11%)	
Comorbidities prior to admission			
Congestive Heart Failure	439 (6%)	3204 (5%)	<0.01
Hypertension	4284 (60%)	32 447 (53%)	<0.01
Atrial fibrillation	1229 (17%)	12 655 (21%)	<0.01
Diabetes	1705 (24%)	12 024 (20%)	<0.01
Stroke/TIA	1688 (24%)	16 752 (27%)	<0.01
mRS score before stroke			<0.01
Slight or no disability (0-2)	5552 (78%)	49 574 (81%)	
At least moderate disability (3-5)	1542 (22%)	11 571 (19%)	
Level of consciousness on arrival at the hospital**			<0.05
Alert	5991 (84%)	51 230 (84%)	
Not alert; but respond to minor stimulation	663 (9%)	5724 (9%)	
Not alert; requires repeated stimulation	281 (4%)	2438 (4%)	
Unresponsive	159 (2%)	1753 (3%)	
NIHSS on arrival at the hospital, score (median (IQR))	5 (2-11)	4 (2-9)	
Method of admission to the hospital			<0.01
Already inpatient	173 (2%)	3288 (5%)	
Ambulance	5966 (84%)	47 096 (77%)	
Walk-in	955 (13%)	10 761 (18%)	

Time from onset of stroke symptoms to admission			<0.01
<180 minutes	2741 (39%)	24 233 (40%)	
180-359 minutes	759 (11%)	5871 (10%)	
≥360 minutes	1516 (21%)	10 773 (18%)	
Time of onset not known	2078 (29%)	20 268 (33%)	

Note. Figures are n (%) except for age, which is mean (std.dev.), and NIHSS on arrival at the hospital, which is median (IQR). mRS = modified Rankin Scale. IQR = interquartile range. The sample with NIHSS scores on arrival was n=6571 in London HASUs and n=47 126 in the rest of England. ** Level of consciousness scores taken from admission NIHSS score (Question 1a).

There was no significant variation in care quality across the 42 time periods in any of the measures relating to brain scanning, stroke nursing care and thrombolysis in London HASUs (all p-values>0.05), but there was significant variation in these measures in the rest of England (all p-values<0.01; Figure 2). For each measure in the rest of England there was variation by time of day every day, with the likelihood of receiving these interventions worse for patients admitted at night.

For all the other quality of care measures there was significant variation by time period of admission across the week both in London and the rest of England (all p-values <0.01). There were three patterns of variation (Table 2). (1) Variation by time of day but not day of the week was observed for assessment by a stroke specialist consultant physician within 12 hours and within 24 hours in London HASUs and admission to a stroke unit within four hours in London and the rest of England (Figure 3). With this pattern similar variations during the day were found each day of the week. (2) Variation by day of the week but not time of day was observed for assessments by a Physiotherapist, Occupational Therapist, and Speech and Language Therapist within 72 hours in London HASUs and the rest of England (Figure 4). With this pattern

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3 care quality was worse for patients admitted on Friday. (3) Variation by time of day and day of
4 the week was observed for assessment by a stroke specialist consultant physician within 12
5 hours and within 24 hours in the rest of England and for therapist assessments within 24 hours
6 in London HASUs and the rest of England (Figure 5). With this pattern, there was variation
7 during the day on Monday to Friday and care quality was worse at weekends.
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14 There was no significant variation in outcomes across the 42 time periods in London HASUs (all
15 p-values>0.05; Figure 6a). In the rest of England there was significant variation in disability
16 (both p-values<0.05, Figures 6b and 6c) but not mortality (p-value>0.05); mRS scores at the
17 end of the inpatient episode varied by time of admission on every day and were worse among
18 patients admitted at night.
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24 There was significant variation in LOS across the 42 time periods in London HASUs and the
25 rest of England both in terms of HASU LOS and total inpatient LOS (all p-values<0.05; Figure
26 7). Median HASU LOS in London varied between 2.6 and 3.6 days across the 42 time periods.
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28 It was difficult to detect a trend by day and time of admission in London HASU LOS and
29 inpatient LOS. In the rest of England median inpatient LOS was longer among those admitted at
30 night.
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37 Results using the four time period specification were broadly similar to those with the 42 time
38 periods, but pooling time periods meant that the extent of variation during the week for some of
39 the quality of care measures was reduced. In these analyses there was no significant variation
40 in London in quality of care measures linked to specialist stroke nurse assessments, rapid
41 access to brain scans and administration of thrombolysis to eligible patients for London HASUs,
42 nor was there in the outcome measures. With the exception of mortality at three days and mRS
43 scores 3-5 at the end of the inpatient spell, all of these measured varied significantly in the rest
44 of England. LOS varied significantly for London HASUs and the rest of England; for London
45 HASUs pooling time periods more clearly indicates longer LOS among patents admitted at the
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3 weekend; for the rest of England the trends were as in the 42 time period model, with longer
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5 LOS among patients admitted at night.
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7 Results were similar when controlling for NIHSS score on arrival at hospital instead of level of
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9 consciousness on the smaller sample of patients with non-missing NIHSS data: results with p-
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11 values < 0.05 and trends across the week were unchanged (Data Supplement).
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Table 2. Quality of care and outcomes across four periods in the week

	London HASUs				Rest of England			
	Weekday	Weekend	Weekday	Weekend	Weekday	Weekend	Weekday	Weekend
	08:00-19:59	08:00-19:59	20:00-07:59	20:00-07:59	08:00-19:59	08:00-19:59	20:00-07:59	20:00-07:59
Quality of care measures that do not vary across the week in London HASUs								
Brain scan within one hour	0.60 (0.58-0.61)	0.61 (0.58-0.63)	0.63 (0.60-0.65)	0.65 (0.61-0.68)	0.44 (0.44-0.45)	0.41 (0.40-0.41)	0.40 (0.39-0.40)	0.39 (0.38-0.41)
Brain scan within 12 hours	0.97 (0.96-0.97)	0.96 (0.95-0.97)	0.95 (0.94-0.96)	0.95 (0.93-0.96)	0.90 (0.90-0.90)	0.88 (0.87-0.89)	0.84 (0.83-0.84)	0.83 (0.82-0.84)
Dysphagia screen within four hours	0.74 (0.72-0.75)	0.75 (0.73-0.77)	0.77 (0.75-0.79)	0.79 (0.76-0.82)	0.70 (0.70-0.71)	0.65 (0.64-0.66)	0.60 (0.59-0.61)	0.58 (0.56-0.59)
Assessment by a nurse trained in stroke management within 24 hours	0.96 (0.95-0.96)	0.94 (0.93-0.96)	0.95 (0.94-0.96)	0.95 (0.94-0.97)	0.89 (0.88-0.89)	0.85 (0.85-0.86)	0.86 (0.86-0.87)	0.83 (0.82-0.84)
Administration of intravenous thrombolysis to eligible patients	0.88 (0.86-0.90)	0.88 (0.84-0.92)	0.86 (0.82-0.91)	0.88 (0.82-0.95)	0.81 (0.80-0.82)	0.80 (0.78-0.82)	0.76 (0.74-0.78)	0.76 (0.72-0.79)
Door-to-needle time within one hour in patients receiving thrombolysis	0.84 (0.81-0.87)	0.89 (0.85-0.93)	0.79 (0.74-0.84)	0.84 (0.77-0.91)	0.60 (0.59-0.62)	0.48 (0.45-0.50)	0.38 (0.35-0.40)	0.37 (0.33-0.41)
Quality of care: measures that vary significantly across the week								
Assessment by a stroke specialist consultant physician within 12 hours	0.39 (0.38-0.40)	0.30 (0.27-0.32)	0.63 (0.61-0.66)	0.64 (0.60-0.68)	0.48 (0.48-0.49)	0.30 (0.29-0.31)	0.51 (0.51-0.52)	0.42 (0.41-0.44)
Assessment by a stroke specialist consultant physician within 24 hours	0.90 (0.89-0.91)	0.87 (0.85-0.89)	0.90 (0.88-0.91)	0.92 (0.90-0.94)	0.80 (0.79-0.80)	0.65 (0.65-0.66)	0.75 (0.74-0.75)	0.62 (0.61-0.64)
Admission to a stroke unit within four hours	0.62 (0.60-0.63)	0.64 (0.61-0.66)	0.67 (0.65-0.70)	0.70 (0.67-0.74)	0.63 (0.63-0.63)	0.59 (0.58-0.60)	0.55 (0.54-0.56)	0.53 (0.52-0.55)
Physiotherapist assessment within 72 hours	0.83 (0.82-0.84)	0.86 (0.84-0.88)	0.85 (0.83-0.87)	0.84 (0.81-0.87)	0.82 (0.81-0.82)	0.83 (0.82-0.84)	0.81 (0.81-0.82)	0.82 (0.80-0.83)
Occupational Therapist assessment within 72 hours	0.79 (0.78-0.80)	0.82 (0.80-0.84)	0.81 (0.79-0.82)	0.80 (0.76-0.83)	0.73 (0.73-0.74)	0.75 (0.75-0.76)	0.73 (0.72-0.74)	0.73 (0.72-0.74)
Swallow assessment by a SLT within 72 hours	0.92 (0.91-0.93)	0.93 (0.91-0.95)	0.93 (0.91-0.95)	0.91 (0.88-0.95)	0.80 (0.80-0.81)	0.81 (0.80-0.82)	0.79 (0.78-0.80)	0.80 (0.78-0.82)
Communication assessment by a SLT	0.77 (0.76-0.78)	0.80 (0.78-0.82)	0.79 (0.77-0.81)	0.76 (0.73-0.80)	0.68 (0.68-0.69)	0.70 (0.70-0.71)	0.68 (0.67-0.69)	0.68 (0.66-0.69)

1	within 72 hours								
2	Physiotherapist assessment within 24 hours	0.56 (0.54-0.57)	0.47 (0.45-0.50)	0.65 (0.63-0.68)	0.48 (0.44-0.52)	0.54 (0.54-0.55)	0.41 (0.40-0.41)	0.53 (0.52-0.54)	0.35 (0.34-0.37)
3	Occupational Therapist assessment within 24 hours	0.49 (0.47-0.50)	0.42 (0.40-0.45)	0.58 (0.55-0.60)	0.41 (0.37-0.45)	0.43 (0.42-0.43)	0.31 (0.30-0.31)	0.42 (0.42-0.43)	0.26 (0.25-0.27)
4	Communication assessment by a SLT within 24 hours	0.48 (0.46-0.49)	0.41 (0.39-0.44)	0.57 (0.54-0.59)	0.40 (0.36-0.44)	0.40 (0.40-0.41)	0.29 (0.28-0.30)	0.40 (0.39-0.41)	0.25 (0.23-0.26)
5	Outcome measures								
6	Mortality at three days	0.03 (0.02-0.03)	0.03 (0.02-0.04)	0.03 (0.02-0.04)	0.02 (0.01-0.03)	0.04 (0.04-0.05)	0.04 (0.04-0.04)	0.05 (0.04-0.05)	0.05 (0.04-0.05)
7	mRS score 3-6	0.55 (0.53-0.56)	0.55 (0.52-0.57)	0.55 (0.52-0.57)	0.56 (0.53-0.59)	0.48 (0.48-0.48)	0.49 (0.48-0.50)	0.51 (0.50-0.51)	0.51 (0.50-0.52)
8	mRS score 3-5*	0.49 (0.47-0.50)	0.47 (0.45-0.50)	0.48 (0.45-0.50)	0.48 (0.44-0.51)	0.40 (0.39-0.40)	0.40 (0.39-0.41)	0.40 (0.39-0.41)	0.40 (0.39-0.41)
9	Length of stay								
10	Length of stay in HASU (days)	3.1 (3.0-3.2)	3.4 (3.2-3.5)	3.0 (2.9-3.1)	3.1 (2.9-3.3.)				
11	Length of stay in hospital (days)	10.8 (10.2-11.3)	12.1 (11.1-13.1)	10.8 (10.0-11.7)	11.5 (10.2-12.9)	8.5 (8.4-8.6)	9.2 (9.0-9.4)	9.7(9.4-9.9)	10.1 (9.6-10.5)

Note.

Figures are average predicted probabilities (95% confidence intervals) of each measure in each time period controlling for the covariates. SLT = Speech and Language Therapist. mRS = modified Rankin Scale. * Patients who died were not included.

DISCUSSION

Principal findings

In our study, we found no evidence for an admission effect across the week on early outcomes in acute stroke patients admitted to a London HASU: three-day mortality and modified Rankin Scale score at hospital discharge did not vary by day and time of admission in London HASUs. This is consistent with a recent study based on administrative data in the UK [9] that found a steady reduction in in-hospital mortality difference between weekday and weekend stroke admissions in 2008-2014 across England and that this difference is no longer statistically significant in 2014).

There was also no variation by day and time of admission across the week in terms of rapid access to brain scanning, stroke nursing care and thrombolysis in London HASUs. Other quality of care measures did significantly vary across the week in London HASUs, and three patterns of variation were detected: by time of day but not day of the week; by day of the week but not time of day; and, by time of day and day of the week. LOS was longer among patients admitted to London HASUs at the weekend. In the rest of England there was variation in all measures by day and time of admission across the week, except for mortality at three days. We hypothesised there would be less variation across the week in care quality measures in London HASUs compared with the rest of England, and that this would translate into less variation in outcomes in London HASUs. The first hypothesis was found to be true but only with respect to “front door” measures of acute stroke care. The second hypothesis was found to be true: there was no variation in mortality at three days and disability at hospital discharge by day and time of admission across the week in London HASUs. This is consistent with previous studies showing that timely access to thrombolysis is associated with good stroke outcomes[36]. In the rest of

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3 England there was no variation in three-day mortality by day and time of admission across the
4 week (but there was in terms of disability after discharge), suggesting the lack of variation in
5 outcomes in London HASUs may not be exclusively attributed to the lack of variation in “front
6 door” quality of care.
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11 12 13 **Strengths and weaknesses** 14

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17 The main strength of our study is the large national dataset we have used containing detailed
18 information on quality of care, outcomes, and patient characteristics. We have examined
19 whether time of admission was related to quality of care using a comprehensive set of indicators
20 from across the acute stroke care pathway. Most of the measures were from a pre-existing set
21 of national acute stroke care indicators, and those that were added had more stringent time
22 constraints to reflect the time-critical nature of acute stroke care. Our outcomes were stroke
23 mortality and disability, where previous studies have focused on mortality[2,4,5,7–10]. The rich
24 set of patient characteristics in the dataset meant we could control for patient factors likely to
25 affect quality of care and outcomes that vary by day and time of admission across the week and
26 between London and the rest of England. There are several weaknesses. First, while case
27 ascertainment in SSNAP was 90% during the time period of our study, these data might not be
28 representative of all stroke patients. For example, not all hospitals receiving acute stroke
29 patients in England participated in SSNAP, and the results may not be representative of
30 hospitals who did not participate. Second, while analyses of hospital administrative data to
31 investigate weekend effects in stroke have been undermined by evidence of variations in
32 inaccurate coding across the week[15], in SSNAP data are inputted voluntarily by hospitals and
33 we cannot exclude the possibility of inaccurate or selective reporting. Particularly problematic for
34 our study would be if this bias was more likely to occur in London or the rest of England and/or if
35 it was more likely to vary by time of admission. Third, we were unable to measure long-term
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3 outcomes as these were not available in SSNAP. Mortality data in SSNAP are currently only
4 available for patients who are in hospital and therefore to reduce the risk of bias we measured
5 mortality at three days after admission when most patients will still be admitted. Three-day
6 mortality has been used in previous studies to evaluate the centralisation of acute stroke
7 services in London[29], but the focus in our study on in-hospital mortality only is a further
8 limitation. Similarly, long-term disability data are not reliably collected in SSNAP, and so this
9 was measured by mRS at the end of the inpatient spell. Fourth, while the richness of our
10 dataset means we have been able to control for confounding factors we cannot exclude the
11 possibility of confounding due to unobserved patient characteristics or staffing levels. Fifth, while
12 the sample size of our study is large in both London and the rest of England, when evaluating
13 quality of care and outcomes across the week the number of observations in each time period
14 was considerably smaller in London. We cannot exclude the possibility that the smaller number
15 of patients in London resulted in wider confidence intervals around the adjusted predicted
16 probabilities in each time period making it less likely to show significant variation in the
17 measures evaluated.
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34 35 36 37 ***Comparison with other studies*** 38

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41 There is a large literature examining weekend effects in health care across a range of clinical
42 areas[37]. In acute stroke there is conflicting evidence as to whether patients admitted at
43 weekends have higher or lower quality of care and better or worse outcomes[1–8], but recent
44 analyses have shown that care quality and outcomes in acute stroke vary across the week, and
45 that comparing weekend versus weekday or in-hours versus out-of-hours effects is flawed as it
46 does not take into account variations by day of the week and time of day[16]. This study, using
47 the same dataset as ours but from an earlier time period and analysing the whole of England
48 and Wales, found that quality of care varied across the entire week, not only between weekends
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3 and weekdays, with a number quality of care measures showing different patterns of variation
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5 over the week. While the findings mirrored our own for the rest of England, one noticeable
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7 difference was in mortality: Bray et al. reported that patients admitted overnight on weekdays
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9 had lower odds of survival (0.90, 95% confidence interval 0.82-0.99) compared to those
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11 admitted during the day at weekdays; this difference might be because our survival measure is
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13 not the same (three versus 30 days) and/or because our extract of the SSNAP dataset is more
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15 recent. What our study adds is analyses of variation in quality of care and outcomes in London
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17 HASUs separately following the centralisation of acute stroke services in London in 2010, which
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19 has been shown to increase the quality of care and outcomes on average across the
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21 week[28,29].
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26 ***Implications***

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30 There are several implications of our study. The first is that London HASUs appear to operate a
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32 uniform service across the week with respect to some but not all aspects of acute stroke care.
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34 Performance standards originally set by Healthcare for London stipulated that London HASUs
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36 should operate a 24/7 service with respect to first assessment by a stroke nurse, rapid access
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38 to brain scans and administration of thrombolysis to eligible patients; our findings show that
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40 London HASUs do operate a 24/7 service with respect to these measures. However, for other
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42 less time-critical measures, such as senior stroke physician assessment within 24 hours and
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44 therapist assessments within 72 hours, we found significant variation by day and time of
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46 admission across the week in London HASUs. This suggests that some performance standards
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48 like “front door” interventions may be emphasised more than others. The second implication is
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50 that there are differences in acute stroke care between London HASUs and the rest of England
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52 across the week, with less variation in quality of care and outcomes in London HASUs. The
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54 main differences were observed in nursing care, brain scanning and thrombolysis provision, and
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3 also with the type of variation observed for stroke consultant care. For these measures, our
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5 results show that the centralised model in London is more effective at providing constant care
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7 across the week. In terms of comparing London and the rest of England, four further issues are
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9 worth bearing in mind. First, our study focuses on patients admitted to London HASUs only, not
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11 other hospitals in London; our data suggest that 6% of acute stroke patients in London are not
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13 treated in a HASU. However, some of these patients will not have been eligible for HASU care
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15 because of greatly delayed presentation or identification of stroke, and others will have had a
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17 stroke after surgical procedures or in another context which precluded their admission to a
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19 HASU. Our focus on London HASUs was deliberate as the aim of our study was to evaluate the
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21 HASU model, but it means that our findings for London HASUs should not be generalised to all
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23 patients in London. Indeed, there is evidence that quality of care is lower for acute stroke
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25 patients in London not treated in a HASU compared with those who are [28]. Second, and
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27 conversely, HASUs operate in many other parts of England using different models of
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29 care[31,38]. In Greater Manchester, for instance, HASUs have also been shown to have higher
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31 quality of care than the rest of England excluding London[28]. Hence the differences observed
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33 between London HASUs and the rest of England cannot be interpreted as a direct comparison
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35 of HASU versus non-HASU care, though if HASU-based care outside London was removed
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37 from the rest of England then the differences observed in this study are likely to be the same or
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39 greater. The third issue is that the London model may not apply to services operating in rural
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41 settings – in particular the greater travel times in rural areas make centralisation challenging[39].
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43 This means that potential benefits of the London model in terms of 24/7 care are unlikely to be
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45 achieved nationwide. The fourth issue is that the centralisation of acute stroke services in
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47 London was estimated to occur at an additional cost of £20 million, allocated to cover the
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49 increased cost per bed day in a HASU[30]. With this additional level of funding it might be
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51 expected that the quality of care in London should improve, though whether it should produce
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53 less variation in quality of care and outcomes across the week in London compared with the rest
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of England depends on the relative levels of funding in both areas. There is some evidence that the reorganisation in London was cost-effective[40,41], but further analyses accounting for the size of the up-front investment, the relatively high costs per day of hyperacute stroke care, the impact on mortality and disability, and the lifetime costs incurred by the NHS, social services and families caring for stroke survivors at different levels of disability would be helpful.

Future research

Further research would be beneficial to evaluate the impact of stroke admission at different times of the week on longer-term mortality and disability outcomes, and to investigate the relationship between quality of care and outcomes and if this relationship varies by time of admission. Further research would also be useful to investigate the reasons for the differences in variation found between London HASUs and the rest of England, and why for some standards care in London HASUs was constant across the week, irrespective of day and time of admission, but for others it was not. This research would help to further inform how acute stroke services ought to be designed in future to maximise patient outcomes in a cost-effective manner.

References

- 1 Turner M, Barber M, Dodds H, *et al*. Stroke patients admitted within normal working hours are more likely to achieve process standards and to have better outcomes. *J Neurol Neurosurg Psychiatry* 2016;**87**:138–43. doi:10.1136/jnnp-2015-311273
- 2 Palmer WL, Bottle A, Davie C, *et al*. Dying for the Weekend. *Arch Neurol* 2012;**69**. doi:10.1001/archneurol.2012.1030
- 3 Tung Y-C, Chang G-M, Chen Y-H. Associations of physician volume and weekend admissions with ischemic stroke outcome in Taiwan: a nationwide population-based study. *Med Care* 2009;**47**:1018–25. doi:10.1097/MLR.0b013e3181a81144
- 4 Saposnik G, Baibergenova A, Bayer N, *et al*. Weekends: A dangerous time for having a stroke? *Stroke* 2007;**38**:1211–5. doi:10.1161/01.STR.0000259622.78616.ea
- 5 Fang J, Saposnik G, Silver FL, *et al*. Association between weekend hospital presentation

- and stroke fatality. *Neurology* 2010;**75**:1589–96. doi:10.1212/WNL.0b013e3181fb84bc
- 6 Patel AA, Mahajan A, Benjo A, *et al*. A Nationwide Analysis of Outcomes of Weekend Admissions for Intracerebral Hemorrhage Shows Disparities Based on Hospital Teaching Status. *The Neurohospitalist* 2016;**6**:51–8. doi:10.1177/1941874415601164
- 7 Reeves MJ, Smith E, Fonarow G, *et al*. Off-hour admission and in-hospital stroke case fatality in the get with the guidelines-stroke program. *Stroke* 2009;**40**:569–76. doi:10.1161/STROKEAHA.108.519355
- 8 Crowley RW, Yeoh HK, Stukenborg GJ, *et al*. Influence of weekend versus weekday hospital admission on mortality following subarachnoid hemorrhage. *J Neurosurg* 2009;**111**:60–6. doi:10.3171/2008.11.JNS081038
- 9 Balinskaite V, Bottle A, Shaw LJ, *et al*. Reorganisation of stroke care and impact on mortality in patients admitted during weekends: a national descriptive study based on administrative data. *BMJ Qual Saf* 2017;:bmjqs – 2017–006681. doi:10.1136/bmjqs-2017-006681
- 10 Walker AS, Mason A, Quan TP, *et al*. Mortality risks associated with emergency admissions during weekends and public holidays: an analysis of electronic health records. *Lancet* 2017;**390**:62–72. doi:10.1016/S0140-6736(17)30782-1
- 11 Concha OP, Gallego B, Hillman K, *et al*. Do variations in hospital mortality Patterns after weekend admission Reflect reduced quality of care or Different patient cohorts? A population-based study. *BMJ Qual Saf* 2014;**23**:215–22. doi:10.1136/bmjqs-2013-002218
- 12 Luyt CE, Combes A, Aegerter P, *et al*. Mortality among patients admitted to intensive care units during weekday day shifts compared with 'off' hours. *Crit Care Med* 2007;**35**:3–11. doi:10.1097/01.CCM.0000249832.36518.11
- 13 Brunot V, Landreau L, Corne P, *et al*. Mortality associated with night and weekend admissions to ICU with on-site intensivist coverage: Results of a nine-year cohort study (2006-2014). *PLoS One* 2016;**11**:1–16. doi:10.1371/journal.pone.0168548
- 14 Aylin P, Alexandrescu R, Jen MH, *et al*. Day of week of procedure and 30 day mortality for elective surgery: Retrospective analysis of hospital episode statistics. *BMJ* 2013;**346**:1–8. doi:10.1136/bmj.f2424
- 15 Li L, Rothwell PM. Biases in detection of apparent 'weekend effect' on outcome with administrative coding data: population based study of stroke. *Bmj* 2016;:i2648. doi:10.1136/bmj.i2648
- 16 Bray BD, Cloud GC, James MA, *et al*. Weekly variation in health-care quality by day and time of admission: a nationwide, registry-based, prospective cohort study of acute stroke care. *Lancet* 2016;**388**:170–7. doi:10.1016/S0140-6736(16)30443-3
- 17 Goddard a F, Lees P. Higher senior staffing levels at weekends and reduced mortality. *BMJ* 2012;**344**:e67–e67. doi:10.1136/bmj.e67
- 18 Bray BD, Ayis S, Campbell J, *et al*. Associations between stroke mortality and weekend working by stroke specialist physicians and registered nurses: Prospective multicentre cohort study. *PLoS Med* 2015;**11**. doi:10.1371/journal.pmed.1001705
- 19 Albright KC, Raman R, Ernstom K, *et al*. Can comprehensive stroke centers erase the 'weekend effect'? *Cerebrovasc Dis* 2009;**27**:107–13. doi:10.1159/000177916
- 20 Albright KC, Savitz SI, Raman R, *et al*. Comprehensive stroke centers and the 'Weekend Effect': The SPOTRIAS experience on behalf of the SPOTRIAS investigators. *Cerebrovasc Dis* 2012;**34**:424–9. doi:10.1159/000345077

- 1
2
3 21 McKinney JS, Deng Y, Kasner SE, *et al.* Comprehensive stroke centers overcome the
4 weekend versus weekday gap in stroke treatment and mortality. *Stroke* 2011;**42**:2403–9.
5 doi:10.1161/STROKEAHA.110.612317
6
7 22 Statistics O for N. 2011 Census: Key Statistics for England and Wales, March 2011.
8 2012;:1–34. [http://www.ons.gov.uk/ons/rel/census/2011-census/key-statistics-for-local-](http://www.ons.gov.uk/ons/rel/census/2011-census/key-statistics-for-local-authorities-in-england-and-wales/stb-2011-census-key-statistics-for-england-and-wales.html)
9 [authorities-in-england-and-wales/stb-2011-census-key-statistics-for-england-and-](http://www.ons.gov.uk/ons/rel/census/2011-census/key-statistics-for-local-authorities-in-england-and-wales/stb-2011-census-key-statistics-for-england-and-wales.html)
10 [wales.html](http://www.ons.gov.uk/ons/rel/census/2011-census/key-statistics-for-local-authorities-in-england-and-wales/stb-2011-census-key-statistics-for-england-and-wales.html)
11
12 23 Morris S, Hunter RM, Ramsay AIG, *et al.* Impact of centralising acute stroke services in
13 English metropolitan areas on mortality and length of hospital stay: difference-in-
14 differences analysis. *BMJ* 2014;**349**:g4757. doi:10.1136/bmj.g4757
15
16 24 Turner S, Ramsay A, Perry C, *et al.* Lessons for major system change: Centralization of
17 stroke services in two metropolitan areas of England. *J Heal Serv Res Policy*
18 2016;**21**:156–65. doi:10.1177/1355819615626189
19
20 25 Davie C, Hunter RM, Mountford J, *et al.* London 's Hyperacute Stroke Units Improve
21 Outcomes and Lower Costs. 2013.
22
23 26 NHS London Strategic Clinical Networks. Stroke acute commissioning and tariff
24 guidance. 2014.
25
26 27 Fulop N, Boaden R, Hunter R, *et al.* Innovations in major system reconfiguration in
27 England: a study of the effectiveness, acceptability and processes of implementation of
28 two models of stroke care. *Implement Sci* 2013;**8**:5. doi:10.1186/1748-5908-8-5
29
30 28 Ramsay AIG, Morris S, Hoffman A, *et al.* Effects of centralizing acute stroke services on
31 stroke care provision in two large metropolitan areas in England. *Stroke* 2015;**46**:2244–
32 51. doi:10.1161/STROKEAHA.115.009723
33
34 29 Morris S, Hunter RM, Ramsay a. IG, *et al.* Impact of centralising acute stroke services in
35 English metropolitan areas on mortality and length of hospital stay: difference-in-
36 differences analysis. *Bmj* 2014;**349**:g4757–g4757. doi:10.1136/bmj.g4757
37
38 30 Healthcare for London. The shape of things to come: Appendix 7d - finance
39 commissioning assurance. *London Healthc London 2009* 2009;:1–87.
40
41 31 Royal College of Physicians. Sentinel Stroke National Audit Programme (SSNAP):
42 Clinical audit first pilot public report. 2013;:1–48.
43
44 32 Royal College of Physicians. First SSNAP Annual Report. How good is stroke care?
45 2014.
46
47 33 Royal College of Physicians. Is stroke care improving ? The Second SSNAP Annual
48 Report. 2015;:32.
49
50 34 Royal College of Physicians. 3rd SSNAP Annual Report for 2015/2016 'Mind the Gap!'
51 *Third Ssn Annu Rep* 2016;:1–219. doi:10.1787/9789264038950-en
52
53 35 Royal College of Physicians. National clinical guideline for stroke. *London R Coll*
54 *Physicians* 2008;:232.
55
56 36 Emberson J, Lees KR, Lyden P, *et al.* Effect of treatment delay, age, and stroke severity
57 on the effects of intravenous thrombolysis with alteplase for acute ischaemic stroke: A
58 meta-analysis of individual patient data from randomised trials. *Lancet* 2014;**384**:1929–
59 35. doi:10.1016/S0140-6736(14)60584-5
60
61 37 Godlee F. What to do about the 'weekend effect'. *Bmj* 2015;**4840**:h4840.
62 doi:10.1136/bmj.h4840

- 1
2
3 38 Royal College of Physicians. Sentinel Stroke National Audit Programme (SSNAP) Acute
4 organisational audit proforma. 2012;:1–35.
5
6 39 Allen M, Pearn K, Villeneuve E, *et al*. Feasibility of a hyper-acute stroke unit model of
7 care across England: a modelling analysis. *BMJ Open* 2017;7:e018143.
8 doi:10.1136/bmjopen-2017-018143
9
10 40 Hunter RM, Fulop NJ, Boaden RJ, *et al*. The potential role of cost-utility analysis in the
11 decision to implement major system change in acute stroke services in metropolitan
12 areas in England. *Heal Res Policy Syst* 2018;16:1–14. doi:10.1186/s12961-018-0301-5
13
14 41 Hunter RM, Davie C, Rudd A, *et al*. Impact on Clinical and Cost Outcomes of a
15 Centralized Approach to Acute Stroke Care in London: A Comparative Effectiveness
16 Before and After Model. *PLoS One* 2013;8:1–9. doi:10.1371/journal.pone.0070420
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6 appear to have influenced the submitted work.
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14 **Ethical approval:** The study received ethical approval on 25/02/14 from NRES committee
15 London Westminster ref 14/LO/0355
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20 **Data sharing:** no additional data available.
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14 important aspects of the study have been omitted; and that any discrepancies from the study as
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16 planned (and, if relevant, registered) have been explained.
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20 **Role of the sponsor:** The sponsor approved all aspects of the study protocol and any
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22 amendments thereto, but played no other role in design or conduct of the study.
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Figure legends

Figure 1. Number of admissions in London and Rest of England across the 42 time periods in the week

Note.

Left-hand y-axis relates to London HASUs, right-hand y-axis to the Rest of England. Shaded areas indicate 20:00-07:59 each day of the week.

Figure 2. Quality of care across the 42 time periods in the week: measures linked to performance standards for London HASUs

(a) Brain scan within one hour

(b) Brain scan within 12 hours

(c) Dysphagia screen within four hours

(d) Assessment by a nurse trained in stroke management within 24 hours

(e) Administration of intravenous thrombolysis to eligible patients

(f) Door-to-needle time within one hour in patients receiving thrombolysis

Note.

Figures are average predicted probabilities of each outcome in each time period controlling for the covariates. Dashed lines represent lower and upper 95% confidence limits. Shaded areas indicate 20:00-07:59 each day of the week. P-values indicate significant variation ($p < 0.05$) or not for each measure over the week in each region. Gaps in the solid line indicate that all patients in that time period achieved that outcome.

Figure 3. Quality of care across the 42 time periods in the week: variation by time of day but not day of the week

(a) Assessment by a stroke specialist consultant physician within 12 and 24 hours in London HASUs

(b) Admission to a stroke unit within four hours

Note.

Figures are average predicted probabilities of each outcome in each time period controlling for the covariates. Dashed lines represent lower and upper 95% confidence limits. Shaded areas indicate 20:00-07:59 each day of the week. P-values indicate significant variation ($p < 0.05$) or not for each measure over the week in each region. Figure 3(a) includes two measures for London HASUs.

Figure 4. Quality of care across the 42 time periods in the week: variation by day of the week but not time of day

(a) Physiotherapist assessment within 72 hours

(b) Occupational Therapist assessment within 72 hours

(c) Swallow assessment by a Speech and Language Therapist within 72 hours

(d) Communication assessment by a Speech and Language Therapist within 72 hours

Note.

Figures are average predicted probabilities of each outcome in each time period controlling for the covariates. Dashed lines represent lower and upper 95% confidence limits. Shaded areas indicate 20:00-07:59 each day of the week. P-values indicate significant variation ($p < 0.05$) or not for each measure over the week in each region. Gaps in the solid line indicate that no patients in that time period achieved that outcome. SLT = Speech and Language Therapist.

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5 **Figure 5. Quality of care across the 42 time periods in the week: variation by time of day**
6 **and day of the week**

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9 **(a) Assessment by a stroke specialist consultant physician within 12 and 24 hours in**

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11 **Rest of England**

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13 **(b) Physiotherapist assessment within 24 hours**

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15 **(c) Occupational Therapist assessment within 24 hours**

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17 **(d) Communication assessment by a Speech and Language Therapist within 24 hours**

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22 Note.

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24 Figures are average predicted probabilities of each outcome in each time period controlling for
25 the covariates. Dashed lines represent lower and upper 95% confidence limits. Shaded areas
26 indicate 20:00-07:59 each day of the week. P-values indicate significant variation ($p < 0.05$) or
27 not for each measure over the week in each region. Figure 5(a) includes two measures for Rest
28 of England. SLT = Speech and Language Therapist.
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37 **Figure 6. Outcomes across the 42 time periods in the week**

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39 **(a) Mortality at three days**

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41 **(b) Modified Rankin Scale score 3-6**

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43 **(c) Modified Rankin Scale score 3-5***

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47 Note.

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49 Figures are average predicted probabilities of each outcome in each time period controlling for
50 the covariates. Dashed lines represent lower and upper 95% confidence limits. Shaded areas
51 indicate 20:00-07:59 each day of the week. P-values indicate significant variation ($p < 0.05$) or
52 not for each measure over the week in each region. Gaps in the solid line indicate that no
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3 patients in that time period achieved that outcome. Note the scaling of the y-axis in Figure 6(a)
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5 is not from zero to one.
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9 **Figure 7. Length of stay across the 42 time periods in the week**

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11 **(a) Length of stay in HASU**

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13 **(b) Length of stay in hospital**

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15 Note.

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18 Figures are average predicted probabilities of each outcome in each time period controlling for
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20 the covariates. Dashed lines represent lower and upper 95% confidence limits. Shaded areas
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22 indicate 20:00-07:59 each day of the week. P-values indicate significant variation ($p < 0.05$) or
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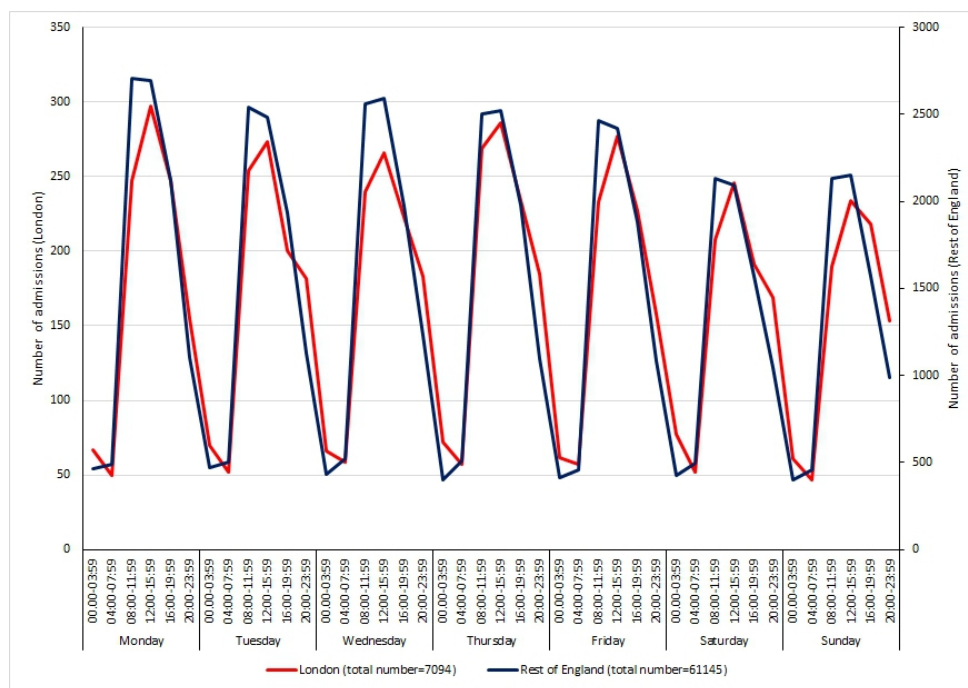


Figure 1. Number of admissions

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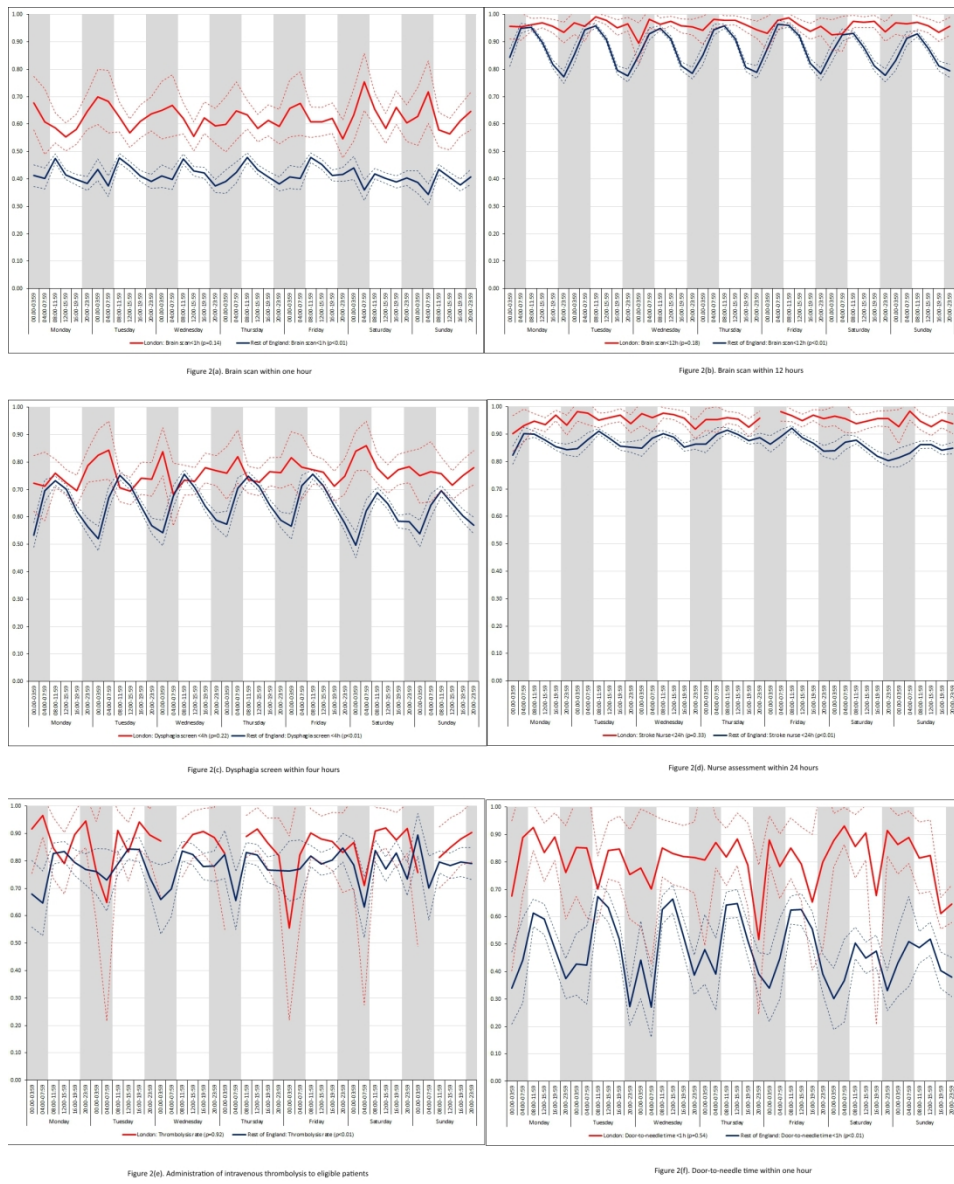


Figure 2

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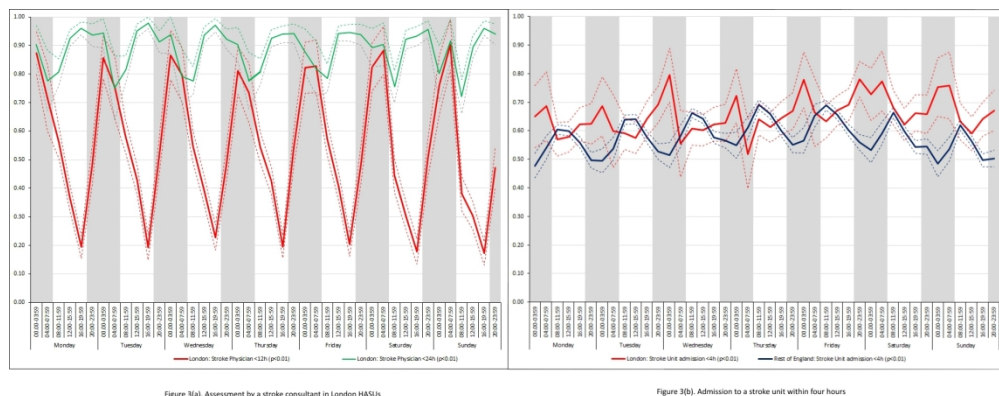


Figure 3(a). Assessment by a stroke consultant in London HASUs

Figure 3(b). Admission to a stroke unit within four hours

Figure 3

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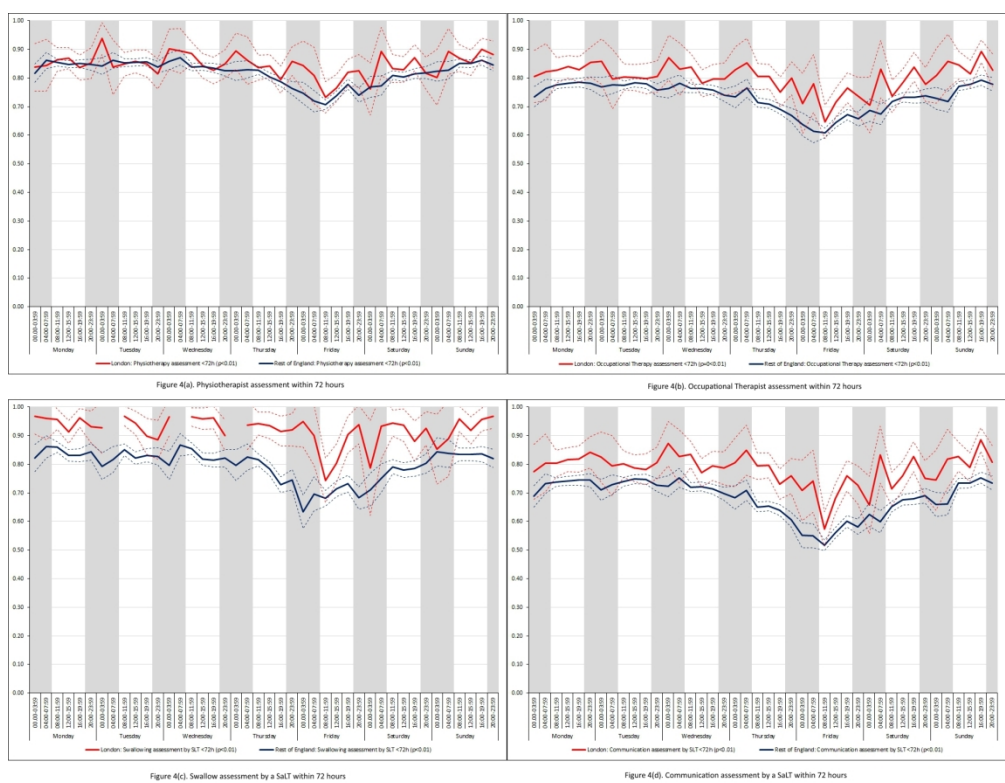


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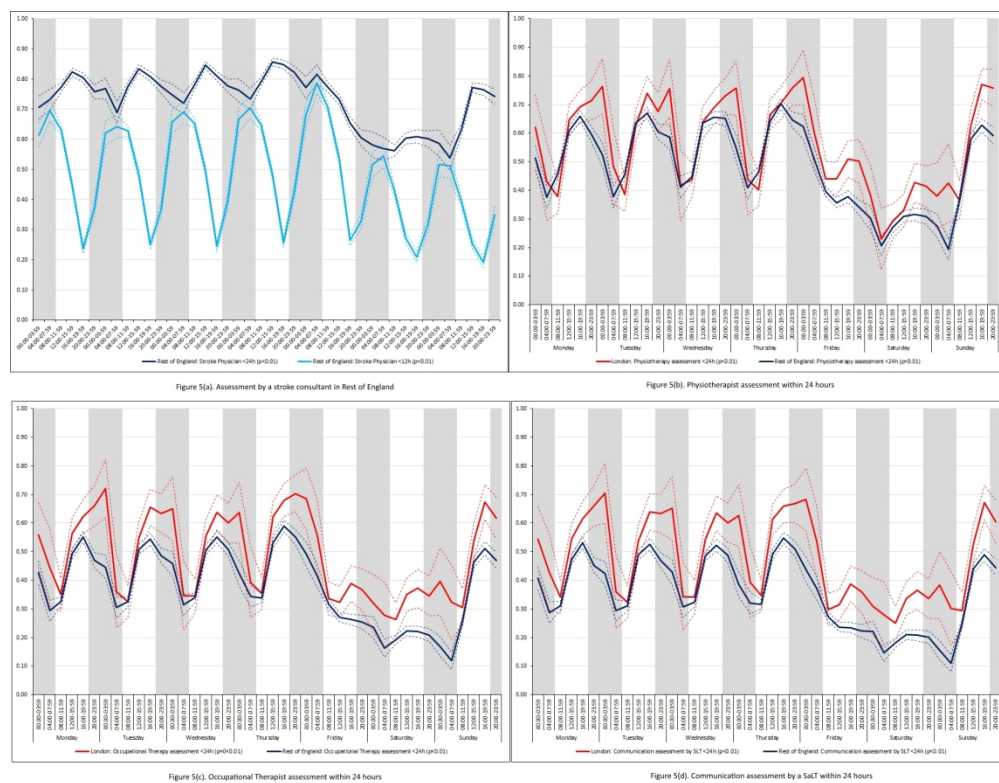


Figure 5

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Figure 6

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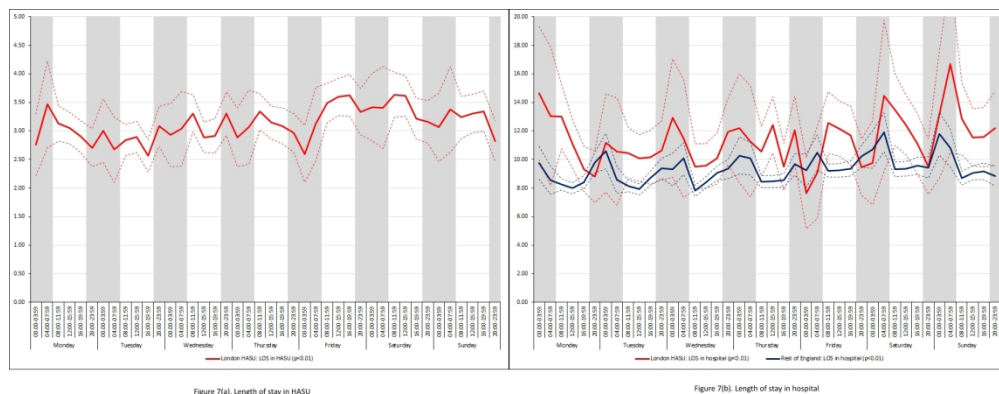


Figure 7

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Supplementary Tables

Supplementary Table 1. Patient characteristics

	London HASUs (n=7094)	Rest of England (n=61 145)	P-value
Sex			<0.01
Male	3719 (52%)	30 536 (50%)	
Female	3375 (48%)	30 609 (50%)	
Age, years (mean (std.dev.))	72 (15)	75 (13)	<0.01
Ethnic group			<0.01
White	4332 (61%)	56 221 (92%)	
Mixed	72 (1%)	141 (<1%)	
Black	650 (9%)	1272 (2%)	
Asian	505 (7%)	362 (<1%)	
Other	526 (7%)	358 (<1%)	
Not available	1009 (14%)	2791 (5%)	
Type of stroke			0.06
Infarction	6252 (88%)	54 355 (89%)	
Primary Intracerebral Haemorrhage	842 (12%)	6790 (11%)	
Comorbidities prior to admission			
Congestive Heart Failure	439 (6%)	3204 (5%)	<0.01
Hypertension	4284 (60%)	32 447 (53%)	<0.01
Atrial fibrillation	1229 (17%)	12 655 (21%)	<0.01
Diabetes	1705 (24%)	12 024 (20%)	<0.01
Stroke/TIA	1688 (24%)	16 752 (27%)	<0.01
mRS score before stroke			<0.01
Slight or no disability (0-2)	5552 (78%)	49 574 (81%)	
At least moderate disability (3-5)	1542 (22%)	11 571 (19%)	
Level of consciousness on arrival at the hospital**			<0.05
Alert	5991 (84%)	51 230 (84%)	
Not alert; but respond to minor stimulation	663 (9%)	5724 (9%)	
Not alert; requires repeated stimulation	281 (4%)	2438 (4%)	
Unresponsive	159 (2%)	1753 (3%)	
NIHSS on arrival at the hospital, score (median (IQR))	5 (2-11)	4 (2-9)	
Method of admission to the hospital			<0.01
Already inpatient	173 (2%)	3288 (5%)	
Ambulance	5966 (84%)	47 096 (77%)	
Walk-in	955 (13%)	10 761 (18%)	
Time from onset of stroke symptoms to admission			<0.01
<180 minutes	2741 (39%)	24 233 (40%)	
180-359 minutes	759 (11%)	5871 (10%)	
≥360 minutes	1516 (21%)	10 773 (18%)	
Time of onset not known	2078 (29%)	20 268 (33%)	

Note. Figures are n (%) except for age, which is mean (std.dev.), and NIHSS on arrival at the hospital, which is median (IQR). mRS = modified Rankin Scale. IQR = interquartile range. The sample with NIHSS scores on arrival was n=6571 in London HASUs and n=47 126 in the rest of England. ** Level of consciousness scores taken from admission NIHSS score (Question 1a).

Supplementary Table 2. Quality of care and outcomes across four periods in the week

	London HASUs				Rest of England			
	Weekday	Weekend	Weekday	Weekend	Weekday	Weekend	Weekday	Weekend
	08:00-19:59	08:00-19:59	20:00-07:59	20:00-07:59	08:00-19:59	08:00-19:59	20:00-07:59	20:00-07:59
Quality of care measures that do not vary across the week in London HASUs								
Brain scan within one hour	0.60 (0.58-0.61)	0.61 (0.58-0.63)	0.63 (0.60-0.65)	0.65 (0.61-0.68)	0.44 (0.44-0.45)	0.41 (0.40-0.41)	0.40 (0.39-0.40)	0.39 (0.38-0.41)
Brain scan within 12 hours	0.97 (0.96-0.97)	0.96 (0.95-0.97)	0.95 (0.94-0.96)	0.95 (0.93-0.96)	0.90 (0.90-0.90)	0.88 (0.87-0.89)	0.84 (0.83-0.84)	0.83 (0.82-0.84)
Dysphagia screen within four hours	0.74 (0.72-0.75)	0.75 (0.73-0.77)	0.77 (0.75-0.79)	0.79 (0.76-0.82)	0.70 (0.70-0.71)	0.65 (0.64-0.66)	0.60 (0.59-0.61)	0.58 (0.56-0.59)
Assessment by a nurse trained in stroke management within 24 hours	0.96 (0.95-0.96)	0.94 (0.93-0.96)	0.95 (0.94-0.96)	0.95 (0.94-0.97)	0.89 (0.88-0.89)	0.85 (0.85-0.86)	0.86 (0.86-0.87)	0.83 (0.82-0.84)
Administration of intravenous thrombolysis to eligible patients	0.88 (0.86-0.90)	0.88 (0.84-0.92)	0.86 (0.82-0.91)	0.88 (0.82-0.95)	0.81 (0.80-0.82)	0.80 (0.78-0.82)	0.76 (0.74-0.78)	0.76 (0.72-0.79)
Door-to-needle time within one hour in patients receiving thrombolysis	0.84 (0.81-0.87)	0.89 (0.85-0.93)	0.79 (0.74-0.84)	0.84 (0.77-0.91)	0.60 (0.59-0.62)	0.45 (0.45-0.50)	0.38 (0.35-0.40)	0.37 (0.33-0.41)
Quality of care: measures that vary significantly across the week								
Assessment by a stroke specialist consultant physician within 12 hours	0.39 (0.38-0.40)	0.30 (0.27-0.32)	0.63 (0.61-0.66)	0.64 (0.60-0.68)	0.48 (0.48-0.49)	0.30 (0.29-0.31)	0.51 (0.51-0.52)	0.42 (0.41-0.44)
Assessment by a stroke specialist consultant physician within 24 hours	0.90 (0.89-0.91)	0.87 (0.85-0.89)	0.90 (0.88-0.91)	0.92 (0.90-0.94)	0.80 (0.79-0.80)	0.65 (0.65-0.66)	0.75 (0.74-0.75)	0.62 (0.61-0.64)
Admission to a stroke unit within four hours	0.62 (0.60-0.63)	0.64 (0.61-0.66)	0.67 (0.65-0.70)	0.70 (0.67-0.74)	0.63 (0.63-0.63)	0.59 (0.58-0.60)	0.55 (0.54-0.56)	0.53 (0.52-0.55)
Physiotherapist assessment within 72 hours	0.83 (0.82-0.84)	0.86 (0.84-0.88)	0.85 (0.83-0.87)	0.84 (0.81-0.87)	0.82 (0.81-0.82)	0.83 (0.82-0.84)	0.81 (0.81-0.82)	0.82 (0.80-0.83)
Occupational Therapist assessment	0.79 (0.78-0.80)	0.82 (0.80-0.84)	0.81 (0.79-0.82)	0.80 (0.76-0.83)	0.73 (0.73-0.74)	0.75 (0.75-0.76)	0.73 (0.72-0.74)	0.73 (0.72-0.74)

within 72 hours								
Swallow assessment by a SLT within 72 hours	0.92 (0.91-0.93)	0.93 (0.91-0.95)	0.93 (0.91-0.95)	0.91 (0.88-0.95)	0.80 (0.80-0.81)	0.81 (0.80-0.82)	0.79 (0.78-0.80)	0.80 (0.78-0.82)
Communication assessment by a SLT within 72 hours	0.77 (0.76-0.78)	0.80 (0.78-0.82)	0.79 (0.77-0.81)	0.76 (0.73-0.80)	0.68 (0.68-0.69)	0.70 (0.70-0.71)	0.68 (0.67-0.69)	0.68 (0.66-0.69)
Physiotherapist assessment within 24 hours	0.56 (0.54-0.57)	0.47 (0.45-0.50)	0.65 (0.63-0.68)	0.48 (0.44-0.52)	0.54 (0.54-0.55)	0.40 (0.40-0.41)	0.53 (0.52-0.54)	0.35 (0.34-0.37)
Occupational Therapist assessment within 24 hours	0.49 (0.47-0.50)	0.42 (0.40-0.45)	0.58 (0.55-0.60)	0.41 (0.37-0.45)	0.43 (0.42-0.43)	0.30 (0.30-0.31)	0.42 (0.42-0.43)	0.26 (0.25-0.27)
Communication assessment by a SLT within 24 hours	0.48 (0.46-0.49)	0.41 (0.39-0.44)	0.57 (0.54-0.59)	0.40 (0.36-0.44)	0.40 (0.40-0.41)	0.29 (0.28-0.30)	0.40 (0.39-0.41)	0.25 (0.23-0.26)
Outcome measures								
Mortality at three days	0.03 (0.02-0.03)	0.03 (0.02-0.04)	0.03 (0.02-0.04)	0.02 (0.01-0.03)	0.04 (0.04-0.05)	0.04 (0.04-0.04)	0.05 (0.04-0.05)	0.05 (0.04-0.05)
mRS score 3-6	0.55 (0.53-0.56)	0.55 (0.52-0.57)	0.55 (0.52-0.57)	0.56 (0.53-0.59)	0.48 (0.48-0.48)	0.49 (0.48-0.50)	0.51 (0.50-0.51)	0.51 (0.50-0.52)
mRS score 3-5*	0.49 (0.47-0.50)	0.47 (0.45-0.50)	0.48 (0.45-0.50)	0.48 (0.44-0.51)	0.40 (0.39-0.40)	0.40 (0.39-0.41)	0.40 (0.39-0.41)	0.40 (0.39-0.41)
Length of stay								
Length of stay in HASU (days)	3.1 (3.0-3.2)	3.4 (3.2-3.5)	3.0 (2.9-3.1)	3.1 (2.9-3.3)				
Length of stay in hospital (days)	10.8 (10.2-11.3)	12.1 (11.1-13.1)	10.8 (10.0-11.7)	11.5 (10.2-12.9)	8.5 (8.4-8.6)	9.2 (9.0-9.4)	9.7(9.4-9.9)	10.1 (9.6-10.5)

Note.

Figures are average predicted probabilities (95% confidence intervals) of each measure in each time period controlling for the covariates. SLT = Speech and Language Therapist. mRS = modified Rankin Scale. * Patients who died were not included.

Supplementary Table S3. Comparison of results controlling for level of consciousness on arrival versus NIHSS score on arrival

	London HASUs		Rest of England	
	Level of consciousness on arrival	NIHSS score on arrival	Level of consciousness on arrival	NIHSS score on arrival
Quality of care: measures linked to performance standards for London HASUs				
Brain scan within one hour	0.14	0.24	<0.01	<0.01
Brain scan within 12 hours	0.18	0.25	<0.01	<0.01
Dysphagia screen within four hours	0.22	0.11	<0.01	<0.01
Assessment by a nurse trained in stroke management within 24 hours	0.33	0.45	<0.01	<0.01
Administration of intravenous thrombolysis to eligible patients	0.92	0.90	<0.01	<0.01
Door-to-needle time within one hour in patients receiving thrombolysis	0.54	0.71	<0.01	<0.01
Quality of care: measures that vary significantly across the week				
Assessment by a stroke specialist consultant physician within 12 hours	<0.01	<0.01	<0.01	<0.01
Assessment by a stroke specialist consultant physician within 24 hours	<0.01	<0.01	<0.01	<0.01
Admission to a stroke unit within four hours	<0.01	<0.01	<0.01	<0.01
Physiotherapist assessment within 72 hours	<0.01	<0.01	<0.01	<0.01
Occupational Therapist assessment within 72 hours	<0.01	<0.01	<0.01	<0.01
Swallow assessment by a SLT within 72 hours	<0.01	<0.01	<0.01	<0.01
Communication assessment by a SLT within 72 hours	<0.01	<0.01	<0.01	<0.01
Physiotherapist assessment within 24 hours	<0.01	<0.01	<0.01	<0.01
Occupational Therapist assessment within 24 hours	<0.01	<0.01	<0.01	<0.01
Communication assessment by a SLT within 24 hours	<0.01	<0.01	<0.01	<0.01
Outcome measures				
Mortality at three days	0.92	0.91	0.51	0.72
mRS score 3-6	0.18	0.15	<0.01	<0.01
mRS score 3-5*	0.20	0.20	0.02	0.02
Length of stay				
Length of stay in HASU	<0.01	<0.01		
Length of stay in hospital	<0.01	<0.01	<0.01	<0.01

Note.

Figures are p-values from Wald tests under the null hypothesis that the regression coefficients for every time period relative to the omitted time period were zero. All models include 42 time periods. SLT = Speech and Language Therapist. mRS = modified Rankin Scale. * Patients who died were not included.

Supplementary Figure 1. Outcomes across the 42 time periods in the week

(a) Mortality at three days

(b) Modified Rankin Scale score 3-6

(c) Modified Rankin Scale score 3-5*

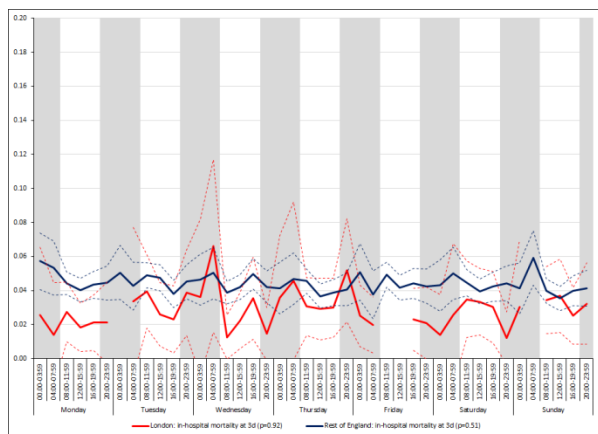


Figure S1(a). Mortality at three days

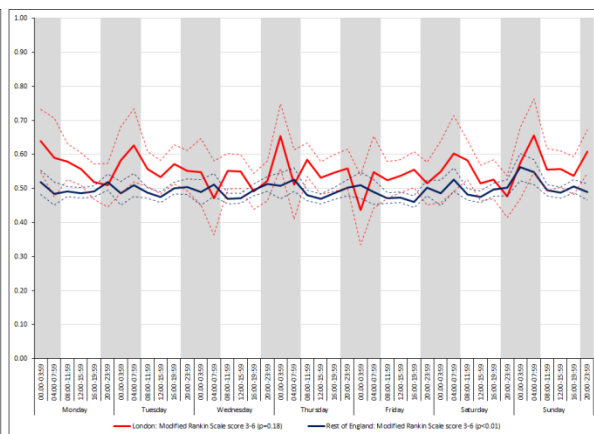


Figure S1(b). Modified Rankin Scale score 3-6

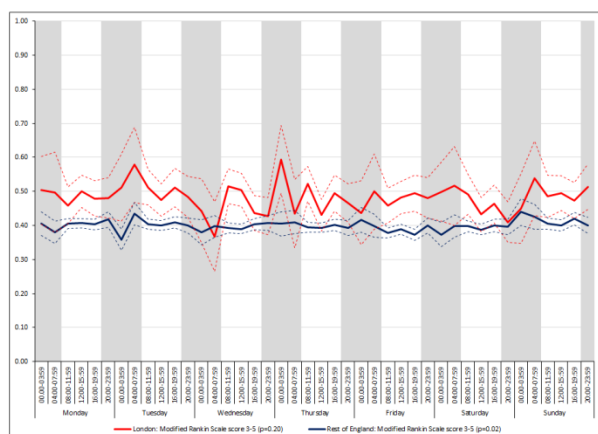


Figure S1(c). Modified Rankin Scale score 3-5

Note.

Figures are average predicted probabilities of each outcome in each time period controlling for the covariates. Dashed lines represent lower and upper 95% confidence limits. Shaded areas indicate 20:00-07:59 each day of the week. P-values indicate significant variation ($p < 0.05$) or not for each measure over the week in each region. Gaps in the solid line indicate that no patients in that time period achieved that outcome. Note the scaling of the y-axis in Figure 6(a) is not from zero to one.

Supplementary Figure 2. Length of stay across the 42 time periods in the week

(a) Length of stay in HASU

(b) Length of stay in hospital

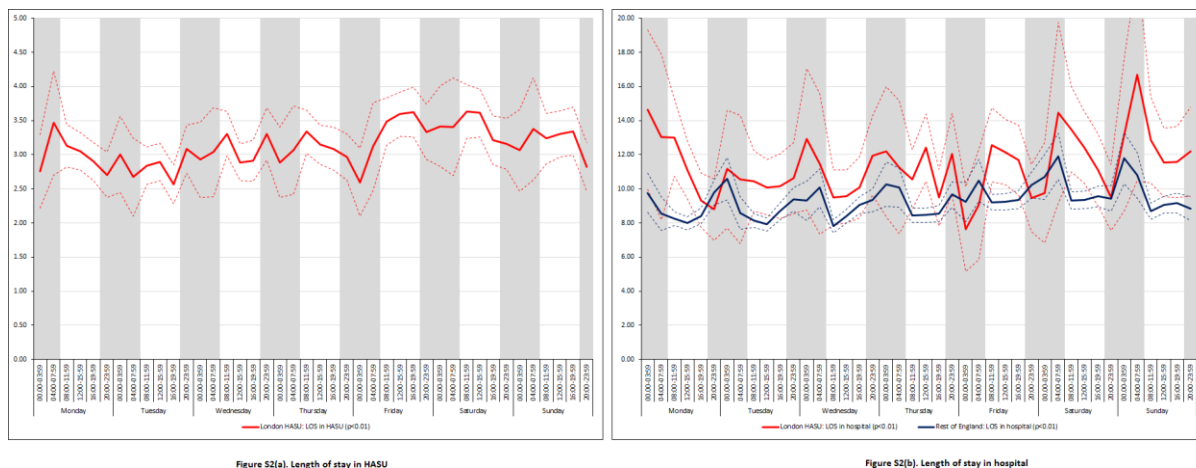


Figure S2(a). Length of stay in HASU

Figure S2(b). Length of stay in hospital

Note.

Figures are average predicted probabilities of each outcome in each time period controlling for the covariates. Dashed lines represent lower and upper 95% confidence limits. Shaded areas indicate 20:00-07:59 each day of the week. P-values indicate significant variation ($p < 0.05$) or not for each measure over the week in each region.

Supplementary Figure 3. Quality of care across the 42 time periods in the week controlling for NIHSS score instead of level of consciousness: measures linked to performance standards for London HASUs

(a) Brain scan within one hour

(b) Brain scan within 12 hours

(c) Dysphagia screen within four hours

(d) Assessment by a nurse trained in stroke management within 24 hours

(e) Administration of intravenous thrombolysis to eligible patients

(f) Door-to-needle time within one hour in patients receiving thrombolysis



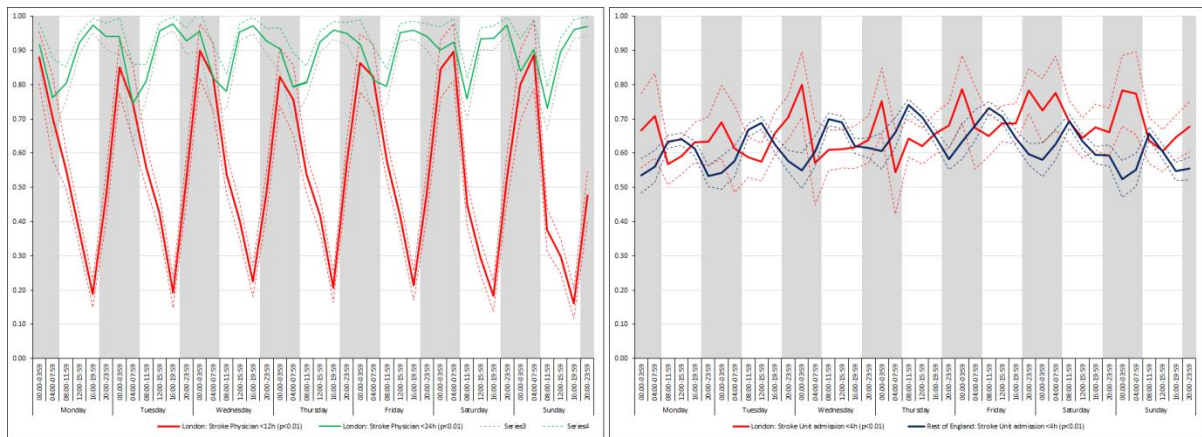
Note.

Figures are average predicted probabilities of each outcome in each time period controlling for the covariates. Dashed lines represent lower and upper 95% confidence limits. Shaded areas indicate 20:00-07:59 each day of the week. P-values indicate significant variation ($p < 0.05$) or not for each measure over the week in each region. Gaps in the solid line indicate that all patients in that time period achieved that outcome.

Supplementary Figure 4. Quality of care across the 42 time periods in the week: variation by time of day but not day of the week controlling for NIHSS score instead of level of consciousness

a) Assessment by a stroke specialist consultant physician within 12 and 24 hours in London HASUs

(b) Admission to a stroke unit within four hours



(a) Assessment by a stroke specialist consultant physician in London HASUs

(b) Admission to a stroke unit within four hours

Note.

Figures are average predicted probabilities of each outcome in each time period controlling for the covariates. Dashed lines represent lower and upper 95% confidence limits. Shaded areas indicate 20:00-07:59 each day of the week. P-values indicate significant variation ($p < 0.05$) or not for each measure over the week in each region. Figure 3(a) includes two measures for London HASUs.

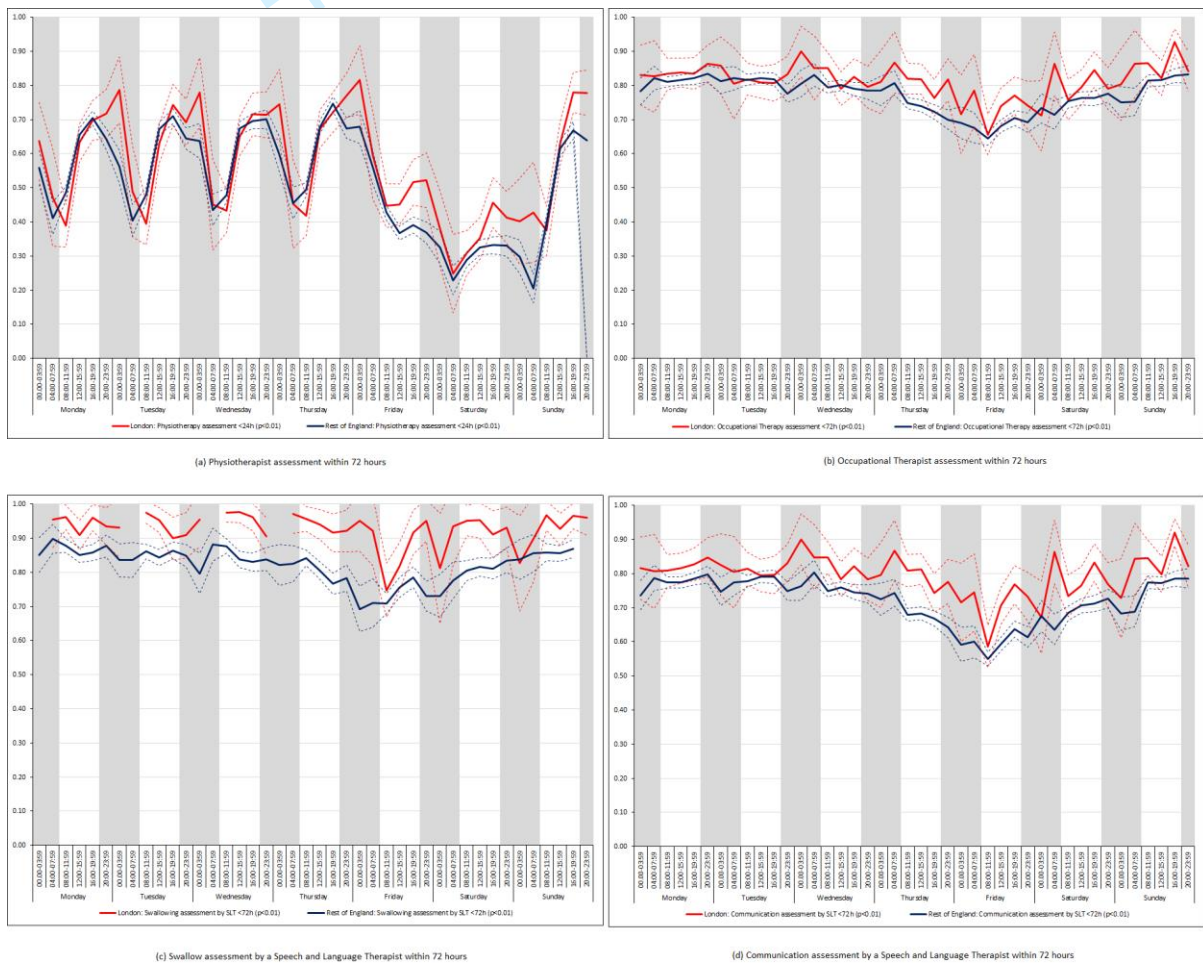
Supplementary Figure 5. Quality of care across the 42 time periods in the week controlling for NIHSS score instead of level of consciousness: variation by day of the week but not time of day

(a) Physiotherapist assessment within 72 hours

(b) Occupational Therapist assessment within 72 hours

(c) Swallow assessment by a Speech and Language Therapist within 72 hours

(d) Communication assessment by a Speech and Language Therapist within 72 hours



Note.

Figures are average predicted probabilities of each outcome in each time period controlling for the covariates. Dashed lines represent lower and upper 95% confidence limits. Shaded areas indicate 20:00-07:59 each day of the week. P-values indicate significant variation ($p < 0.05$) or not for each measure over the week in each region. Gaps in the solid line

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3 indicate that no patients in that time period achieved that outcome. SLT = Speech and
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For peer review only

Supplementary Figure 6. Quality of care across the 42 time periods in the week:

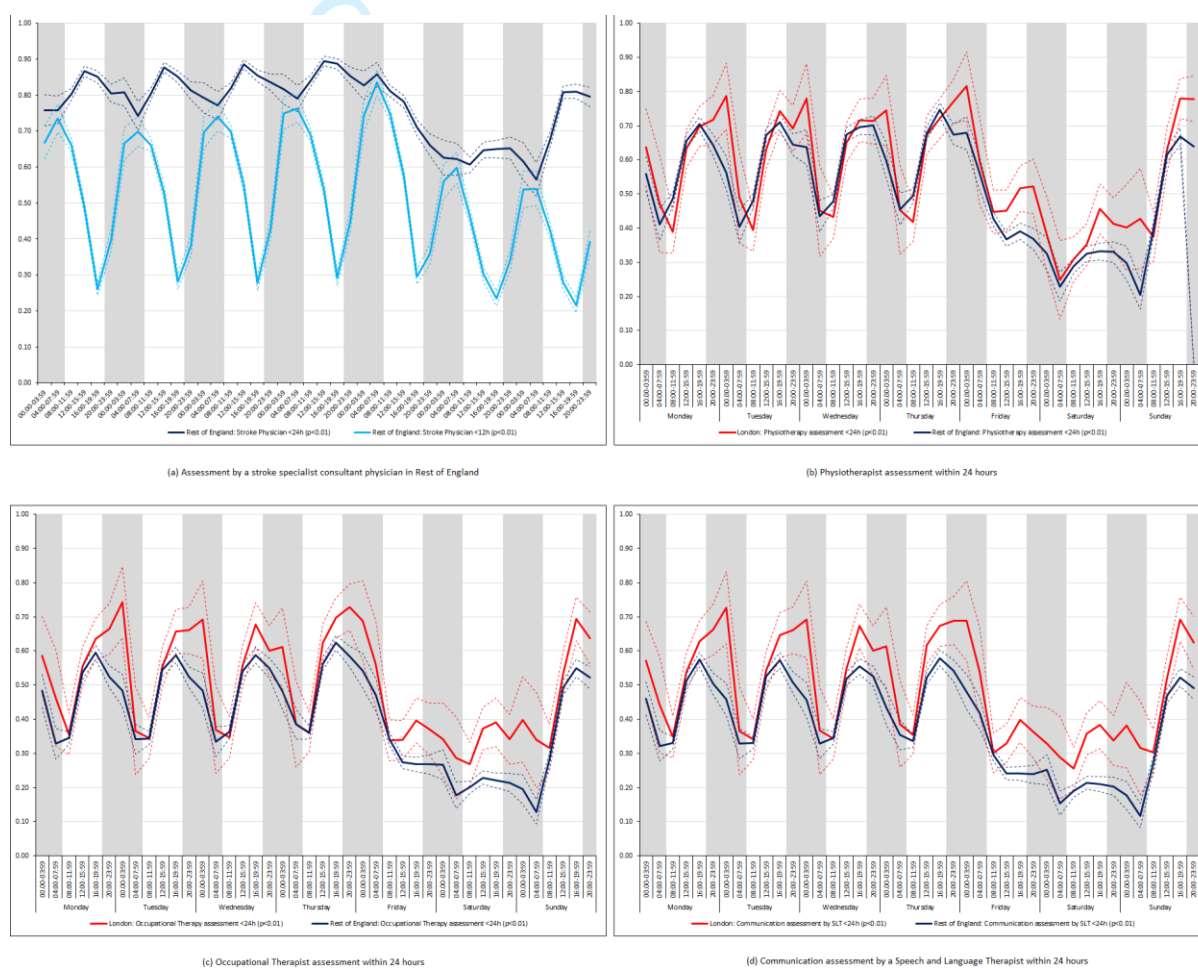
variation by time of day and day of the week controlling for NIHSS score instead of level of consciousness

(a) Assessment by a stroke specialist consultant physician within 12 and 24 hours in Rest of England

(b) Physiotherapist assessment within 24 hours

(c) Occupational Therapist assessment within 24 hours

(d) Communication assessment by a Speech and Language Therapist within 24 hours



Note.

Figures are average predicted probabilities of each outcome in each time period controlling for the covariates. Dashed lines represent lower and upper 95% confidence limits. Shaded areas indicate 20:00-07:59 each day of the week. P-values indicate significant variation

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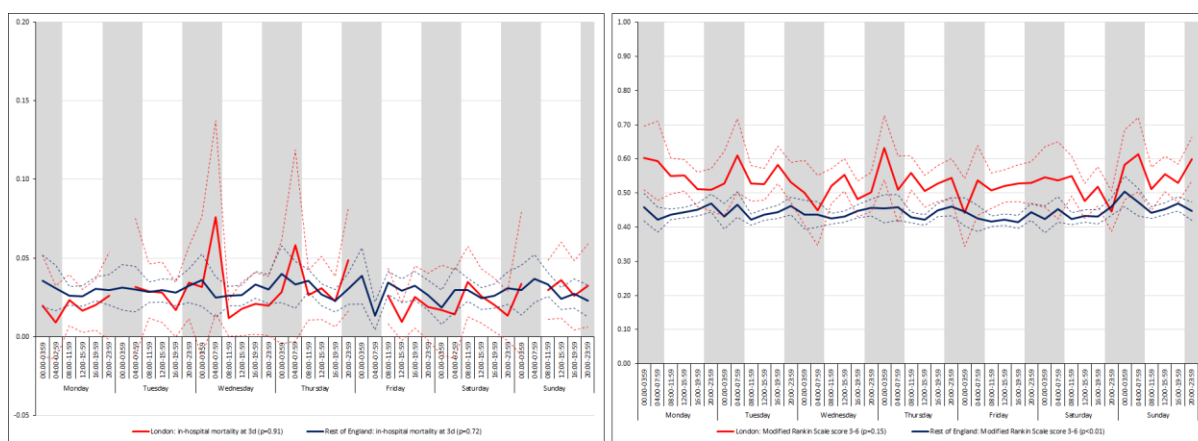
For peer review only

Supplementary Figure 7. Outcomes across the 42 time periods in the week controlling for NIHSS score instead of level of consciousness

(a) Mortality at three days

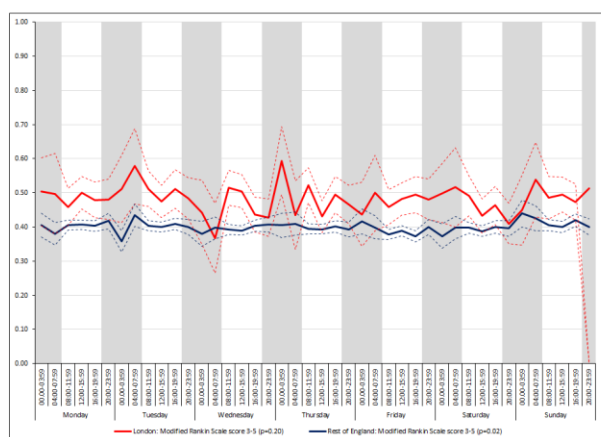
(b) Modified Rankin Scale score 3-6

(c) Modified Rankin Scale score 3-5*



(a) Mortality at three days

(b) Modified Rankin Scale score 3-6

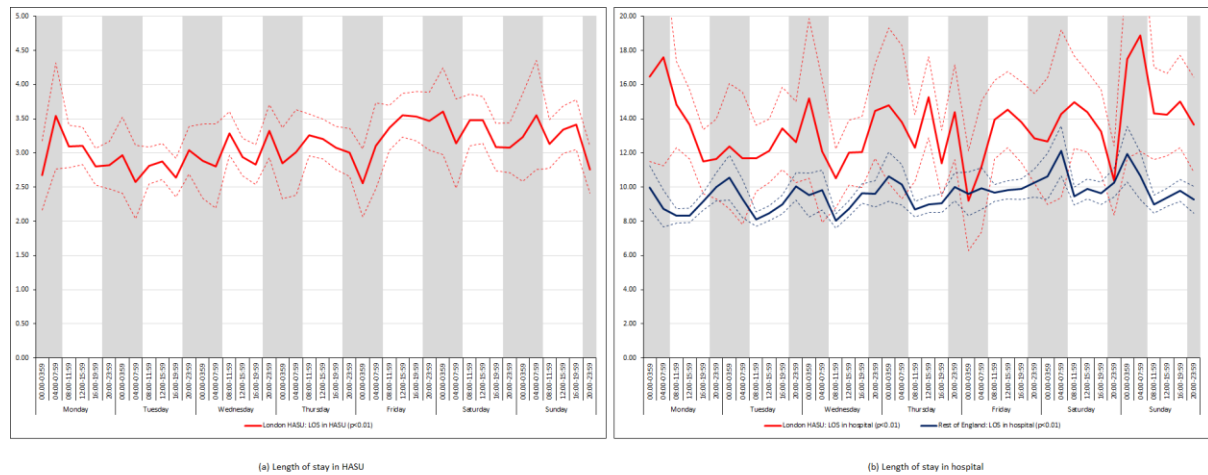


(c) Modified Rankin Scale score 3-5*

Note.

Figures are average predicted probabilities of each outcome in each time period controlling for the covariates. Dashed lines represent lower and upper 95% confidence limits. Shaded areas indicate 20:00-07:59 each day of the week. P-values indicate significant variation ($p < 0.05$) or not for each measure over the week in each region. Gaps in the solid line indicate that no patients in that time period achieved that outcome. Note the scaling of the y-axis in Figure 6(a) is not from zero to one.

Supplementary Figure 8. Length of stay across the 42 time periods in the week controlling for NIHSS score instead of level of consciousness



(a) Length of stay in HASU

(b) Length of stay in hospital

Note.

Figures are average predicted probabilities of each outcome in each time period controlling for the covariates. Dashed lines represent lower and upper 95% confidence limits. Shaded areas indicate 20:00-07:59 each day of the week. P-values indicate significant variation ($p < 0.05$) or not for each measure over the week in each region.

STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of cohort studies

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(a) Indicate the study’s design with a commonly used term in the title or the abstract	Title: P1; Abstract: P1-2
		(b) Provide in the abstract an informative and balanced summary of what was done and what was found	P1-2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	P3-4
Objectives	3	State specific objectives, including any prespecified hypotheses	P4, paragraph 3
Methods			
Study design	4	Present key elements of study design early in the paper	P4, paragraph 3; P5-6
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	P5, paragraph 1
Participants	6	(a) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up	P5, paragraph 1
		(b) For matched studies, give matching criteria and number of exposed and unexposed	Not applicable
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	P5, paragraph 2; P6, paragraphs 1-3; P7, paragraph 1
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	P5, paragraphs 1&2; P6, paragraphs 1&2
Bias	9	Describe any efforts to address potential sources of bias	P6, paragraph 3; P7, paragraph 1
Study size	10	Explain how the study size was arrived at	P5, paragraph 1; P6, paragraph 1
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	P5, paragraph 2 P6, paragraph 1-3; P7, paragraph 1

Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding	P6, paragraph 3; P7, paragraph 1
		(b) Describe any methods used to examine subgroups and interactions	Not applicable
		(c) Explain how missing data were addressed	Not applicable
		(d) If applicable, explain how loss to follow-up was addressed	Not applicable
		(e) Describe any sensitivity analyses	P7, paragraph 1; Supplementary Table 3
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	P8, paragraph 1; Supplementary Table 1
		(b) Give reasons for non-participation at each stage	Not applicable
		(c) Consider use of a flow diagram	Not applicable
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	P8, paragraph 1; Supplementary Table 1
		(b) Indicate number of participants with missing data for each variable of interest	Not applicable
		(c) Summarise follow-up time (eg, average and total amount)	Not applicable
Outcome data	15*	Report numbers of outcome events or summary measures over time	Supplementary Table 2
Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	Supplementary Table 2
		(b) Report category boundaries when continuous variables were categorized	Not applicable
		(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	Supplementary Table 2
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	Supplementary Table 3
Discussion			
Key results	18	Summarise key results with reference to study objectives	P11
Limitations			

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Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	P12-13
Generalisability	21	Discuss the generalisability (external validity) of the study results	P13-15
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	P20, paragraph 1

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at <http://www.plosmedicine.org/>, Annals of Internal Medicine at <http://www.annals.org/>, and Epidemiology at <http://www.epidem.com/>). Information on the STROBE Initiative is available at www.strobe-statement.org.

BMJ Open

Variation in quality of acute stroke care by day and time of admission: prospective cohort study of weekday and weekend centralised hyperacute stroke unit care and non-centralised services

Journal:	<i>BMJ Open</i>
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Complete List of Authors:	Melnychuk, Mariya; University College London, Department of Applied Health Research; Universidad Rey Juan Carlos, Morris, Stephen; University College London, Department of Applied Health Research Black, Georgia; University College London, Applied Health Research; Dr Ramsay, Angus I. G.; University College London, Department of Applied Health Research Eng, Jeannie; Barts Health NHS Trust Rudd, Anthony; Royal College of Physicians, London, Clinical Effectiveness and Evaluation Unit Baim-Lance, Abigail; Center for Innovation in Mental Health (CIMH), CUNY 55 W. 125th St. - 6th Floor New York, NY 10027 Brown, Martin; UCL, Neurology Fulop, Naomi; University College London, Applied Health Research Simister, Robert; Comprehensive Stroke Service, University College London Hospitals NHS Foundation Trust, London UK
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Secondary Subject Heading:	Health services research
Keywords:	HEALTH ECONOMICS, Health economics < HEALTH SERVICES ADMINISTRATION & MANAGEMENT, Stroke < NEUROLOGY

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Manuscripts

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3 TITLE: Variation in quality of acute stroke care by day and time of admission: prospective cohort
4 study of weekday and weekend centralised hyperacute stroke unit care and non-centralised
5 services
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Word count: 5704 (excluding tables); 6170 (with tables)

ABSTRACT

Objective: To investigate variations in quality of acute stroke care and outcomes by day and time of admission in London hyperacute stroke units compared with the rest of England.

Design: Prospective cohort study using anonymised patient-level data from the Sentinel Stroke National Audit Programme.

Setting: Acute stroke services in London hyperacute stroke units and the rest of England.

Participants: 68 239 patients with a primary diagnosis of stroke admitted between January and December 2014.

Interventions: Hub-and-spoke model for care of suspected acute stroke patients in London with performance standards designed to deliver uniform access to high-quality hyperacute stroke unit care across the week.

Main outcome measures: 16 indicators of quality of acute stroke care, mortality at three days after admission to the hospital, disability at the end of the inpatient spell, length of stay.

Results: There was no variation in quality of care by day and time of admission to the hospital across the week in terms of stroke nursing assessment, brain scanning, and thrombolysis in London hyperacute stroke units, nor was there variation in three-day mortality or disability at hospital discharge (all p-values>0.05). Other quality of care measures significantly varied by day and time of admission across the week in London (all p-values<0.01). In the rest of England there was variation in all measures by day and time of admission across the week (all p-values<0.01), except for mortality at three days (p-value>0.05).

Conclusions:

The London hyperacute stroke unit model achieved performance standards for “front door” stroke care across the week. The same benefits were not achieved by other models of care in the rest of England. There was no weekend effect for mortality in London or the rest of the

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3 England. Other aspects of care were not constant across the week in London hyperacute stroke
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5 units, indicating some performance standards were perceived to be more important than others.
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9 **Article summary**

10 ***Strengths and weaknesses***

- 13 • We used a large national dataset containing detailed information on quality of stroke
14 care, outcomes, and patient characteristics.
- 15
16 • We examined whether time of admission was related to quality of care using a
17 comprehensive set of indicators from across the acute stroke care pathway to reflect the
18 time-critical nature of acute stroke care.
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20 • Our outcomes were stroke short-term mortality and disability, buy we were unable to
21 measure long-term outcomes as these were not available in SSNAP.
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INTRODUCTION

There is conflicting evidence as to whether or not patients presenting with acute stroke symptoms receive lower quality of care and have worse outcomes if admitted to hospital outside of normal weekday working hours or at weekends (the “weekend effect”). Some studies have shown that acute stroke patients admitted at weekends have lower quality of care[1,2] and higher mortality[1–10], while others have shown the opposite[11–14]. Evaluation of these studies is further complicated by recent evidence that stroke incidence reporting at the weekend may be unreliable in older studies[15]. Recent work based upon data from the Stroke Sentinel National Audit Programme (SSNAP) dataset further shows that care quality and outcomes in acute stroke vary across the week, and concluded that binary comparisons of weekend versus weekday or in-hours versus out-of-hours processes and effects oversimplify more likely variations by day of week and time of day [16]. Further, no studies have investigated the impact of time of admission on disability following a stroke.

If there is lower quality of care and there are worse outcomes at the weekend these could be linked to reduced staffing levels[17]; for acute stroke care, nurse staffing levels at weekends has been shown to be a significant predictor of mortality[18], while evidence from the United States suggests that specialised stroke units, with round-the-clock availability of specialist stroke teams and rapid access to imaging and thrombolysis, reduce variation in quality of care and outcomes across the week[19–21].

In 2010 London centralised its acute stroke services using a hub-and-spoke network model [22] [23,24]. Out of 34 hospitals that had historically provided acute stroke care [25], 8 were selected as host sites for Hyperacute Stroke Units (HASUs). The HASU model involved the London Ambulance Service taking all patients with suspected stroke symptom onset within 48 hours to one of the eight HASUs[26]. HASUs receive patients with suspected stroke and routinely provide immediate assessment by specialised stroke assessment teams, access to immediate brain imaging, and the immediate delivery of intravenous thrombolysis where appropriate. Acute stroke

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3 patients seen at other medical facilities were similarly transferred as an emergency to a HASU.
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5 The aim of the HASUs was to provide specialised care for all acute stroke patients during the first
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7 72 hours after onset of stroke. After 72 hours, patients requiring ongoing inpatient treatment are
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9 transferred to one of the twenty-four Acute Stroke Units in London linked to HASUs. Eight of these
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11 were in the same hospital trust as a HASU[27].
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14 Performance standards for HASUs, linked to payments, were initially set by Healthcare for
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16 London[28] and subsequently the London Strategic Clinical Networks to maintain high quality of
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18 care across the HASU stay. Some standards were set to provide rapid access to time-critical
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20 “front door” measures, e.g., dysphagia screen within four hours of admission, brain scans within
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22 one hour, administration of thrombolysis to eligible patients[26] within 60 minutes). Other
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24 standards were set with less stringent time constraints (e.g., stroke specialist consultant physician
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26 assessment within 24 hours, physiotherapist assessment within 72 hours).
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29 On average across all patients, the quality of acute stroke care in London increased as a result
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31 of the centralisation and was significantly higher than elsewhere in England on all measures
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33 analysed [29], and mortality decreased[30]. Following these findings, the aim of this study was to
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35 investigate variations in the quality of acute stroke care and outcomes by day and time of
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37 admission in London HASUs and the rest of England. We used national audit data for all patients
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39 in England who had a stroke during a 12-month period recorded by the Sentinel Stroke National
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41 Audit Programme (SSNAP)[31]. We hypothesised were that there would be less variation across
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43 the week in care quality measures in within London HASUs compared with the variation in the
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45 rest of England, and that this would also translate into less variation in outcomes in London
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47 HASUs.
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55 **METHODS**

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Data and measures

We obtained anonymised patient-level data from the Sentinel Stroke National Clinical Audit Programme (SSNAP)[31], for all patients in England with a primary diagnosis of stroke (ischaemic stroke or primary intracerebral haemorrhage) between 1 January and 31 December 2014. SSNAP collects data on clinical characteristics, care quality (from the time of admission up to 6 months after stroke) and outcomes for all stroke patients admitted to acute care hospitals in England[32–34]. During our study period the case ascertainment in the SSNAP, which is calculated as the proportion of all acute stroke patients admitted to hospitals, for England was estimated to be 90%.[35] We excluded patients treated at hospitals in Wales from our analysis because for Wales the case ascertainment was estimated to be 60%[33].

The following quality of care indicators were measured from time of hospital admission (or onset of stroke symptoms for those who were already in hospital): brain scan within one hour and within 12 hours; dysphagia screen within four hours; assessment by a nurse trained in stroke management within 24 hours; administration of intravenous thrombolysis to eligible patients; door-to-needle time within one hour in patients receiving thrombolysis; assessment by a stroke specialist consultant physician within 12 hours* and within 24 hours; admission to a stroke unit within four hours; assessments by a Physiotherapist within 24 hours* and within 72 hours; by Occupational Therapist within 24 hours* and within 72 hours; and by Speech and Language Therapist within 24 hours* and within 72 hours. These measures are quality indicators routinely reported by SSNAP; we also included measures (marked with a *) with more stringent time constraints to reflect the time-critical nature of acute stroke care. Outcomes were measured as whether or not the patient died within three days and disability using the modified Rankin Scale (mRS) score 0-2 versus 3-6 (moderate, moderately severe or severe disability or death) at the end of the inpatient stay. We also analysed mRS score 0-2 versus 3-5 at the end of the inpatient

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3 stay, excluding patients who died. Mortality data beyond hospital discharge were not available in
4 SSNAP; we therefore measured mortality up to three days after admission to minimise the number
5 of missed deaths. We analysed length of stay (LOS) in the HASU (in London only) and LOS in
6 hospital. The denominators used for each measure were consistent with the SSNAP key
7 indicators[36]. Most outcomes were measured for all patients, but there were exceptions: patients
8 who were medically unwell or refused to be screened were excluded from the dysphagia screen
9 measure; only patients with ischaemic stroke who met the Royal College of Physicians guideline
10 minimum threshold for thrombolysis were included in the thrombolysis rate; door-to-needle times
11 included only those who received thrombolysis with a final diagnosis of stroke; patients who were
12 persistently medically unwell, declined to be assessed or had no relevant deficit were excluded
13 from the therapy performance measures.

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15 To examine variations across the week we initially used a flexible specification of time of
16 admission, measured in six four-hour periods from 00:00 to 03:59, 04:00 to 07:59, 08:00 to 11:59,
17 12:00 to 15:59, 16:00 to 19:59, 20:00 to 23:59 for every day of the week (42 periods). We also
18 created a more restrictive measure to examine broad trends across the week: Monday to Friday
19 08:00 to 19:59; Monday to Friday 20:00 to 07.59; Saturday and Sunday 08:00 to 19:59; Saturday
20 and Sunday 20:00 to 07.59(four periods) following Bray et al.[16] who found variations across the
21 week with both specifications.

22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 **Statistical analysis**

44 We ran patient-level logistic regressions, regressing each measure against time period of
45 admission. For LOS we used parametric survival models (modelled as time to event of discharge)
46 assuming a lognormal survival distribution. We ran separate models for London and the rest of
47 England. In every model we controlled for sex, age (continuous variable), ethnic group (six
48 categories), type of stroke (infarction or primary intracerebral haemorrhage), comorbidities prior
49 to admission (five options), mRS before stroke (0 to 2, 3 to 5), level of consciousness on arrival
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3 at the hospital (four categories), method of admission to the hospital (three categories), time from
4 onset of stroke symptoms to admission (four categories), month of admission (12 categories),
5 and hospital Trust. When analysing mRS scores 0-2 versus 3-5 at the end of the inpatient spell
6 we additionally controlled for the number of days after admission at which the mRS score was
7 measured. We were unable to do this for the analysis of mRS score 0-2 versus 3-6 as date of
8 death was not available. We tested for statistically significant variations across the week using
9 Wald tests and reported the results as joint p-values under the null hypothesis that the regression
10 coefficients for every time period relative to the omitted time period were zero. We calculated the
11 average predicted probability of each outcome (predicted median LOS in the case of the LOS
12 variables) in each time period controlling for the covariates. Patients admitted with a diagnosis of
13 acute stroke in London who were not treated in a HASU were excluded (6% all London patients
14 in our dataset were not treated in a HASU). P-values < 0.05 were considered to be statistically
15 significant. Data on National Institutes of Health Stroke Scale (NIHSS) score, a validated measure
16 of stroke severity on a scale from 0 (no stroke symptoms) to 42 (severe stroke), were available
17 for 93% patients in London HASUs and 77% patients in the rest of England. Due to the extent of
18 missing NIHSS data, in our main analysis we controlled for stroke severity using level of
19 consciousness on arrival at the hospital (one component of NIHSS); we then reran all analyses
20 controlling for NIHSS on arrival at the hospital on the smaller sample instead of level of
21 consciousness on arrival. The findings using NIHSS score on arrival were qualitatively the same
22 and are presented in the Supplementary Figures S1-S6.
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47 **Patient and public involvement**

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49 Two stroke patient representatives contributed to the design of our study protocol and
50 development of the research questions; they also contributed to discussions of interim findings
51 presented at study steering committee meetings in June 2015 and July 2016, raising issues
52 related to variation in quality of care and mortality, which we incorporated into our analysis.
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3 They were consulted on the methods for disseminating the outputs of this study and ensure that
4 we were addressing questions and communicating lessons in a meaningful way. The findings of
5 this research will be disseminated to the relevant patient community in an accessible way.
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9 **Results**

10 The study cohort comprised 68 239 patients (7094 from London HASUs, 61 145 from the rest of
11 England) from 208 hospitals (eight London HASUs, 200 hospitals from the rest of England). The
12 number of admissions varied across the week, with similar trends for London HASUs and the rest
13 of England: there were more admissions during the day than at night; more admissions in the day
14 during the week compared with during the day at the weekend; similar numbers of admissions
15 during the night each day; and the highest number of admissions was during the day on Monday
16 (Figure 1). In London HASUs the total number of admissions across all hospitals during the 12-
17 month period ranged from 47-297 across the 42 time periods; in the rest of England it ranged
18 from 398-2709. There was slightly higher proportion of men than women in London compared
19 with the rest of England, the mean age was slightly lower, and patients were less likely to be white
20 (all p-values<0.001; Table 1). There were also differences in the pattern of pre-existing
21 comorbidities, London HASUs case mix was characterised by a larger proportion of people having
22 congestive heart failure, hypertension and diabetes, while in the rest of England, patients were
23 more likely to have atrial fibrillation and previously have had a stroke or TIA (all p-values<0.001).
24 mRS before stroke was higher in London HASUs compared to the rest of England, suggesting
25 there were more people with at least moderate disability (<0.001). A higher proportion of patients
26 arrived to the hospital in an ambulance in London compared to the rest of England (<0.001). A
27 slightly higher proportion of patients was admitted to the hospital in London compared to the rest
28 of England within more than six hours from onset of stroke symptoms, but the proportion of the
29 patients with unknown time of symptoms' onset was also lower in London (<0.001).
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56 **Table 1. Patient characteristics**

	London HASUs (n=7094)	Rest of England (n=61 145)	Effect size	P-value
Sex				0.0001
Male	3719 (52%)	30 536 (50%)	2%	
Female	3375 (48%)	30 609 (50%)	-2%	
Age, years (mean (std.dev.))	72 (15)	75 (13)	-3 years	<0.0001
Ethnic group				<0.0001
White	4332 (61%)	56 221 (92%)	-31%	
Mixed	72 (1%)	141 (<1%)	<1%	
Black	650 (9%)	1272 (2%)	7%	
Asian	505 (7%)	362 (<1%)	6%	
Other	526 (7%)	358 (<1%)	6%	
Not available	1009 (14%)	2791 (5%)	9%	
Type of stroke				0.0531
Infarction	6252 (88%)	54 355 (89%)	-1%	
Primary Intracerebral Haemorrhage	842 (12%)	6790 (11%)	1%	
Comorbidities prior to admission				
Congestive Heart Failure	439 (6%)	3204 (5%)	1%	0.0008
Hypertension	4284 (60%)	32 447 (53%)	7%	<0.0001
Atrial fibrillation	1229 (17%)	12 655 (21%)	-4%	<0.0001
Diabetes	1705 (24%)	12 024 (20%)	4%	<0.0001
Stroke/TIA	1688 (24%)	16 752 (27%)	-4%	<0.0001
mRS score before stroke				<0.0001
Slight or no disability (0-2)	5552 (78%)	49 574 (81%)	-3%	
At least moderate disability (3-5)	1542 (22%)	11 571 (19%)	3%	
Level of consciousness on arrival at the hospital**				0.0263

Alert	5991 (84%)	51 230 (84%)	0%	
Not alert; but respond to minor stimulation	663 (9%)	5724 (9%)	0%	
Not alert; requires repeated stimulation	281 (4%)	2438 (4%)	0%	
Unresponsive	159 (2%)	1753 (3%)	-1%	
NIHSS on arrival at the hospital, score (median (IQR))	5 (2-11)	4 (2-9)	1 IQR	<0.0001
Method of admission to the hospital				<0.0001
Already inpatient	173 (2%)	3288 (5%)	-3%	
Ambulance	5966 (84%)	47 096 (77%)	7%	
Walk-in	955 (14%)	10 761 (18%)	-4%	
Time from onset of stroke symptoms to admission				<0.0001
<180 minutes	2741 (39%)	24 233 (40%)	-1%	
180-359 minutes	759 (11%)	5871 (10%)	1%	
≥360 minutes	1516 (21%)	10 773 (18%)	3%	
Time of onset not known	2078 (29%)	20 268 (33%)	4%	

Note. Figures are n (%) except for age, which is mean (std.dev.), and NIHSS on arrival at the hospital, which is median (IQR). mRS = modified Rankin Scale. IQR = interquartile range. The sample with NIHSS scores on arrival was n=6571 in London HASUs and n=47 126 in the rest of England. ** Level of consciousness scores taken from admission NIHSS score (Question 1a). P-value threshold adjusted for multiple testing is 0.0038

There was no significant variation in care quality across the 42 time periods in any of the measures relating to brain scanning, stroke nursing care and thrombolysis in London HASUs (all p-values>0.05), but there was significant variation in these measures in the rest of England (all p-values<0.001; Figure 2). For each measure in the rest of England there was variation by

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3 time of day every day, with the likelihood of receiving these interventions worse for patients
4 admitted at night.
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7 For all the other quality of care measures there was significant variation by time period of
8 admission across the week both in London and the rest of England (all p-values <0.001). There
9 were three patterns of variation. (1) Variation by time of day but not day of the week was
10 observed for assessment by a stroke specialist consultant physician within 12 hours and within
11 24 hours in London HASUs and admission to a stroke unit within four hours in London and the
12 rest of England (Figure 3). With this pattern similar variations during the day were found each
13 day of the week. (2) Variation by day of the week but not time of day was observed for
14 assessments by a Physiotherapist, Occupational Therapist, and Speech and Language
15 Therapist within 72 hours in London HASUs and the rest of England (Figure 4). With this pattern
16 care quality was worse for patients admitted on Friday. (3) Variation by time of day and day of
17 the week was observed for assessment by a stroke specialist consultant physician within 12
18 hours and within 24 hours in the rest of England and for therapist assessments within 24 hours
19 in London HASUs and the rest of England (Figure 5). With this pattern, there was variation
20 during the day on Monday to Friday and care quality was worse at weekends.
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23 There was no significant variation in outcomes across the 42 time periods in London HASUs (all
24 p-values>0.05; Figure 6a). In the rest of England there was significant variation in disability (p-
25 value<0.001 for mRS scores 0-6, and p-value=0.022 for mRS scores 0-5), Figures 6b and 6c)
26 but not mortality (p-value>0.05); mRS scores at the end of the inpatient episode varied by time
27 of admission on every day and were worse among patients admitted at night. It is worth noting
28 that, based on the point estimates in each period, it appears there is more variation in mRS
29 scores in London HASUs. One reason why the variation in London HASUs was not statistically
30 significant might be because of the larger uncertainty at each time point.
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33 There was significant variation in LOS across the 42 time periods in London HASUs and the
34 rest of England both in terms of HASU LOS and total inpatient LOS (p-value<0.001 for London
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3 HASUs LOS, p-value=0.005 for total LOS in London hospitals and p-values<0.001 for LOS in
4 the rest of England hospitals; Figure 7). Median HASU LOS in London varied between 2.6 and
5 3.6 days across the 42 time periods. It was difficult to detect a trend by day and time of
6 admission in London HASU LOS and inpatient LOS. In the rest of England median inpatient
7 LOS was longer among those admitted at night.
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13 Results using the four time period specification (Table 2) were broadly similar to those with the
14 42 time periods, but pooling time periods meant that the extent of variation during the week for
15 some of the quality of care measures was reduced (for unadjusted figures and p-values, see
16 Supplementary Table 1 and Supplementary Table 2 respectively). In these analyses there was
17 no significant variation in London in quality of care measures linked to specialist stroke nurse
18 assessments, rapid access to brain scans and administration of thrombolysis to eligible patients
19 for London HASUs, nor was there in the outcome measures. With the exception of mortality at
20 three days and mRS scores 3-5 at the end of the inpatient spell, all of these measured varied
21 significantly in the rest of England. LOS varied significantly for London HASUs and the rest of
22 England; for London HASUs pooling time periods more clearly indicates longer LOS among
23 patents admitted at the weekend; for the rest of England the trends were as in the 42 time
24 period model, with longer LOS among patients admitted at night.
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39 Results were similar when controlling for NIHSS score on arrival at hospital instead of level of
40 consciousness on the smaller sample of patients with non-missing NIHSS data: results with p-
41 values<0.05 and trends across the week were unchanged (Figures S1-S6 and Table 3 in the
42 Supplementary materials).
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Table 2. Quality of care and outcomes across four periods in the week

	London HASUs					Rest of England				
	Weekday	Weekend	Weekday	Weekend	p-value	Weekday	Weekend	Weekday	Weekend	p-value
	08:00-19:59	08:00-19:59	20:00-07:59	20:00-07:59		08:00-19:59	08:00-19:59	20:00-07:59	20:00-07:59	
Quality of care measures that do not vary across the week in London HASUs										
Brain scan within one hour	0.60 (0.58-0.61)	0.61 (0.58-0.63)	0.63 (0.60-0.65)	0.65 (0.61-0.68)	0.0344	0.44 (0.44-0.45)	0.41 (0.40-0.41)	0.40 (0.39-0.40)	0.39 (0.38-0.41)	<0.0001
Brain scan within 12 hours	0.97 (0.96-0.97)	0.96 (0.95-0.97)	0.95 (0.94-0.96)	0.95 (0.93-0.96)	0.0093	0.90 (0.90-0.90)	0.88 (0.87-0.89)	0.84 (0.83-0.84)	0.83 (0.82-0.84)	<0.0001
Dysphagia screen within four hours	0.74 (0.72-0.75)	0.75 (0.73-0.77)	0.77 (0.75-0.79)	0.79 (0.76-0.82)	0.0029	0.70 (0.70-0.71)	0.65 (0.64-0.66)	0.60 (0.59-0.61)	0.58 (0.56-0.59)	<0.0001
Assessment by a nurse trained in stroke management within 24 hours	0.96 (0.95-0.96)	0.94 (0.93-0.96)	0.95 (0.94-0.96)	0.95 (0.94-0.97)	0.1872	0.89 (0.88-0.89)	0.85 (0.85-0.86)	0.86 (0.86-0.87)	0.83 (0.82-0.84)	<0.0001
Administration of intravenous thrombolysis to eligible patients	0.88 (0.86-0.90)	0.88 (0.84-0.92)	0.86 (0.82-0.91)	0.88 (0.82-0.95)	0.9327	0.81 (0.80-0.82)	0.80 (0.78-0.82)	0.76 (0.74-0.78)	0.76 (0.72-0.79)	<0.0001
Door-to-needle time within one hour in patients receiving thrombolysis	0.84 (0.81-0.87)	0.89 (0.85-0.93)	0.79 (0.74-0.84)	0.84 (0.77-0.91)	0.0269	0.60 (0.59-0.62)	0.48 (0.45-0.50)	0.38 (0.35-0.40)	0.37 (0.33-0.41)	<0.0001
Quality of care: measures that vary significantly across the week										
Assessment by a stroke specialist consultant physician within 12 hours	0.39 (0.38-.40)	0.30 (0.27-0.32)	0.63 (0.61-0.66)	0.64 (0.60-0.68)	<0.0001	0.48 (0.48-0.49)	0.30 (0.29-0.31)	0.51 (0.51-0.52)	0.42 (0.41-0.44)	<0.0001
Assessment by a stroke specialist consultant physician within 24 hours	0.90 (0.89-0.91)	0.87 (0.85-0.89)	0.90 (0.88-0.91)	0.92 (0.90-0.94)	0.0043	0.80 (0.79-0.80)	0.65 (0.65-0.66)	0.75 (0.74-0.75)	0.62 (0.61-0.64)	<0.0001
Admission to a stroke unit within four hours	0.62 (0.60-0.63)	0.64 (0.61-0.66)	0.67 (0.65-0.70)	0.70 (0.67-0.74)	<0.0001	0.63 (0.63-0.63)	0.59 (0.58-0.60)	0.55 (0.54-0.56)	0.53 (0.52-0.55)	<0.0001

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1	Physiotherapist assessment within 72 hours	0.83 (0.82-0.84)	0.86 (0.84-0.88)	0.85 (0.83-0.87)	0.84 (0.81-0.87)	0.0693	0.82 (0.81-0.82)	0.83 (0.82-0.84)	0.81 (0.81-0.82)	0.82 (0.80-0.83)	0.0010
2	Occupational Therapist assessment within 72 hours	0.79 (0.78-0.80)	0.82 (0.80-0.84)	0.81 (0.79-0.82)	0.80 (0.76-0.83)	0.0967	0.73 (0.73-0.74)	0.75 (0.75-0.76)	0.73 (0.72-0.74)	0.73 (0.72-0.74)	<0.0001
3	Swallow assessment by a SLT within 72 hours	0.92 (0.91-0.93)	0.93 (0.91-0.95)	0.93 (0.91-0.95)	0.91 (0.88-0.95)	0.5838	0.80 (0.80-0.81)	0.81 (0.80-0.82)	0.79 (0.78-0.80)	0.80 (0.78-0.82)	0.0946
4	Communication assessment by a SLT within 72 hours	0.53 (0.51-0.54)	0.56 (0.54-0.59)	0.55 (0.53-0.58)	0.52 (0.48-0.56)	0.0739	0.33 (0.32-0.33)	0.36 (0.35-0.37)	0.34 (0.33-0.35)	0.34 (0.32-0.35)	<0.0001
5	Physiotherapist assessment within 24 hours	0.56 (0.54-0.57)	0.47 (0.45-0.50)	0.65 (0.63-0.68)	0.48 (0.44-0.52)	<0.0001	0.54 (0.54-0.55)	0.41 (0.40-0.41)	0.53 (0.52-0.54)	0.35 (0.34-0.37)	<0.0001
6	Occupational Therapist assessment within 24 hours	0.49 (0.47-0.50)	0.42 (0.40-0.45)	0.58 (0.55-0.60)	0.41 (0.37-0.45)	<0.0001	0.43 (0.42-0.43)	0.31 (0.30-0.31)	0.42 (0.42-0.43)	0.26 (0.25-0.27)	<0.0001
7	Communication assessment by a SLT within 24 hours	0.29 (0.28-0.31)	0.22 (0.20-0.24)	0.39 (0.37-0.42)	0.23 (0.20-0.27)	<0.0001	0.17 (0.17-0.17)	0.10 (0.09-0.10)	0.19 (0.18-0.20)	0.08 (0.07-0.09)	<0.0001
8	Outcome measures										
9	Mortality at three days	0.03 (0.02-0.03)	0.03 (0.02-0.04)	0.03 (0.02-0.04)	0.02 (0.01-0.03)	0.3310	0.04 (0.04-0.05)	0.04 (0.04-0.04)	0.05 (0.04-0.05)	0.05 (0.04-0.05)	0.1055
10	mRS score 3-6	0.55 (0.53-0.56)	0.55 (0.52-0.57)	0.55 (0.52-0.57)	0.56 (0.53-0.59)	0.8672	0.48 (0.48-0.48)	0.49 (0.48-0.50)	0.51 (0.50-0.51)	0.51 (0.50-0.52)	<0.0001
11	mRS score 3-5*	0.49 (0.47-0.50)	0.47 (0.45-0.50)	0.48 (0.45-0.50)	0.48 (0.44-0.51)	0.7497	0.40 (0.39-0.40)	0.40 (0.39-0.41)	0.40 (0.39-0.41)	0.40 (0.39-0.41)	0.3746
12	Length of stay										
13	Length of stay in HASU (days)	3.1 (3.0-3.2)	3.4 (3.2-3.5)	3.0 (2.9-3.1)	3.1 (2.9-3.3)	0.0007					
14	Length of stay in hospital (days)	10.8 (10.2-11.3)	12.1 (11.1-13.1)	10.8 (10.0-11.7)	11.5 (10.2-12.9)	0.0359	8.5 (8.4-8.6)	9.2 (9.0-9.4)	9.7(9.4-9.9)	10.1 (9.6-10.5)	<0.0001

Note.

Figures are average predicted probabilities (95% confidence intervals) of each measure in each time period controlling for the covariates. SLT = Speech and Language Therapist. mRS = modified Rankin Scale. * Patients who died were not included. P-value threshold adjusted for multiple testing is 0.0025 for London HASUs and 0.0024 for the rest of England.

DISCUSSION

Principal findings

In our study, we found no evidence for an admission effect across the week on early outcomes in acute stroke patients admitted to a London HASU: three-day mortality and modified Rankin Scale score at hospital discharge did not vary by day and time of admission in London HASUs. This is consistent with a recent study based on administrative data in the UK [9] that found a steady reduction in in-hospital mortality difference between weekday and weekend stroke admissions in 2008-2014 across England and that this difference is no longer statistically significant in 2014).

There was also no variation by day and time of admission across the week in terms of rapid access to brain scanning, stroke nursing care and thrombolysis in London HASUs. Other quality of care measures did significantly vary across the week in London HASUs, and three patterns of variation were detected: by time of day but not day of the week; by day of the week but not time of day; and, by time of day and day of the week. LOS was longer among patients admitted to London HASUs at the weekend. In the rest of England there was variation in all measures by day and time of admission across the week, except for mortality at three days. We hypothesised there would be less variation across the week in care quality measures in London HASUs compared with the rest of England, and that this would translate into less variation in outcomes in London HASUs. The lower variation in care quality measures across the week in London HASUs was confirmed, but only with respect to “front door” measures of acute stroke care. With respect to the health outcomes: there was no variation in mortality at three days and disability at hospital discharge by day and time of admission across the week in London HASUs. This is consistent with previous studies showing that timely access to thrombolysis is associated with

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3 good stroke outcomes[37]. In the rest of England there was no variation in three-day mortality
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5 by day and time of admission across the week (but there was in terms of disability after
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7 discharge), suggesting the lack of variation in outcomes in London HASUs may not be
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9 exclusively attributed to the lack of variation in “front door” quality of care.
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12 13 **Strengths and weaknesses**

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18 The main strength of our study is the large national dataset we have used containing detailed
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20 information on quality of care, outcomes, and patient characteristics. We have examined
21
22 whether time of admission was related to quality of care using a comprehensive set of indicators
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24 from across the acute stroke care pathway. Most of the measures were from a pre-existing set
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26 of national acute stroke care indicators, and those that were added had more stringent time
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28 constraints to reflect the time-critical nature of acute stroke care. Our outcomes were stroke
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30 mortality and disability, where previous studies have focused on mortality[2,4,5,7–10]. The rich
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32 set of patient characteristics in the dataset meant we could control for patient factors likely to
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34 affect quality of care and outcomes that vary by day and time of admission across the week and
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36 between London and the rest of England. There are several weaknesses. First, while case
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38 ascertainment in SSNAP was 90% during the time period of our study, these data might not be
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40 representative of all stroke patients. For example, not all hospitals receiving acute stroke
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42 patients in England participated in SSNAP, and the results may not be representative of
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44 hospitals who did not participate. Second, while analyses of hospital administrative data to
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46 investigate weekend effects in stroke have been undermined by evidence of variations in
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48 inaccurate coding across the week[15], in SSNAP data are inputted voluntarily by hospitals and
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50 we cannot exclude the possibility of inaccurate or selective reporting. Particularly problematic for
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52 our study would be if this bias was more likely to occur in London or the rest of England and/or if
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54 it was more likely to vary by time of admission. Third, we were unable to measure long-term
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3 outcomes as these were not available in SSNAP. Mortality data in SSNAP are currently only
4 available for patients who are in hospital and therefore to reduce the risk of bias we measured
5 mortality at three days after admission when most patients will still be admitted. Three-day
6 mortality has been used in previous studies to evaluate the centralisation of acute stroke
7 services in London[30], but the focus in our study on in-hospital mortality only is a further
8 limitation. Similarly, long-term disability data are not reliably collected in SSNAP, and so this
9 was measured by mRS at the end of the inpatient spell. Fourth, while the richness of our
10 dataset means we have been able to control for confounding factors we cannot exclude the
11 possibility of confounding due to unobserved patient characteristics or staffing levels. Fifth, while
12 the sample size of our study is large in both London and the rest of England, when evaluating
13 quality of care and outcomes across the week the number of observations in each time period
14 was considerably smaller in London. We cannot exclude the possibility that the smaller number
15 of patients in London resulted in wider confidence intervals around the adjusted predicted
16 probabilities in each time period making it less likely to show significant variation in the
17 measures evaluated.
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34 35 36 37 ***Comparison with other studies*** 38

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41 There is a large literature examining weekend effects in health care across a range of clinical
42 areas[38]. In acute stroke there is conflicting evidence as to whether patients admitted at
43 weekends have higher or lower quality of care and better or worse outcomes[1–8], but recent
44 analyses have shown that care quality and outcomes in acute stroke vary across the week, and
45 that comparing weekend versus weekday or in-hours versus out-of-hours effects is flawed as it
46 does not take into account variations by day of the week and time of day[16]. This study, using
47 the same dataset as ours but from an earlier time period and analysing the whole of England
48 and Wales, found that quality of care varied across the entire week, not only between weekends
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3 and weekdays, with a number quality of care measures showing different patterns of variation
4 over the week. While the findings mirrored our own for the rest of England, one noticeable
5 difference was in mortality: Bray et al. reported that patients admitted overnight on weekdays
6 had lower odds of survival (0.90, 95% confidence interval 0.82-0.99) compared to those
7 admitted during the day at weekdays; this difference might be because our survival measure is
8 not the same (three versus 30 days) and/or because our extract of the SSNAP dataset is more
9 recent. What our study adds is analyses of variation in quality of care and outcomes in London
10 HASUs separately following the centralisation of acute stroke services in London in 2010, which
11 has been shown to increase the quality of care and outcomes on average across the
12 week[29,30].
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26 **Implications**

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30 There are several implications of our study. The first is that London HASUs appear to operate a
31 uniform service across the week with respect to some but not all aspects of acute stroke care.
32 Performance standards originally set by Healthcare for London stipulated that London HASUs
33 should operate a 24/7 service with respect to first assessment by a stroke nurse, rapid access
34 to brain scans and administration of thrombolysis to eligible patients; our findings show that
35 London HASUs do operate a 24/7 service with respect to these measures. However, for other
36 less time-critical measures, such as senior stroke physician assessment within 24 hours and
37 therapist assessments within 72 hours, we found significant variation by day and time of
38 admission across the week in London HASUs. This suggests that some performance standards
39 like “front door” interventions may be emphasised more than others. The second implication is
40 that there are differences in acute stroke care between London HASUs and the rest of England
41 across the week, with less variation in quality of care and outcomes in London HASUs. The
42 main differences were observed in nursing care, brain scanning and thrombolysis provision, and
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3 also with the type of variation observed for stroke consultant care. For these measures, our
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5 results show that the centralised model in London is more effective at providing constant care
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7 across the week. In terms of comparing London and the rest of England, four further issues are
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9 worth bearing in mind. First, our study focuses on patients admitted to London HASUs only, not
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11 other hospitals in London; our data suggest that 6% of acute stroke patients in London are not
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13 treated in a HASU. However, some of these patients will not have been eligible for HASU care
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15 because of greatly delayed presentation or identification of stroke, and others will have had a
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17 stroke after surgical procedures or in another context which precluded their admission to a
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19 HASU. Our focus on London HASUs was deliberate as the aim of our study was to evaluate the
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21 HASU model, but it means that our findings for London HASUs should not be generalised to all
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23 patients in London. Indeed, there is evidence that quality of care is lower for acute stroke
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25 patients in London not treated in a HASU compared with those who are [29]. Second, and
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27 conversely, HASUs operate in many other parts of England using different models of
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29 care[31,39]. In Greater Manchester, for instance, HASUs have also been shown to have higher
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31 quality of care than the rest of England excluding London[29]. Hence the differences observed
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33 between London HASUs and the rest of England cannot be interpreted as a direct comparison
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35 of HASU versus non-HASU care, though if HASU-based care outside London was removed
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37 from the rest of England then the differences observed in this study are likely to be the same or
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39 greater. The third issue is that the London model may not apply to services operating in rural
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41 settings – in particular the greater travel times in rural areas make centralisation challenging[40].
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43 This means that potential benefits of the London model in terms of 24/7 care are unlikely to be
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45 achieved nationwide. The fourth issue is that the centralisation of acute stroke services in
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47 London was estimated to occur at an additional cost of £20 million, allocated to cover the
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49 increased cost per bed day in a HASU[28]. With this additional level of funding it might be
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51 expected that the quality of care in London should improve, though whether it should produce
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53 less variation in quality of care and outcomes across the week in London compared with the rest
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of England depends on the relative levels of funding in both areas. There is some evidence that the reorganisation in London was cost-effective[41,42], but further analyses accounting for the size of the up-front investment, the relatively high costs per day of hyperacute stroke care, the impact on mortality and disability, and the lifetime costs incurred by the NHS, social services and families caring for stroke survivors at different levels of disability would be helpful.

Future research

Further research would be beneficial to evaluate the impact of stroke admission at different times of the week on longer-term mortality and disability outcomes, and to investigate the relationship between quality of care and outcomes and if this relationship varies by time of admission. Further research would also be useful to investigate the reasons for the differences in variation found between London HASUs and the rest of England, and why for some standards care in London HASUs was constant across the week, irrespective of day and time of admission, but for others it was not. Also, accounting for the organisational factors at the stroke unit level could explain an important part of the variation in quality of acute stroke care and outcomes by day and time of admission in London HASUs and the rest of England. This research would help to further inform how acute stroke services ought to be designed in future to maximise patient outcomes in a cost-effective manner.

References

- 1 Turner M, Barber M, Dodds H, *et al*. Stroke patients admitted within normal working hours are more likely to achieve process standards and to have better outcomes. *J Neurol Neurosurg Psychiatry* 2016;**87**:138–43. doi:10.1136/jnnp-2015-311273
- 2 Palmer WL, Bottle A, Davie C, *et al*. Dying for the Weekend. *Arch Neurol* 2012;**69**. doi:10.1001/archneurol.2012.1030
- 3 Tung Y-C, Chang G-M, Chen Y-H. Associations of physician volume and weekend admissions with ischemic stroke outcome in Taiwan: a nationwide population-based study. *Med Care* 2009;**47**:1018–25. doi:10.1097/MLR.0b013e3181a81144

- 1
2
3 4 Saposnik G, Baibergenova A, Bayer N, *et al.* Weekends: A dangerous time for having a
4 stroke? *Stroke* 2007;**38**:1211–5. doi:10.1161/01.STR.0000259622.78616.ea
- 5 5 Fang J, Saposnik G, Silver FL, *et al.* Association between weekend hospital presentation
6 and stroke fatality. *Neurology* 2010;**75**:1589–96. doi:10.1212/WNL.0b013e3181fb84bc
- 7 6 Patel AA, Mahajan A, Benjo A, *et al.* A Nationwide Analysis of Outcomes of Weekend
8 Admissions for Intracerebral Hemorrhage Shows Disparities Based on Hospital Teaching
9 Status. *The Neurohospitalist* 2016;**6**:51–8. doi:10.1177/1941874415601164
- 10 7 Reeves MJ, Smith E, Fonarow G, *et al.* Off-hour admission and in-hospital stroke case
11 fatality in the get with the guidelines-stroke program. *Stroke* 2009;**40**:569–76.
12 doi:10.1161/STROKEAHA.108.519355
- 13 8 Crowley RW, Yeoh HK, Stukenborg GJ, *et al.* Influence of weekend versus weekday
14 hospital admission on mortality following subarachnoid hemorrhage. *J Neurosurg*
15 2009;**111**:60–6. doi:10.3171/2008.11.JNS081038
- 16 9 Balinskaite V, Bottle A, Shaw LJ, *et al.* Reorganisation of stroke care and impact on
17 mortality in patients admitted during weekends: a national descriptive study based on
18 administrative data. *BMJ Qual Saf* 2017;:bmjqs – 2017–006681. doi:10.1136/bmjqs-
19 2017-006681
- 20 10 Walker AS, Mason A, Quan TP, *et al.* Mortality risks associated with emergency
21 admissions during weekends and public holidays: an analysis of electronic health
22 records. *Lancet* 2017;**390**:62–72. doi:10.1016/S0140-6736(17)30782-1
- 23 11 Concha OP, Gallego B, Hillman K, *et al.* Do variations in hospital mortality Patterns after
24 weekend admission Reflect reduced quality of care or Different patient cohorts? A
25 population-based study. *BMJ Qual Saf* 2014;**23**:215–22. doi:10.1136/bmjqs-2013-002218
- 26 12 Luyt CE, Combes A, Aegerter P, *et al.* Mortality among patients admitted to intensive
27 care units during weekday day shifts compared with 'off' hours. *Crit Care Med* 2007;**35**:3–
28 11. doi:10.1097/01.CCM.0000249832.36518.11
- 29 13 Brunot V, Landreau L, Corne P, *et al.* Mortality associated with night and weekend
30 admissions to ICU with on-site intensivists coverage: Results of a nine-year cohort study
31 (2006-2014). *PLoS One* 2016;**11**:1–16. doi:10.1371/journal.pone.0168548
- 32 14 Aylin P, Alexandrescu R, Jen MH, *et al.* Day of week of procedure and 30 day mortality
33 for elective surgery: Retrospective analysis of hospital episode statistics. *BMJ*
34 2013;**346**:1–8. doi:10.1136/bmj.f2424
- 35 15 Li L, Rothwell PM. Biases in detection of apparent 'weekend effect' on outcome with
36 administrative coding data: population based study of stroke. *Bmj* 2016;:i2648.
37 doi:10.1136/bmj.i2648
- 38 16 Bray BD, Cloud GC, James MA, *et al.* Weekly variation in health-care quality by day and
39 time of admission: a nationwide, registry-based, prospective cohort study of acute stroke
40 care. *Lancet* 2016;**388**:170–7. doi:10.1016/S0140-6736(16)30443-3
- 41 17 Goddard a F, Lees P. Higher senior staffing levels at weekends and reduced mortality.
42 *BMJ* 2012;**344**:e67–e67. doi:10.1136/bmj.e67
- 43 18 Bray BD, Ayis S, Campbell J, *et al.* Associations between stroke mortality and weekend
44 working by stroke specialist physicians and registered nurses: Prospective multicentre
45 cohort study. *PLoS Med* 2015;**11**. doi:10.1371/journal.pmed.1001705
- 46 19 Albright KC, Raman R, Ernstrom K, *et al.* Can comprehensive stroke centers erase the
47 'weekend effect'? *Cerebrovasc Dis* 2009;**27**:107–13. doi:10.1159/000177916
- 48
49
50
51
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53
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55
56
57
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59
60

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2
3 20 Albright KC, Savitz SI, Raman R, *et al.* Comprehensive stroke centers and the 'Weekend Effect': The SPOTRIAS experience on behalf of the SPOTRIAS investigators. *Cerebrovasc Dis* 2012;**34**:424–9. doi:10.1159/000345077
- 4
5
6
7 21 McKinney JS, Deng Y, Kasner SE, *et al.* Comprehensive stroke centers overcome the weekend versus weekday gap in stroke treatment and mortality. *Stroke* 2011;**42**:2403–9. doi:10.1161/STROKEAHA.110.612317
- 8
9
10 22 Statistics O for N. 2011 Census: Key Statistics for England and Wales, March 2011. 2012;:1–34.<http://www.ons.gov.uk/ons/rel/census/2011-census/key-statistics-for-local-authorities-in-england-and-wales/stb-2011-census-key-statistics-for-england-and-wales.html>
- 11
12
13
14
15 23 Morris S, Hunter RM, Ramsay AIG, *et al.* Impact of centralising acute stroke services in English metropolitan areas on mortality and length of hospital stay: difference-in-differences analysis. *BMJ* 2014;**349**:g4757. doi:10.1136/bmj.g4757
- 16
17
18 24 Turner S, Ramsay A, Perry C, *et al.* Lessons for major system change: Centralization of stroke services in two metropolitan areas of England. *J Heal Serv Res Policy* 2016;**21**:156–65. doi:10.1177/1355819615626189
- 19
20
21
22 25 Davie C, Hunter RM, Mountford J, *et al.* London 's Hyperacute Stroke Units Improve Outcomes and Lower Costs. 2013.
- 23
24
25 26 NHS London Strategic Clinical Networks. Stroke acute commissioning and tariff guidance. 2014.
- 26
27 27 Fulop N, Boaden R, Hunter R, *et al.* Innovations in major system reconfiguration in England: a study of the effectiveness, acceptability and processes of implementation of two models of stroke care. *Implement Sci* 2013;**8**:5. doi:10.1186/1748-5908-8-5
- 28
29
30 28 Healthcare for London. The shape of things to come: Appendix 7d - finance commissioning assurance. *London Healthc London* 2009 2009;:1–87.
- 31
32
33 29 Ramsay AIG, Morris S, Hoffman A, *et al.* Effects of centralizing acute stroke services on stroke care provision in two large metropolitan areas in England. *Stroke* 2015;**46**:2244–51. doi:10.1161/STROKEAHA.115.009723
- 34
35
36
37 30 Morris S, Hunter RM, Ramsay a. IG, *et al.* Impact of centralising acute stroke services in English metropolitan areas on mortality and length of hospital stay: difference-in-differences analysis. *Bmj* 2014;**349**:g4757–g4757. doi:10.1136/bmj.g4757
- 38
39
40 31 Royal College of Physicians. Sentinel Stroke National Audit Programme (SSNAP): Clinical audit first pilot public report. 2013;:1–48.
- 41
42
43 32 Royal College of Physicians. First SSNAP Annual Report. How good is stroke care? 2014.
- 44
45
46 33 Royal College of Physicians. Is stroke care improving ? The Second SSNAP Annual Report. 2015;:32.
- 47
48 34 Royal College of Physicians. 3rd SSNAP Annual Report for 2015/2016 'Mind the Gap!' *Third Ssn Annu Rep* 2016;:1–219. doi:10.1787/9789264038950-en
- 49
50
51 35 Royal College of Physicians. *Sentinel Stroke National Audit Programme (SSNAP) Clinical Audit*. 2015.
- 52
53 36 Royal College of Physicians. National clinical guideline for stroke. *London R Coll Physicians* 2008;:232.
- 54
55
56 37 Emberson J, Lees KR, Lyden P, *et al.* Effect of treatment delay, age, and stroke severity
- 57
58
59
60

- 1
2
3 on the effects of intravenous thrombolysis with alteplase for acute ischaemic stroke: A
4 meta-analysis of individual patient data from randomised trials. *Lancet* 2014;**384**:1929–
5 35. doi:10.1016/S0140-6736(14)60584-5
6
7 38 Godlee F. What to do about the ‘weekend effect’. *Bmj* 2015;**4840**:h4840.
8 doi:10.1136/bmj.h4840
9
10 39 Royal College of Physicians. Sentinel Stroke National Audit Programme (SSNAP) Acute
11 organisational audit proforma. 2012;:1–35.
12
13 40 Allen M, Pearn K, Villeneuve E, *et al*. Feasibility of a hyper-acute stroke unit model of
14 care across England: a modelling analysis. *BMJ Open* 2017;**7**:e018143.
15 doi:10.1136/bmjopen-2017-018143
16
17 41 Hunter RM, Fulop NJ, Boaden RJ, *et al*. The potential role of cost-utility analysis in the
18 decision to implement major system change in acute stroke services in metropolitan
19 areas in England. *Heal Res Policy Syst* 2018;**16**:1–14. doi:10.1186/s12961-018-0301-5
20
21 42 Hunter RM, Davie C, Rudd A, *et al*. Impact on Clinical and Cost Outcomes of a
22 Centralized Approach to Acute Stroke Care in London: A Comparative Effectiveness
23 Before and After Model. *PLoS One* 2013;**8**:1–9. doi:10.1371/journal.pone.0070420
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3 **Contributors:** Mariya Melnychuk (MM), Steve Morris (SM), Naomi J Fulop (NJF), Rob Simister
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11 manuscript is an honest, accurate, and transparent account of the study being reported; that no
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13 important aspects of the study have been omitted; and that any discrepancies from the study as
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15 planned (and, if relevant, registered) have been explained.
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Figure legends

Figure 1. Number of admissions in London and Rest of England across the 42 time periods in the week

Note.

Left-hand y-axis relates to London HASUs, right-hand y-axis to the Rest of England. Shaded areas indicate 20:00-07:59 each day of the week.

Figure 2. Quality of care across the 42 time periods in the week: measures linked to performance standards for London HASUs

(a) Brain scan within one hour

(b) Brain scan within 12 hours

(c) Dysphagia screen within four hours

(d) Assessment by a nurse trained in stroke management within 24 hours

(e) Administration of intravenous thrombolysis to eligible patients

(f) Door-to-needle time within one hour in patients receiving thrombolysis

Note.

Figures are average predicted probabilities of each outcome in each time period controlling for the covariates. Dashed lines represent lower and upper 95% confidence limits. Shaded areas indicate 20:00-07:59 each day of the week. P-values indicate significant variation ($p < 0.05$) or not for each measure over the week in each region. Gaps in the solid line indicate that all patients in that time period achieved that outcome.

Figure 3. Quality of care across the 42 time periods in the week: variation by time of day but not day of the week

(a) Assessment by a stroke specialist consultant physician within 12 and 24 hours in

London HASUs

(b) Admission to a stroke unit within four hours

Note.

Figures are average predicted probabilities of each outcome in each time period controlling for the covariates. Dashed lines represent lower and upper 95% confidence limits. Shaded areas indicate 20:00-07:59 each day of the week. P-values indicate significant variation ($p < 0.05$) or not for each measure over the week in each region. Figure 3(a) includes two measures for London HASUs.

Figure 4. Quality of care across the 42 time periods in the week: variation by day of the week but not time of day

(a) Physiotherapist assessment within 72 hours

(b) Occupational Therapist assessment within 72 hours

(c) Swallow assessment by a Speech and Language Therapist within 72 hours

(d) Communication assessment by a Speech and Language Therapist within 72 hours

Note.

Figures are average predicted probabilities of each outcome in each time period controlling for the covariates. Dashed lines represent lower and upper 95% confidence limits. Shaded areas indicate 20:00-07:59 each day of the week. P-values indicate significant variation ($p < 0.05$) or not for each measure over the week in each region. Gaps in the solid line indicate that no patients in that time period achieved that outcome. SLT = Speech and Language Therapist.

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5 **Figure 5. Quality of care across the 42 time periods in the week: variation by time of day**
6 **and day of the week**

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9 **(a) Assessment by a stroke specialist consultant physician within 12 and 24 hours in**

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11 **Rest of England**

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13 **(b) Physiotherapist assessment within 24 hours**

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15 **(c) Occupational Therapist assessment within 24 hours**

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17 **(d) Communication assessment by a Speech and Language Therapist within 24 hours**

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22 Note.

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24 Figures are average predicted probabilities of each outcome in each time period controlling for
25 the covariates. Dashed lines represent lower and upper 95% confidence limits. Shaded areas
26 indicate 20:00-07:59 each day of the week. P-values indicate significant variation ($p < 0.05$) or
27 not for each measure over the week in each region. Figure 5(a) includes two measures for Rest
28 of England. SLT = Speech and Language Therapist.
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37 **Figure 6. Outcomes across the 42 time periods in the week**

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39 **(a) Mortality at three days**

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41 **(b) Modified Rankin Scale score 3-6**

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43 **(c) Modified Rankin Scale score 3-5***

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47 Note.

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49 Figures are average predicted probabilities of each outcome in each time period controlling for
50 the covariates. Dashed lines represent lower and upper 95% confidence limits. Shaded areas
51 indicate 20:00-07:59 each day of the week. P-values indicate significant variation ($p < 0.05$) or
52 not for each measure over the week in each region. Gaps in the solid line indicate that no
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3 patients in that time period achieved that outcome. Note the scaling of the y-axis in Figure 6(a)
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5 is not from zero to one.
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9 **Figure 7. Length of stay across the 42 time periods in the week**

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11 **(a) Length of stay in HASU**

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13 **(b) Length of stay in hospital**

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15 Note.

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18 Figures are average predicted probabilities of each outcome in each time period controlling for
19 the covariates. Dashed lines represent lower and upper 95% confidence limits. Shaded areas
20 indicate 20:00-07:59 each day of the week. P-values indicate significant variation ($p < 0.05$) or
21 not for each measure over the week in each region.
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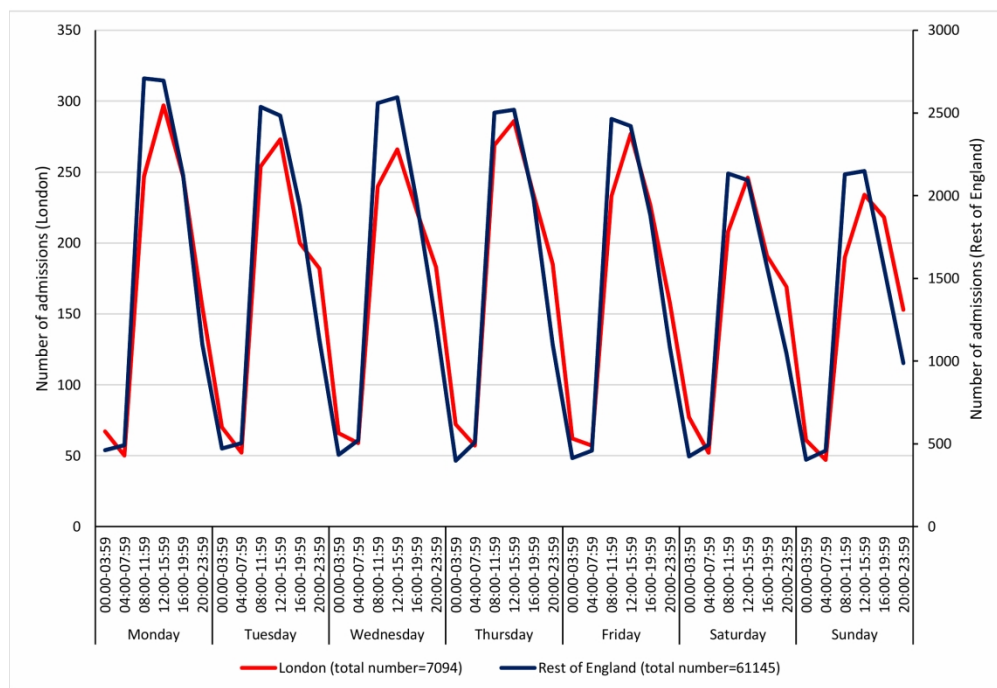


Figure 1. Number of admissions

Figure 1. Number of admissions

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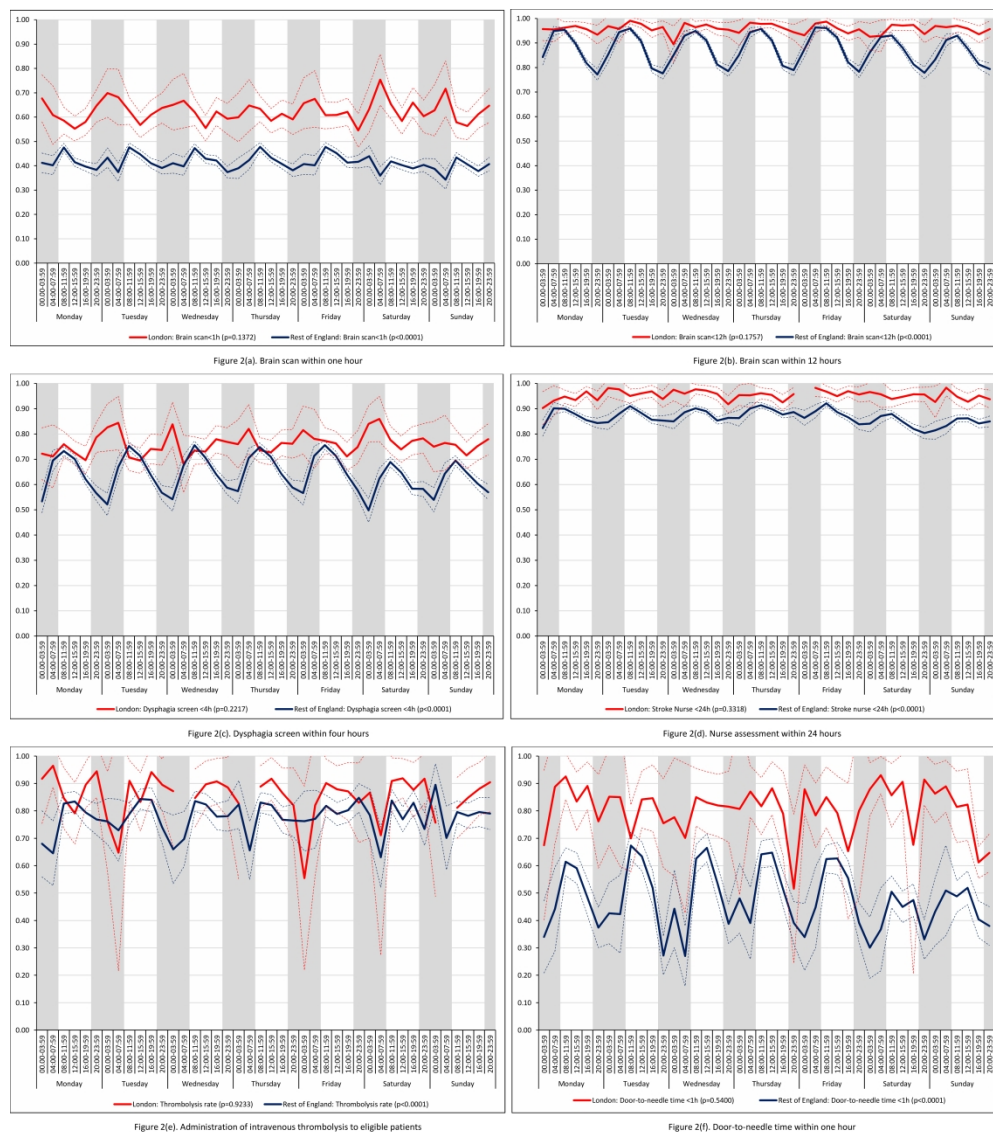


Figure 2. Quality of care across the 42 time periods in the week: measures linked to performance standards for London HASUs

408x469mm (300 x 300 DPI)

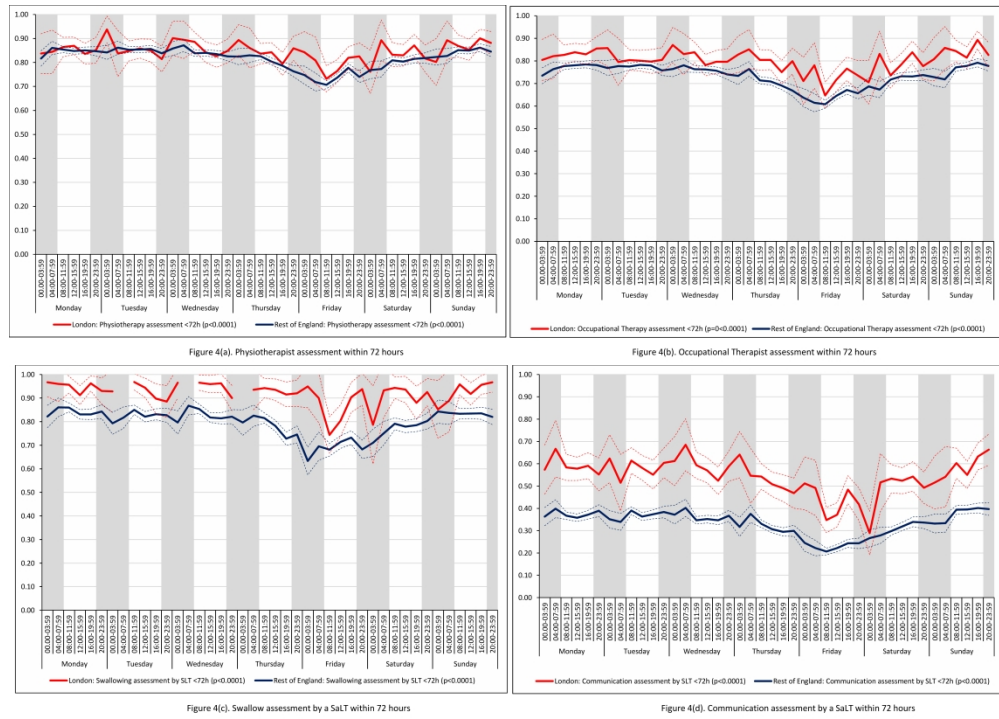


Figure 4. Quality of care across the 42 time periods in the week: variation by day of the week but not time of day

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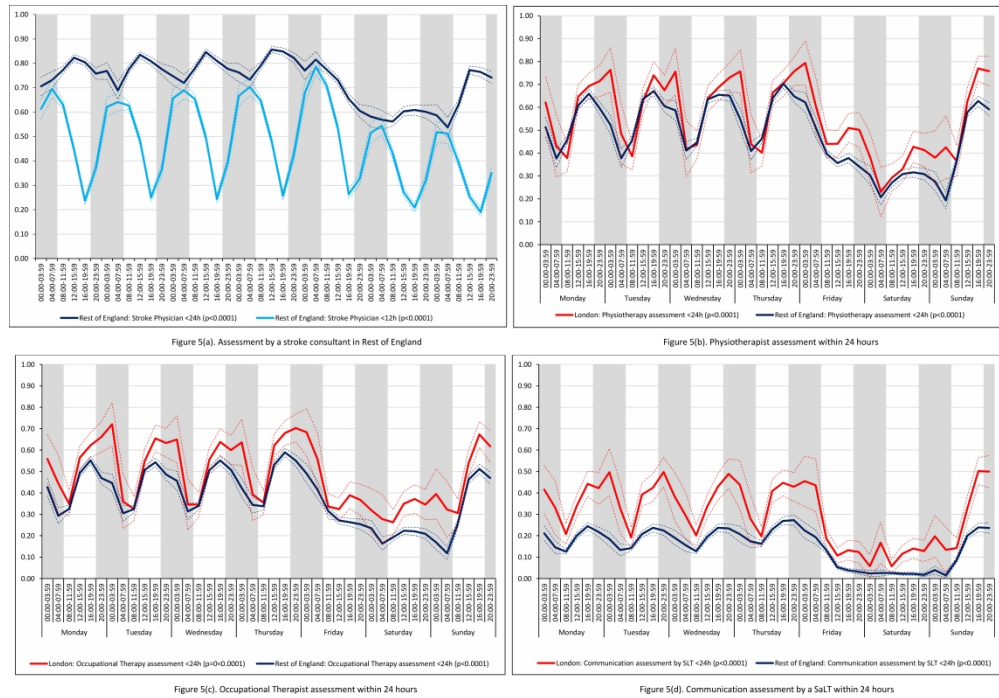


Figure 5. Quality of care across the 42 time periods in the week: variation by time of day and day of the week

408x287mm (300 x 300 DPI)

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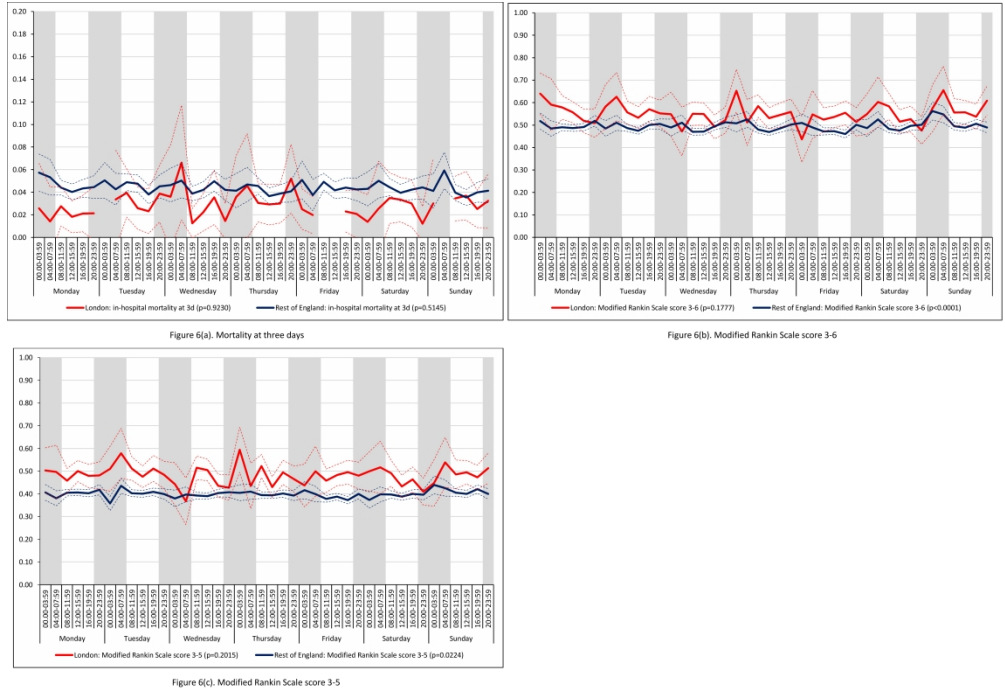


Figure 6. Outcomes across the 42 time periods in the week

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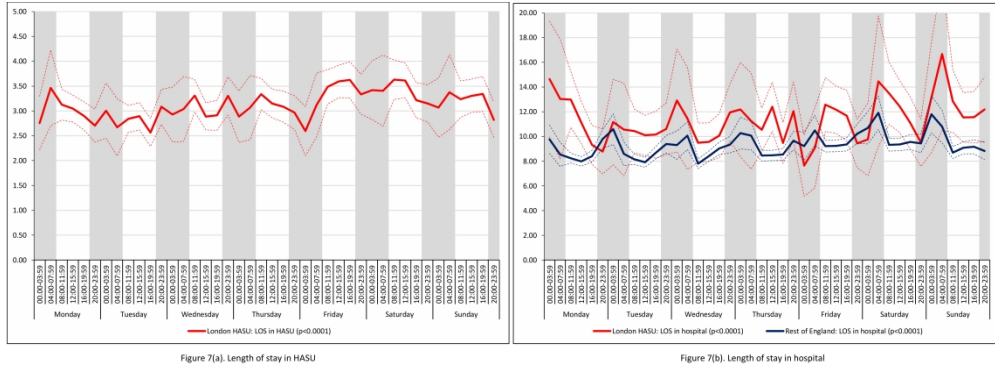


Figure 7. Length of stay across the 42 time periods in the week

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Supplementary Tables

Supplementary Table 1. Quality of care and outcomes across four periods in the week unadjusted figures

	London HASUs					Rest of England				
	Weekday	Weekend	Weekday	Weekend	p-value	Weekday	Weekend	Weekday	Weekend	p-value
	08:00-19:59	08:00-19:59	20:00-07:59	20:00-07:59		08:00-19:59	08:00-19:59	20:00-07:59	20:00-07:59	
Quality of care measures that do not vary across the week in London HASUs										
Brain scan within one hour	0.58 (0.57-0.60)	0.62 (0.59-0.64)	0.61 (0.58-0.63)	0.63 (0.59-0.67)	0.0443	0.42 (0.41-0.43)	0.41 (0.40-0.42)	0.42 (0.41-0.43)	0.43 (0.42-0.45)	0.2145
Brain scan within 12 hours	0.95 (0.95-0.96)	0.96 (0.94-0.97)	0.93 (0.91-0.94)	0.92 (0.90-0.94)	0.0000	0.88 (0.88-0.89)	0.88 (0.87-0.88)	0.84 (0.83-0.84)	0.84 (0.83-0.85)	0.0000
Dysphagia screen within four hours	0.74 (0.72-0.75)	0.76 (0.73-0.78)	0.77 (0.74-0.79)	0.78 (0.74-0.81)	0.0359	0.69 (0.69-0.70)	0.66 (0.65-0.66)	0.61 (0.60-0.62)	0.60 (0.58-0.62)	0.0000
Assessment by a nurse trained in stroke management within 24 hours	0.96 (0.95-0.96)	0.95 (0.94-0.96)	0.95 (0.93-0.96)	0.95 (0.94-0.97)	0.4109	0.88 (0.88-0.89)	0.86 (0.85-0.86)	0.86 (0.85-0.86)	0.84 (0.82-0.85)	0.0000
Administration of intravenous thrombolysis to eligible patients	0.88 (0.85-0.90)	0.87 (0.83-0.92)	0.87 (0.83-0.91)	0.88 (0.81-0.95)	0.9905	0.80 (0.79-0.81)	0.79 (0.77-0.81)	0.74 (0.72-0.77)	0.75 (0.72-0.79)	0.0000
Door-to-needle time within one hour in patients receiving thrombolysis	0.84 (0.81-0.87)	0.88 (0.84-0.93)	0.79 (0.74-0.85)	0.85 (0.78-0.92)	0.0677	0.60 (0.59-0.62)	0.48 (0.45-0.51)	0.38 (0.35-0.41)	0.36 (0.32-0.41)	0.0000
Quality of care: measures that vary significantly across the week										
Assessment by a stroke specialist consultant physician within 12 hours	0.39 (0.37-.40)	0.30 (0.28-0.33)	0.63 (0.60-0.65)	0.65 (0.61-0.69)	0.0000	0.47 (0.47-0.48)	0.30 (0.30-0.31)	0.52 (0.51-0.53)	0.44 (0.42-0.45)	0.0000
Assessment by a stroke specialist consultant physician within 24 hours	0.90 (0.89-0.91)	0.87 (0.86-0.89)	0.90 (0.88-0.91)	0.92 (0.90-0.94)	0.0173	0.79 (0.79-0.80)	0.66 (0.65-0.67)	0.74 (0.73-0.75)	0.63 (0.62-0.65)	0.0000
Admission to a stroke unit within four hours	0.62 (0.60-0.63)	0.65 (0.62-0.67)	0.68 (0.66-0.70)	0.71 (0.67-0.74)	0.0000	0.62 (0.62-0.63)	0.60 (0.59-0.61)	0.55 (0.54-0.56)	0.55 (0.53-0.57)	0.0000
Physiotherapist assessment within 72 hours	0.83 (0.82-0.84)	0.86 (0.84-0.88)	0.85 (0.83-0.87)	0.84 (0.81-0.87)	0.0538	0.82 (0.82-0.82)	0.83 (0.82-0.84)	0.80 (0.79-0.81)	0.81 (0.79-0.82)	0.0000
Occupational Therapist assessment within 72 hours	0.79 (0.77-0.80)	0.82 (0.79-0.84)	0.81 (0.79-0.83)	0.80 (0.77-0.84)	0.0993	0.74 (0.73-0.74)	0.75 (0.74-0.76)	0.71 (0.70-0.72)	0.72 (0.71-0.74)	0.0000
Swallow assessment by a SLT within 72 hours	0.92 (0.90-0.93)	0.94 (0.92-0.96)	0.93 (0.91-0.95)	0.93 (0.89-0.96)	0.3473	0.80 (0.79-0.80)	0.81 (0.80-0.82)	0.79 (0.78-0.81)	0.80 (0.79-0.82)	0.1258
Communication assessment by a SLT within 72 hours	0.53 (0.51-0.55)	0.57 (0.55-0.60)	0.54 (0.52-0.57)	0.50 (0.46-0.55)	0.0191	0.32 (0.32-0.33)	0.36 (0.35-0.37)	0.34 (0.33-0.35)	0.34 (0.32-0.35)	0.0000
Physiotherapist assessment within 24 hours	0.56 (0.55-0.58)	0.47 (0.44-0.50)	0.65 (0.63-0.68)	0.49 (0.45-0.53)	0.0000	0.54 (0.54-0.55)	0.40 (0.40-0.41)	0.52 (0.51-0.53)	0.35 (0.33-0.36)	0.0000

hours										
Occupational Therapist assessment within 24 hours	0.49 (0.47-0.50)	0.42 (0.39-0.45)	0.58 (0.56-0.61)	0.43 (0.39-0.47)	0.0000	0.43 (0.42-0.43)	0.30 (0.30-0.31)	0.41 (0.40-0.42)	0.26 (0.25-0.27)	0.0000
Communication assessment by a SLT within 24 hours	0.29 (0.28-0.31)	0.23 (0.20-0.25)	0.39 (0.36-0.41)	0.22 (0.19-0.25)	0.0000	0.17 (0.17-0.17)	0.10 (0.09-0.10)	0.19 (0.18-0.20)	0.08 (0.07-0.09)	0.0000
Outcome measures										
Mortality at three days	0.02 (0.02-0.03)	0.04 (0.03-0.05)	0.03 (0.02-0.03)	0.02 (0.01-0.03)	0.0547	0.04 (0.04-0.04)	0.04 (0.04-0.04)	0.06 (0.05-0.06)	0.06 (0.05-0.06)	0.0000
mRS score 3-6	0.55 (0.53-0.56)	0.58 (0.55-0.60)	0.52 (0.50-0.55)	0.54 (0.50-0.58)	0.0553	0.46 (0.46-0.47)	0.50 (0.49-0.51)	0.54 (0.53-0.55)	0.54 (0.53-0.56)	0.0000
mRS score 3-5*	0.48 (0.46-0.49)	0.51 (0.48-0.54)	0.46 (0.43-0.49)	0.47 (0.43-0.52)	0.1024	0.38 (0.37-0.38)	0.41 (0.40-0.42)	0.44 (0.43-0.45)	0.44 (0.42-0.46)	0.0000
Length of stay										
Length of stay in HASU (days)	3.0 (2.9-3.1)	3.3 (3.2-3.5)	2.9 (2.7-3.0)	3.0 (2.8-3.2)	0.0000					
Length of stay in hospital (days)	7.8 (7.4-8.1)	9.2 (8.5-10.0)	7.6 (7.0-8.2)	8.0 (7.0-9.0)	0.0016	6.6 (6.5-6.6)	7.5 (7.3-7.7)	8.4 (8.2-8.6)	8.7 (8.3-9.1)	0.0000

Note.

Figures are average predicted probabilities (95% confidence intervals) of each measure in each time period controlling for the covariates. SLT = Speech and Language Therapist. mRS = modified Rankin Scale. * Patients who died were not included. P-value threshold adjusted for multiple testing is 0.0025 for London HASUs and 0.0024 for the rest of England.

Supplementary Table 2A. Quality of care and outcomes across four periods in the week (p-values comparison between Wald test and Likelihood-ratio test)

	London HASUs					Rest of England						
	Weekday	Weekend	Weekday	Weekend	p-value	p-value	Weekday	Weekend	Weekday	Weekend	p-value	p-value
	08:00-19:59	08:00-19:59	20:00-07:59	20:00-07:59	Wald	Likelihood-ratio test	08:00-19:59	08:00-19:59	20:00-07:59	20:00-07:59	Wald	Likelihood-ratio test
Quality of care measures that do not vary across the week in London HASUs												
Brain scan within one hour	0.60 (0.58-0.61)	0.61 (0.58-0.63)	0.63 (0.60-0.65)	0.65 (0.61-0.68)	0.0344	0.0336	0.44 (0.44-0.45)	0.41 (0.40-0.41)	0.40 (0.39-0.40)	0.39 (0.38-0.41)	0.0000	0.0000
Brain scan within 12 hours	0.97 (0.96-0.97)	0.96 (0.95-0.97)	0.95 (0.94-0.96)	0.95 (0.93-0.96)	0.0093	0.0110	0.90 (0.90-0.90)	0.88 (0.87-0.89)	0.84 (0.83-0.84)	0.83 (0.82-0.84)	0.0000	0.0000
Dysphagia screen within four hours	0.74 (0.72-0.75)	0.75 (0.73-0.77)	0.77 (0.75-0.79)	0.79 (0.76-0.82)	0.0029	0.0026	0.70 (0.70-0.71)	0.65 (0.64-0.66)	0.60 (0.59-0.61)	0.58 (0.56-0.59)	0.0000	0.0000
Assessment by a nurse trained in stroke management within 24 hours	0.96 (0.95-0.96)	0.94 (0.93-0.96)	0.95 (0.94-0.96)	0.95 (0.94-0.97)	0.1872	0.1896	0.89 (0.88-0.89)	0.85 (0.85-0.86)	0.86 (0.86-0.87)	0.83 (0.82-0.84)	0.0000	0.0000
Administration of intravenous thrombolysis to eligible patients	0.88 (0.86-0.90)	0.88 (0.84-0.92)	0.86 (0.82-0.91)	0.88 (0.82-0.95)	0.9327	0.9341	0.81 (0.80-0.82)	0.80 (0.78-0.82)	0.76 (0.74-0.78)	0.76 (0.72-0.79)	0.0000	0.0000
Door-to-needle time within one hour in patients receiving thrombolysis	0.84 (0.81-0.87)	0.89 (0.85-0.93)	0.79 (0.74-0.84)	0.84 (0.77-0.91)	0.0269	0.0233	0.60 (0.59-0.62)	0.48 (0.45-0.50)	0.38 (0.35-0.40)	0.37 (0.33-0.41)	0.0000	0.0000
Quality of care: measures that vary significantly across the week												
Assessment by a stroke specialist consultant physician within 12 hours	0.39 (0.38-0.40)	0.30 (0.27-0.32)	0.63 (0.61-0.66)	0.64 (0.60-0.68)	0.0000	0.0000	0.48 (0.48-0.49)	0.30 (0.29-0.31)	0.51 (0.51-0.52)	0.42 (0.41-0.44)	0.0000	0.0000

Assessment by a stroke specialist consultant physician within 24 hours	0.90 (0.89-0.91)	0.87 (0.85-0.89)	0.90 (0.88-0.91)	0.92 (0.90-0.94)	0.0043	0.0048	0.80 (0.79-0.80)	0.65 (0.65-0.66)	0.75 (0.74-0.75)	0.62 (0.61-0.64)	0.0000	0.0000
Admission to a stroke unit within four hours	0.62 (0.60-0.63)	0.64 (0.61-0.66)	0.67 (0.65-0.70)	0.70 (0.67-0.74)	0.0000	0.0000	0.63 (0.63-0.63)	0.59 (0.58-0.60)	0.55 (0.54-0.56)	0.53 (0.52-0.55)	0.0000	0.0000
Physiotherapist assessment within 72 hours	0.83 (0.82-0.84)	0.86 (0.84-0.88)	0.85 (0.83-0.87)	0.84 (0.81-0.87)	0.0693	0.0666	0.82 (0.81-0.82)	0.83 (0.82-0.84)	0.81 (0.81-0.82)	0.82 (0.80-0.83)	0.0010	0.0009
Occupational Therapist assessment within 72 hours	0.79 (0.78-0.80)	0.82 (0.80-0.84)	0.81 (0.79-0.82)	0.80 (0.76-0.83)	0.0967	0.0936	0.73 (0.73-0.74)	0.75 (0.75-0.76)	0.73 (0.72-0.74)	0.73 (0.72-0.74)	0.0000	0.0000
Swallow assessment by a SLT within 72 hours	0.92 (0.91-0.93)	0.93 (0.91-0.95)	0.93 (0.91-0.95)	0.91 (0.88-0.95)	0.5838	0.5795	0.80 (0.80-0.81)	0.81 (0.80-0.82)	0.79 (0.78-0.80)	0.80 (0.78-0.82)	0.0946	0.0946
Communication assessment by a SLT within 72 hours	0.53 (0.51-0.54)	0.56 (0.54-0.59)	0.55 (0.53-0.58)	0.52 (0.48-0.56)	0.0739	0.0735	0.33 (0.32-0.33)	0.36 (0.35-0.37)	0.34 (0.33-0.35)	0.34 (0.32-0.35)	0.0000	0.0000
Physiotherapist assessment within 24 hours	0.56 (0.54-0.57)	0.47 (0.45-0.50)	0.65 (0.63-0.68)	0.48 (0.44-0.52)	0.0000	0.0000	0.54 (0.54-0.55)	0.41 (0.40-0.41)	0.53 (0.52-0.54)	0.35 (0.34-0.37)	0.0000	0.0000
Occupational Therapist assessment within 24 hours	0.49 (0.47-0.50)	0.42 (0.40-0.45)	0.58 (0.55-0.60)	0.41 (0.37-0.45)	0.0000	0.0000	0.43 (0.42-0.43)	0.31 (0.30-0.31)	0.42 (0.42-0.43)	0.26 (0.25-0.27)	0.0000	0.0000
Communication assessment by a SLT within 24 hours	0.29 (0.28-0.31)	0.22 (0.20-0.24)	0.39 (0.37-0.42)	0.23 (0.20-0.27)	0.0000	0.0000	0.17 (0.17-0.17)	0.10 (0.09-0.10)	0.19 (0.18-0.20)	0.08 (0.07-0.09)	0.0000	0.0000
Outcome measures												
Mortality at three days	0.03 (0.02-0.03)	0.03 (0.02-0.04)	0.03 (0.02-0.04)	0.02 (0.01-0.03)	0.3310	0.3298	0.04 (0.04-0.05)	0.04 (0.04-0.04)	0.05 (0.04-0.05)	0.05 (0.04-0.05)	0.1055	0.1030
mRS score 3-6	0.55 (0.53-0.56)	0.55 (0.52-0.57)	0.55 (0.52-0.57)	0.56 (0.53-0.59)	0.8672	0.8673	0.48 (0.48-0.48)	0.49 (0.48-0.50)	0.51 (0.50-0.51)	0.51 (0.50-0.52)	0.0000	0.0000

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mRS score 3-5*	0.49 (0.47-0.50)	0.47 (0.45-0.50)	0.48 (0.45-0.50)	0.48 (0.44-0.51)	0.7497	0.7494	0.40 (0.39-0.40)	0.40 (0.39-0.41)	0.40 (0.39-0.41)	0.40 (0.39-0.41)	0.3746	0.3750
Length of stay												
Length of stay in HASU (days)	3.1 (3.0-3.2)	3.4 (3.2-3.5)	3.0 (2.9-3.1)	3.1 (2.9-3.3)	0.0007	0.0008						
Length of stay in hospital (days)	10.8 (10.2-11.3)	12.1 (11.1-13.1)	10.8 (10.0-11.7)	11.5 (10.2-12.9)	0.0359	0.0359	8.5 (8.4-8.6)	9.2 (9.0-9.4)	9.7 (9.4-9.9)	10.1 (9.6-10.5)	0.0000	0.0000

Note.

Figures are average predicted probabilities (95% confidence intervals) of each measure in each time period controlling for the covariates. SLT = Speech and Language Therapist. mRS = modified Rankin Scale. * Patients who died were not included. P-value threshold adjusted for multiple testing is 0.0025 for London HASUs and 0.0024 for the rest of England.

Supplementary Table 3. Quality of care and outcomes across four periods in the week cotrolling for NIHSS score on arrival

	London HASUs					Rest of England				
	Weekday	Weekend	Weekday	Weekend	p-value	Weekday	Weekend	Weekday	Weekend	p-value
	08:00-19:59	08:00-19:59	20:00-07:59	20:00-07:59		08:00-19:59	08:00-19:59	20:00-07:59	20:00-07:59	
Quality of care measures that do not vary across the week in London HASUs										
Brain scan within one hour	0.60 (0.59-0.62)	0.61 (0.59-0.64)	0.63 (0.61-0.66)	0.65 (0.62-0.69)	0.0256	0.47 (0.46-0.47)	0.43 (0.42-0.44)	0.41 (0.41-0.42)	0.41 (0.40-0.43)	0.0000
Brain scan within 12 hours	0.97 (0.97-0.98)	0.97 (0.96-0.98)	0.95 (0.94-0.96)	0.94 (0.92-0.96)	0.0012	0.91 (0.91-0.92)	0.89 (0.89-0.90)	0.85 (0.84-0.86)	0.85 (0.84-0.86)	0.0000
Dysphagia screen within four hours	0.74 (0.73-0.76)	0.76 (0.74-0.79)	0.78 (0.76-0.81)	0.80 (0.77-0.84)	0.0003	0.74 (0.73-0.74)	0.68 (0.68-0.69)	0.64 (0.63-0.65)	0.61 (0.60-0.63)	0.0000
Assessment by a nurse trained in stroke management within 24 hours	0.96 (0.96-0.97)	0.95 (0.94-0.96)	0.95 (0.94-0.96)	0.96 (0.95-0.98)	0.1191	0.92 (0.92-0.93)	0.89 (0.89-0.90)	0.90 (0.90-0.91)	0.88 (0.87-0.89)	0.0000
Administration of intravenous thrombolysis to eligible patients	0.89 (0.86-0.91)	0.89 (0.85-0.93)	0.88 (0.83-0.92)	0.87 (0.81-0.94)	0.9436	0.83 (0.82-0.84)	0.83 (0.81-0.84)	0.78 (0.76-0.80)	0.79 (0.75-0.82)	0.0000
Door-to-needle time within one hour in patients receiving thrombolysis	0.84 (0.81-0.87)	0.89 (0.85-0.93)	0.79 (0.74-0.85)	0.85 (0.78-0.92)	0.0673	0.62 (0.60-0.63)	0.48 (0.46-0.51)	0.39 (0.36-0.42)	0.38 (0.33-0.42)	0.0000
Quality of care: measures that vary significantly across the week										
Assessment by a stroke specialist consultant physician within 12 hours	0.39 (0.38-.40)	0.29 (0.27-0.31)	0.64 (0.62-0.67)	0.65 (0.62-0.69)	0.0000	0.52 (0.52-0.53)	0.33 (0.32-0.34)	0.55 (0.54-0.56)	0.46 (0.44-0.47)	0.0000
Assessment by a stroke specialist consultant physician within 24 hours	0.90 (0.89-0.91)	0.88 (0.86-0.89)	0.90 (0.89-0.92)	0.94 (0.92-0.96)	0.0005	0.84 (0.83-0.84)	0.70 (0.69-0.71)	0.79 (0.78-0.80)	0.67 (0.65-0.68)	0.0000
Admission to a stroke unit within four hours	0.62 (0.61-0.64)	0.65 (0.62-0.68)	0.69 (0.66-0.71)	0.71 (0.67-0.74)	0.0000	0.67 (0.67-0.68)	0.63 (0.62-0.64)	0.59 (0.58-0.60)	0.57 (0.56-0.59)	0.0000
Physiotherapist assessment within 72 hours	0.84 (0.83-0.85)	0.87 (0.85-0.89)	0.86 (0.84-0.88)	0.85 (0.82-0.88)	0.1845	0.85 (0.85-0.85)	0.86 (0.86-0.87)	0.85 (0.84-0.85)	0.85 (0.84-0.86)	0.0022
Occupational Therapist assessment within 72 hours	0.80 (0.79-0.81)	0.83 (0.81-0.85)	0.82 (0.80-0.84)	0.81 (0.78-0.84)	0.0707	0.77 (0.77-0.77)	0.79 (0.78-0.80)	0.77 (0.76-0.78)	0.77 (0.76-0.78)	0.0005
Swallow assessment by a SLT within 72 hours	0.93 (0.91-0.94)	0.95 (0.93-0.97)	0.94 (0.92-0.96)	0.91 (0.87-0.85)	0.2298	0.83 (0.82-0.83)	0.84 (0.83-0.85)	0.82 (0.81-0.83)	0.82 (0.80-0.84)	0.1677
Communication assessment by a SLT within 72 hours	0.54 (0.52-0.55)	0.57 (0.54-0.60)	0.56 (0.54-0.59)	0.53 (0.49-0.57)	0.1069	0.33 (0.32-0.33)	0.36 (0.35-0.37)	0.33 (0.32-0.34)	0.34 (0.32-0.36)	0.0000

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Physiotherapist assessment within 24 hours	0.57 (0.55-0.58)	0.49 (0.46-0.51)	0.66 (0.64-0.69)	0.49 (0.45-0.53)	0.0000	0.57 (0.57-0.58)	0.43 (0.42-0.44)	0.57 (0.56-0.58)	0.38 (0.36-0.39)	0.0000
Occupational Therapist assessment within 24 hours	0.49 (0.48-0.51)	0.43 (0.41-0.46)	0.59 (0.56-0.61)	0.42 (0.38-0.46)	0.0000	0.45 (0.45-0.46)	0.33 (0.32-0.33)	0.46 (0.45-0.47)	0.28 (0.27-0.30)	0.0000
Communication assessment by a SLT within 24 hours	0.30 (0.28-0.31)	0.22 (0.20-0.25)	0.40 (0.38-0.43)	0.24 (0.20-0.27)	0.0000	0.17 (0.17-0.18)	0.10 (0.09-0.10)	0.19 (0.18-0.20)	0.08 (0.07-0.09)	0.0000
Outcome measures										
Mortality at three days	0.02 (0.02-0.03)	0.03 (0.02-0.04)	0.03 (0.02-0.04)	0.02 (0.01-0.03)	0.2987	0.03 (0.03-0.03)	0.03 (0.02-0.03)	0.03 (0.03-0.03)	0.03 (0.02-0.03)	0.6904
mRS score 3-6	0.53 (0.52-0.54)	0.52 (0.50-0.55)	0.53 (0.51-0.55)	0.54 (0.510-0.57)	0.8754	0.43 (0.43-0.44)	0.44 (0.43-0.45)	0.45 (0.44-0.46)	0.46 (0.44-0.47)	0.0000
mRS score 3-5*	0.49 (0.47-0.50)	0.47 (0.45-0.50)	0.48 (0.45-0.50)	0.48 (0.44-0.51)	0.7497	0.40 (0.39-0.40)	0.40 (0.39-0.41)	0.40 (0.39-0.41)	0.40 (0.39-0.41)	0.3746
Length of stay										
Length of stay in HASU (days)	3.1 (3.0-3.2)	3.3 (3.2-3.5)	3.0 (2.9-3.1)	3.1 (2.9-3.3)	0.0080					
Length of stay in hospital (days)	12.8 (12.1-13.6)	14.4 (13.2-15.6)	13.2 (12.2-14.3)	13.2 (11.7-14.7)	0.0562	8.9 (8.7-9.0)	9.5 (9.3-9.8)	9.9 (9.6-10.2)	10.4 (10.0-10.9)	0.0000

Note.

Figures are average predicted probabilities (95% confidence intervals) of each measure in each time period controlling for the covariates. SLT = Speech and Language Therapist. mRS = modified Rankin Scale. * Patients who died were not included. P-value threshold adjusted for multiple testing is 0.0025 for London HASUs and 0.0024 for the rest of England.

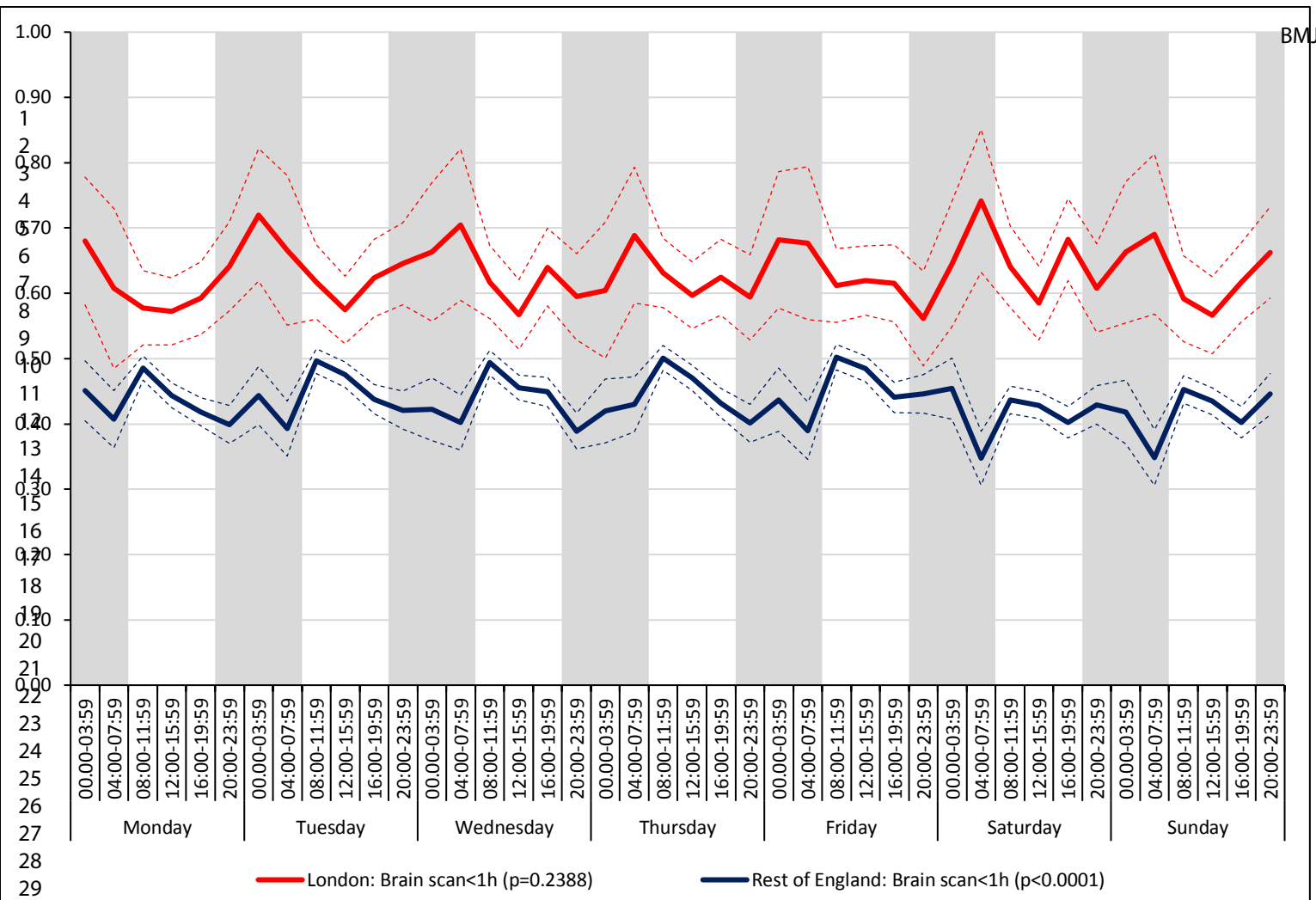


Figure S1(a). Brain scan within one hour

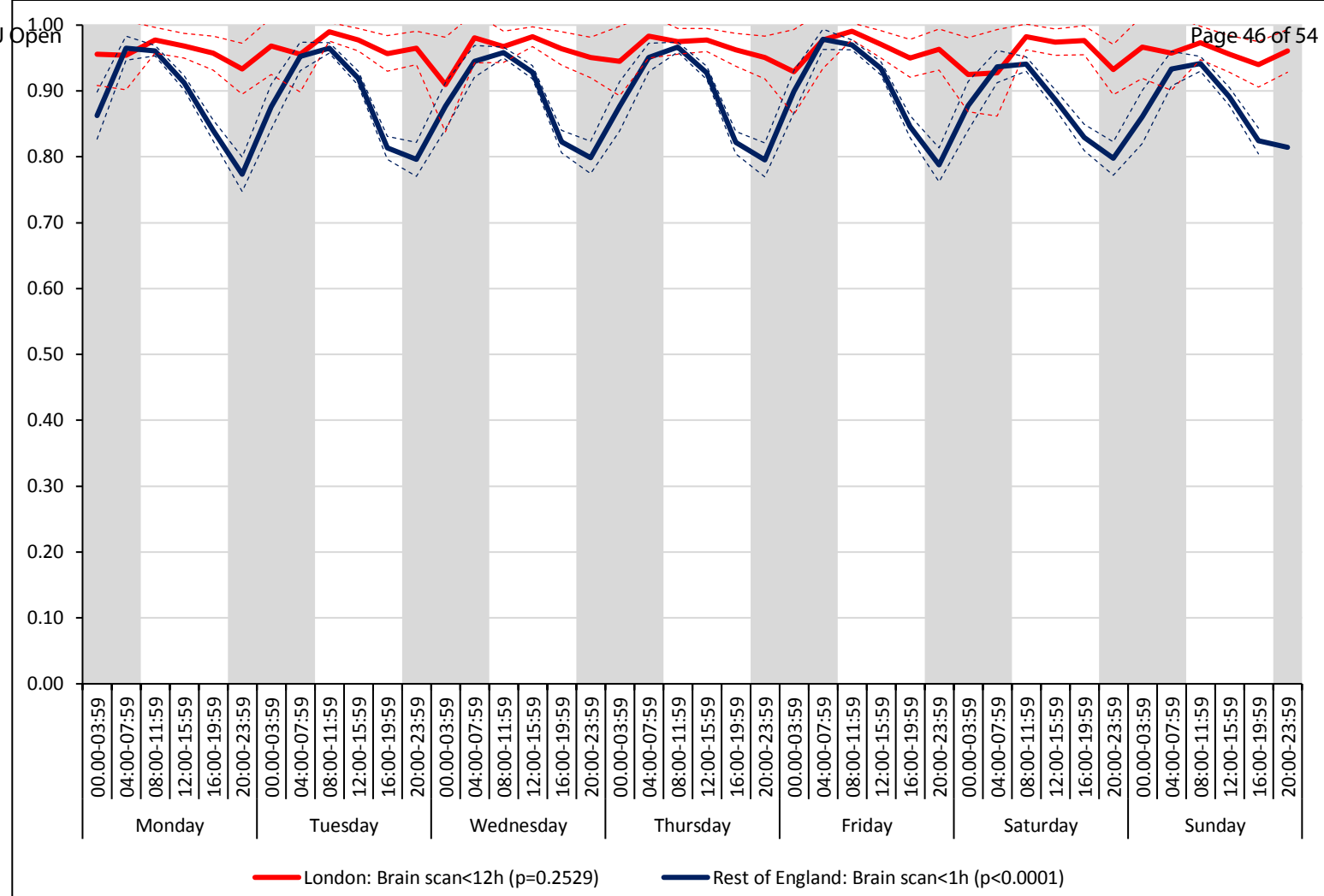


Figure S1(b). Brain scan within 12 hours

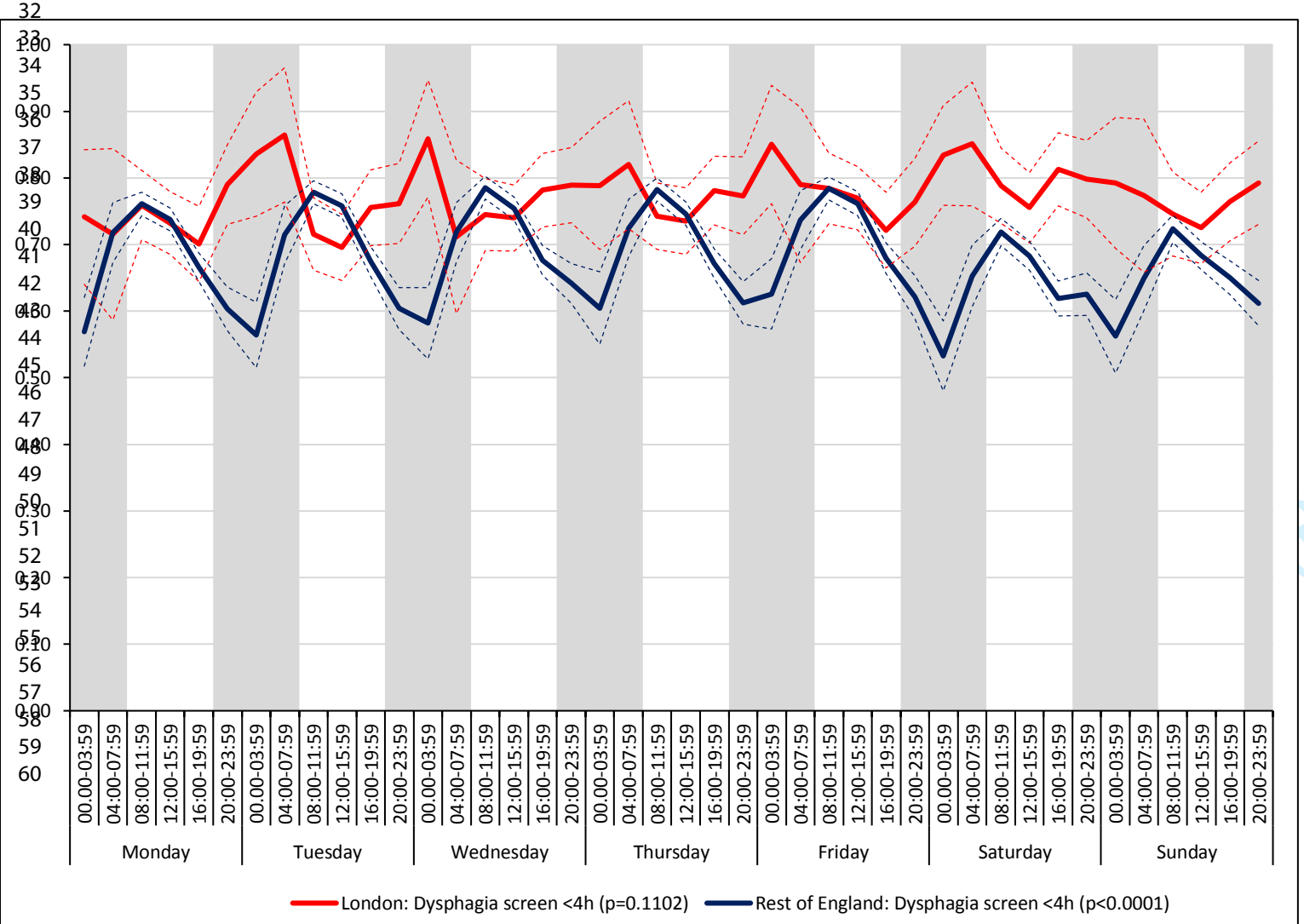


Figure S1(c). Dysphagia screen within four hours

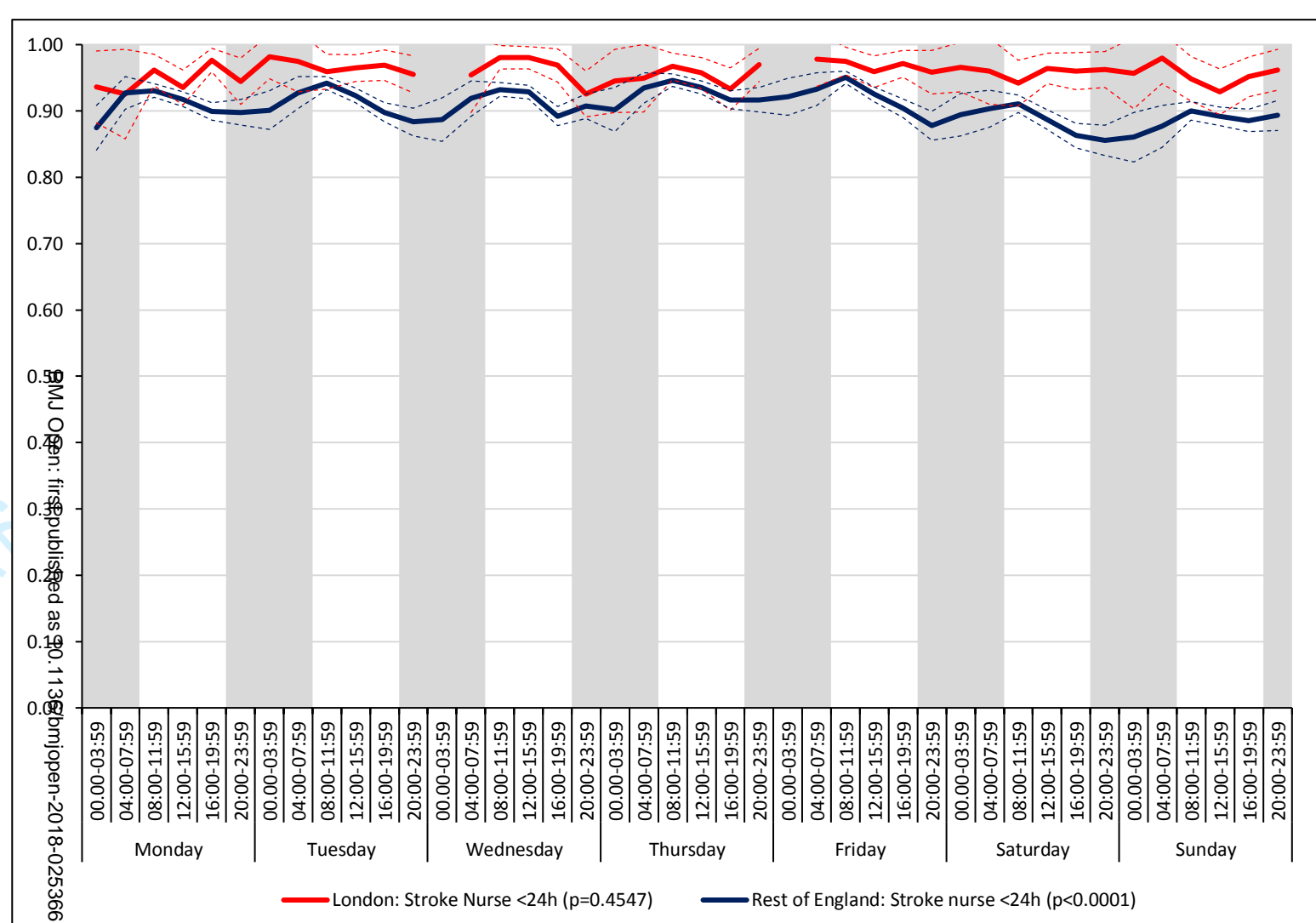


Figure S1(d). Nurse assessment within 24 hours

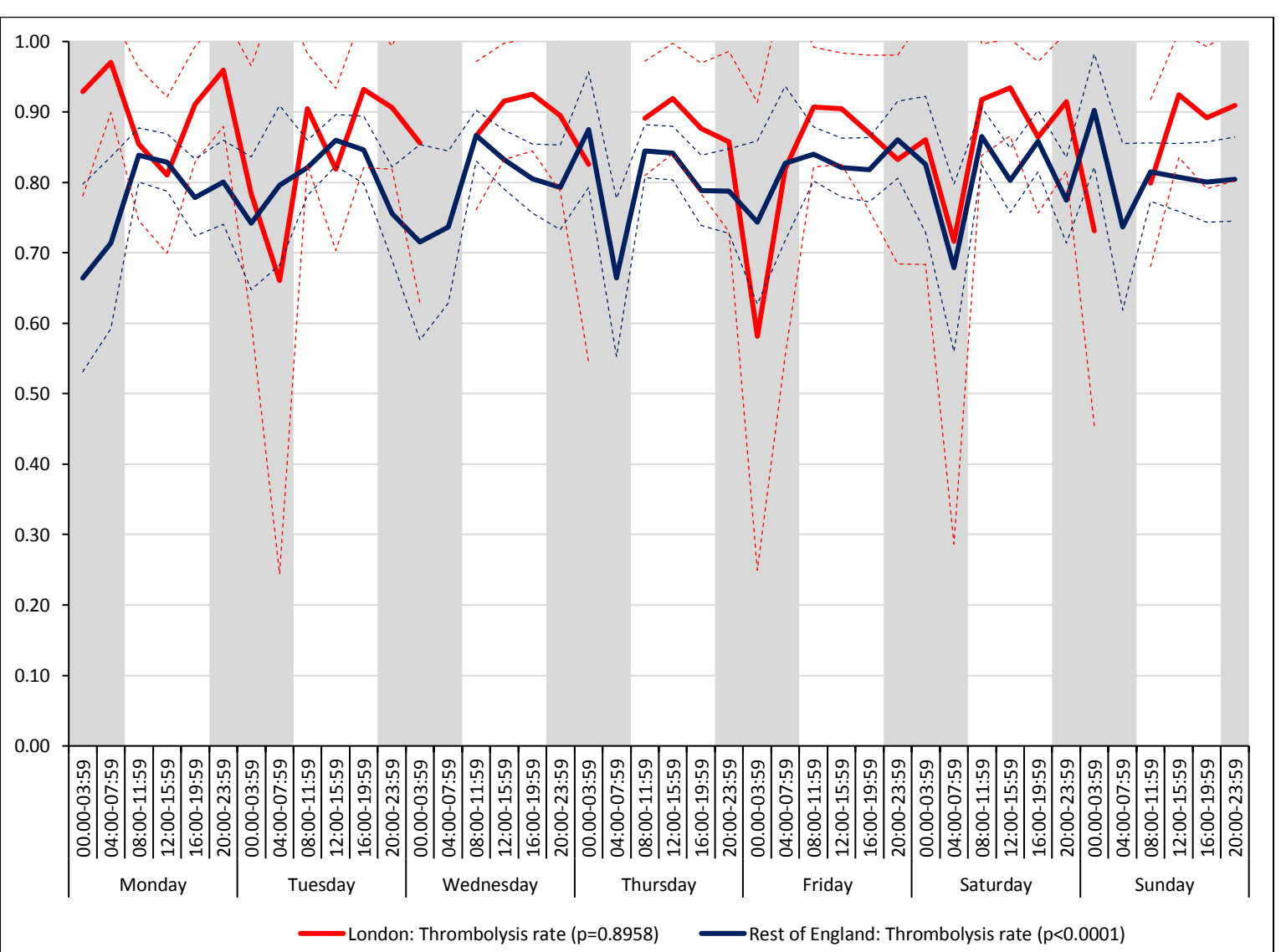


Figure S1(e). Administration of intravenous thrombolysis to eligible patients

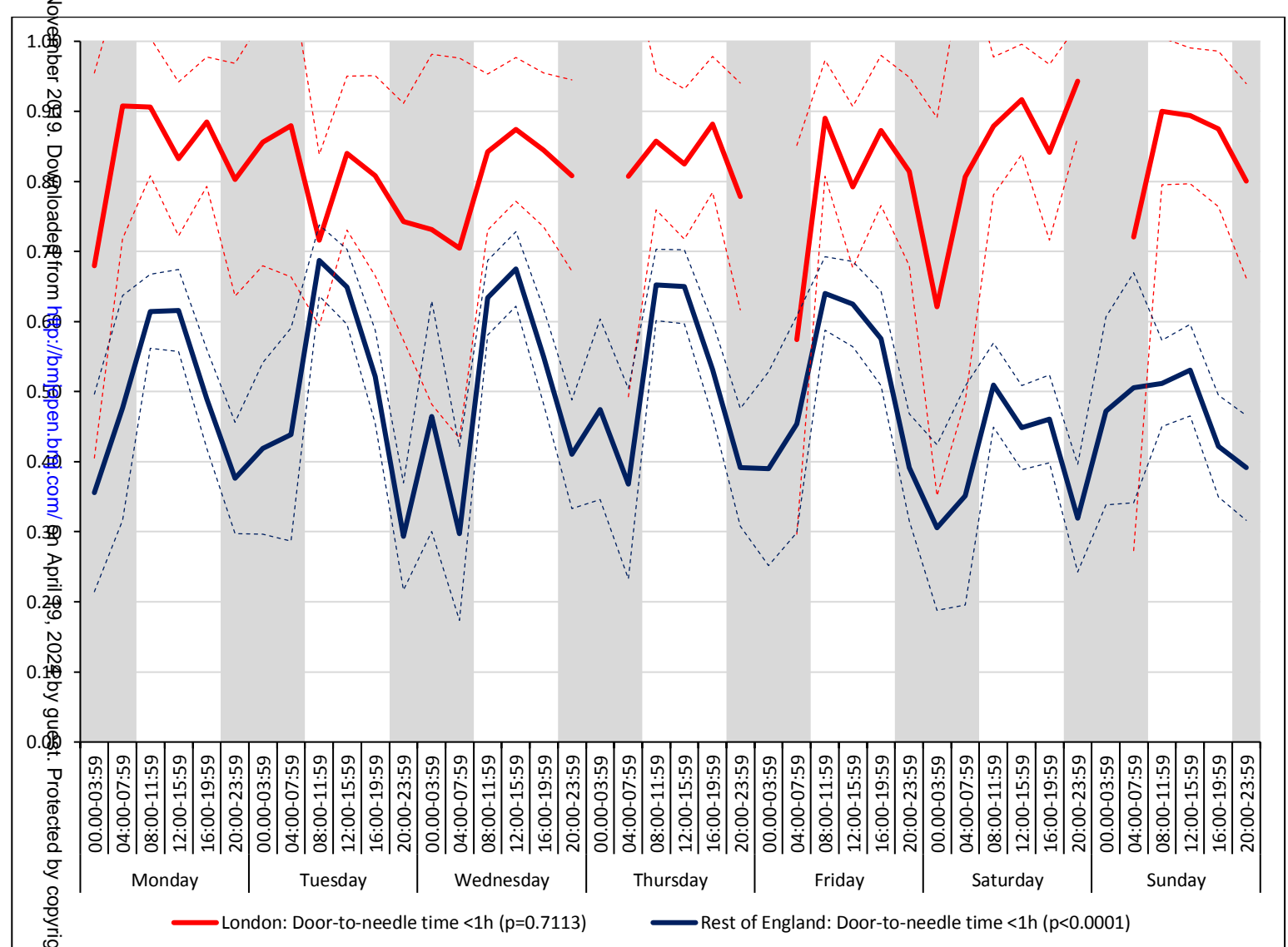


Figure S1(f). Door-to-needle time within one hour

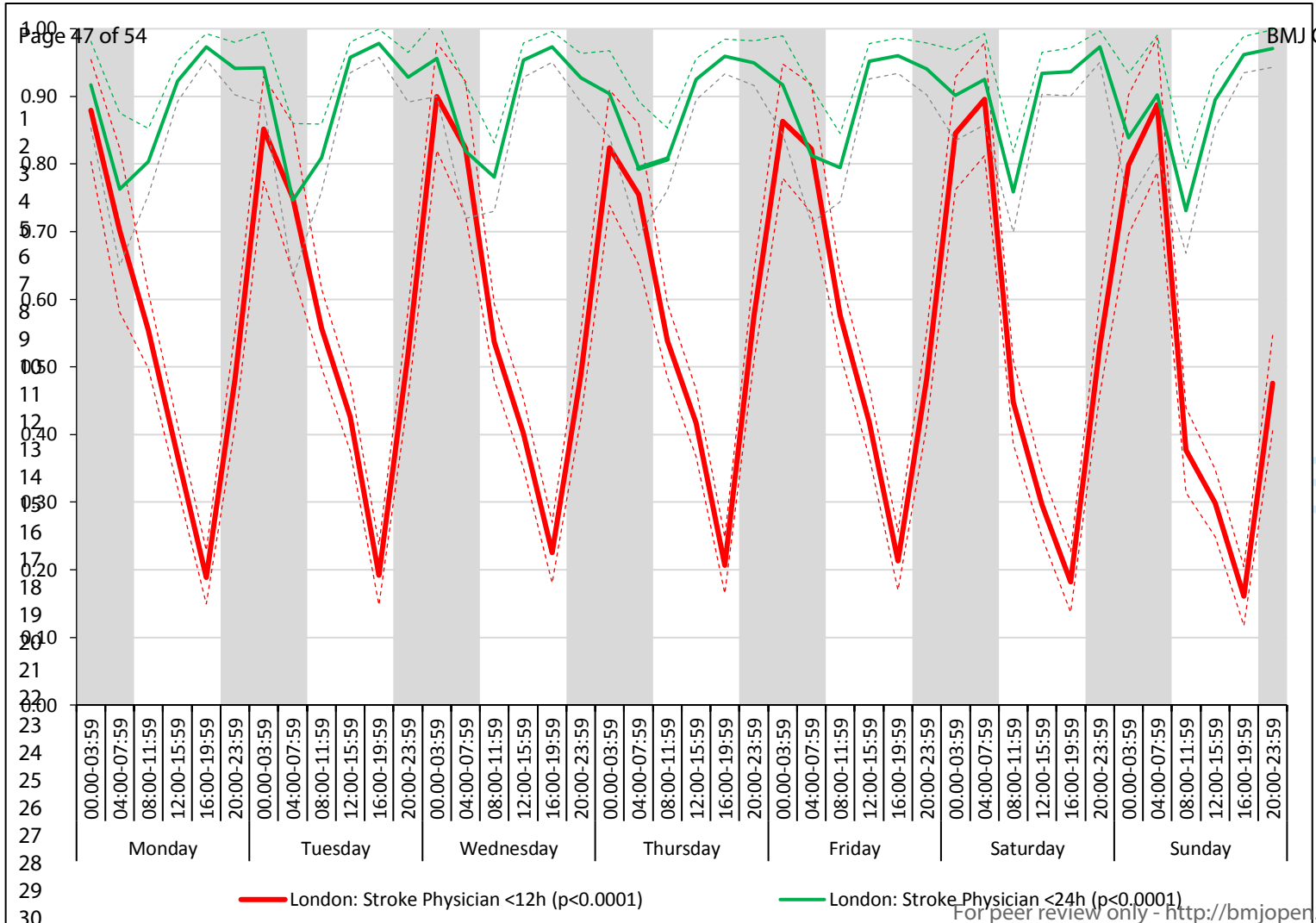


Figure S2(a). Assessment by a stroke consultant in London HASUs

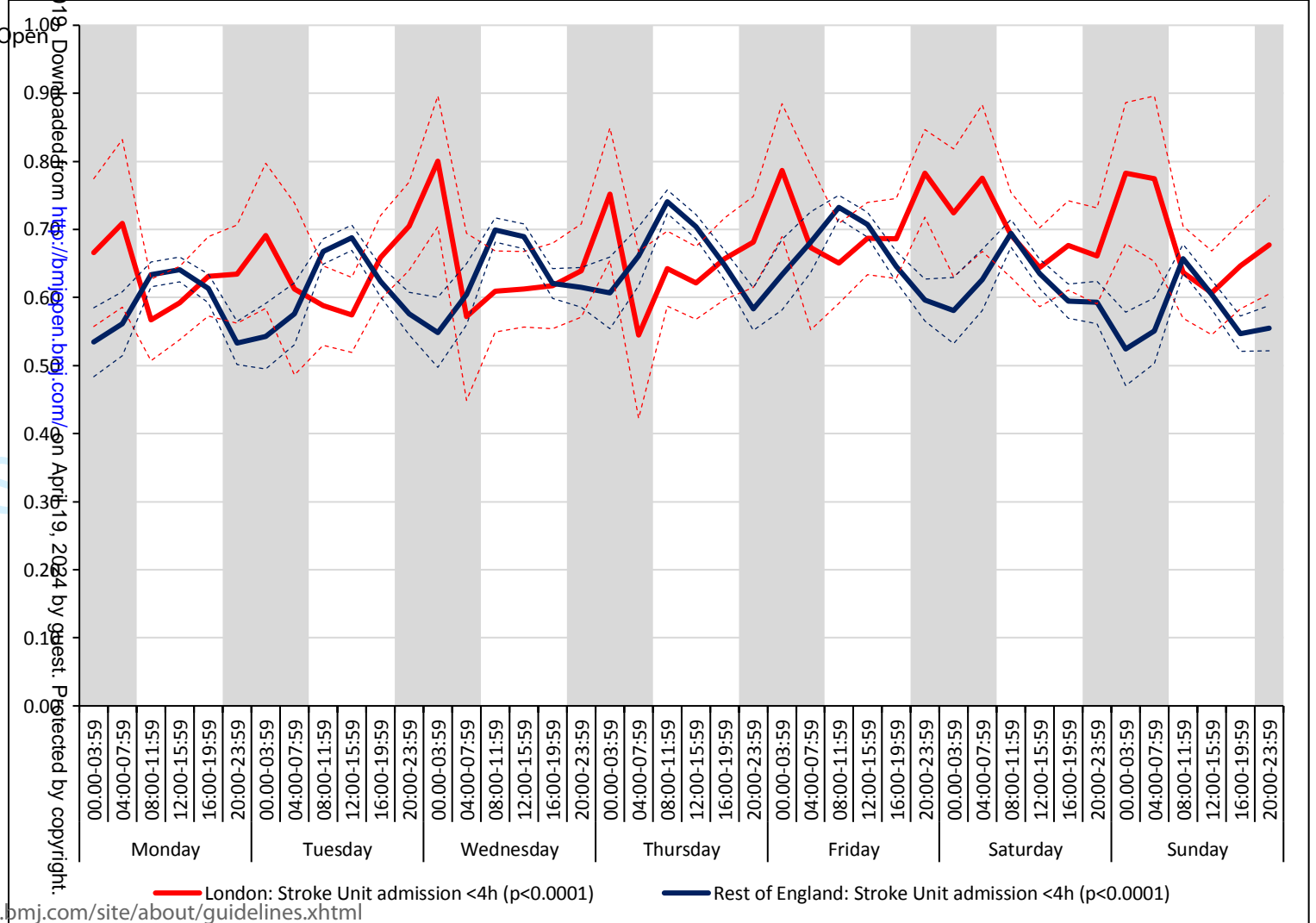
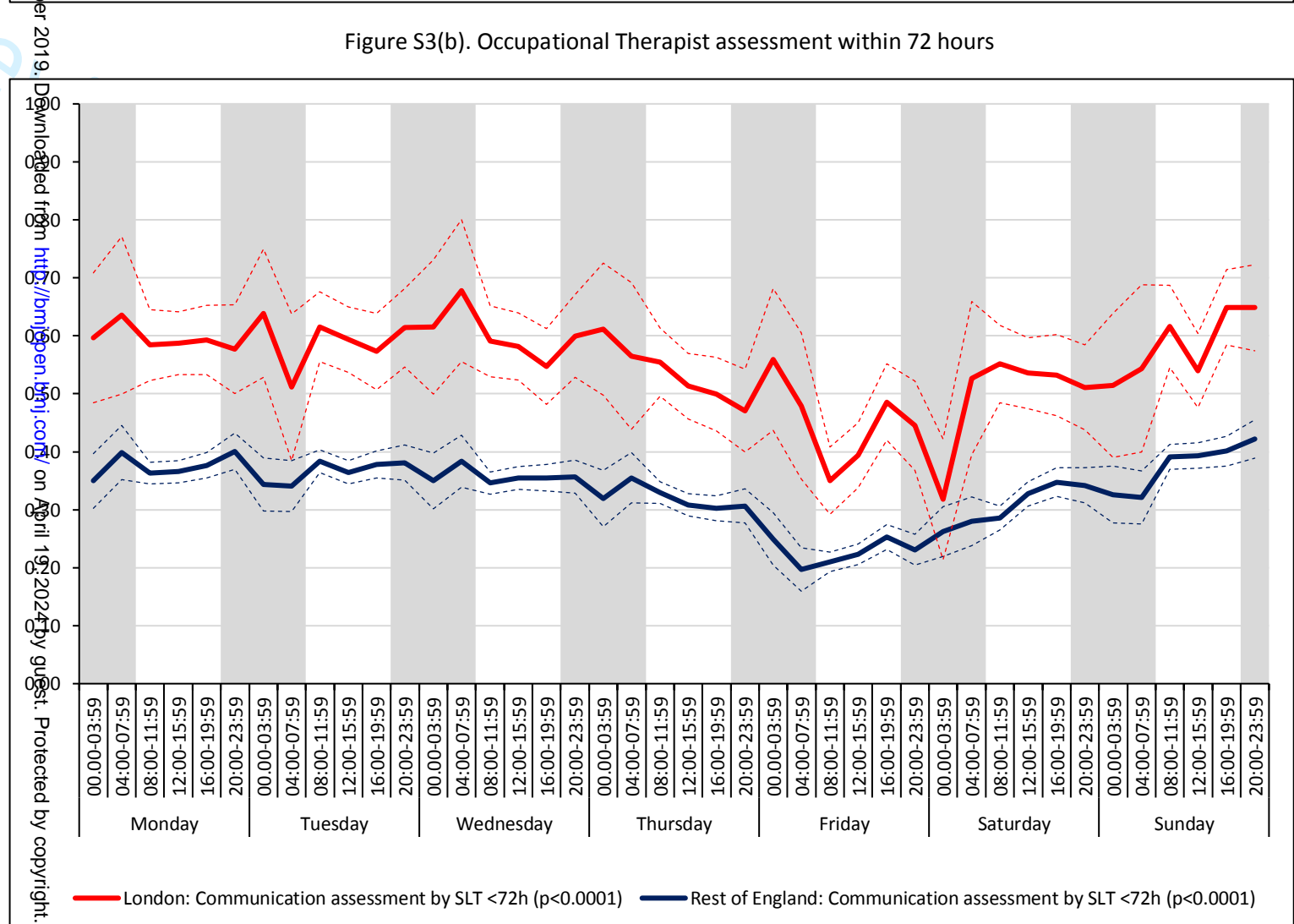
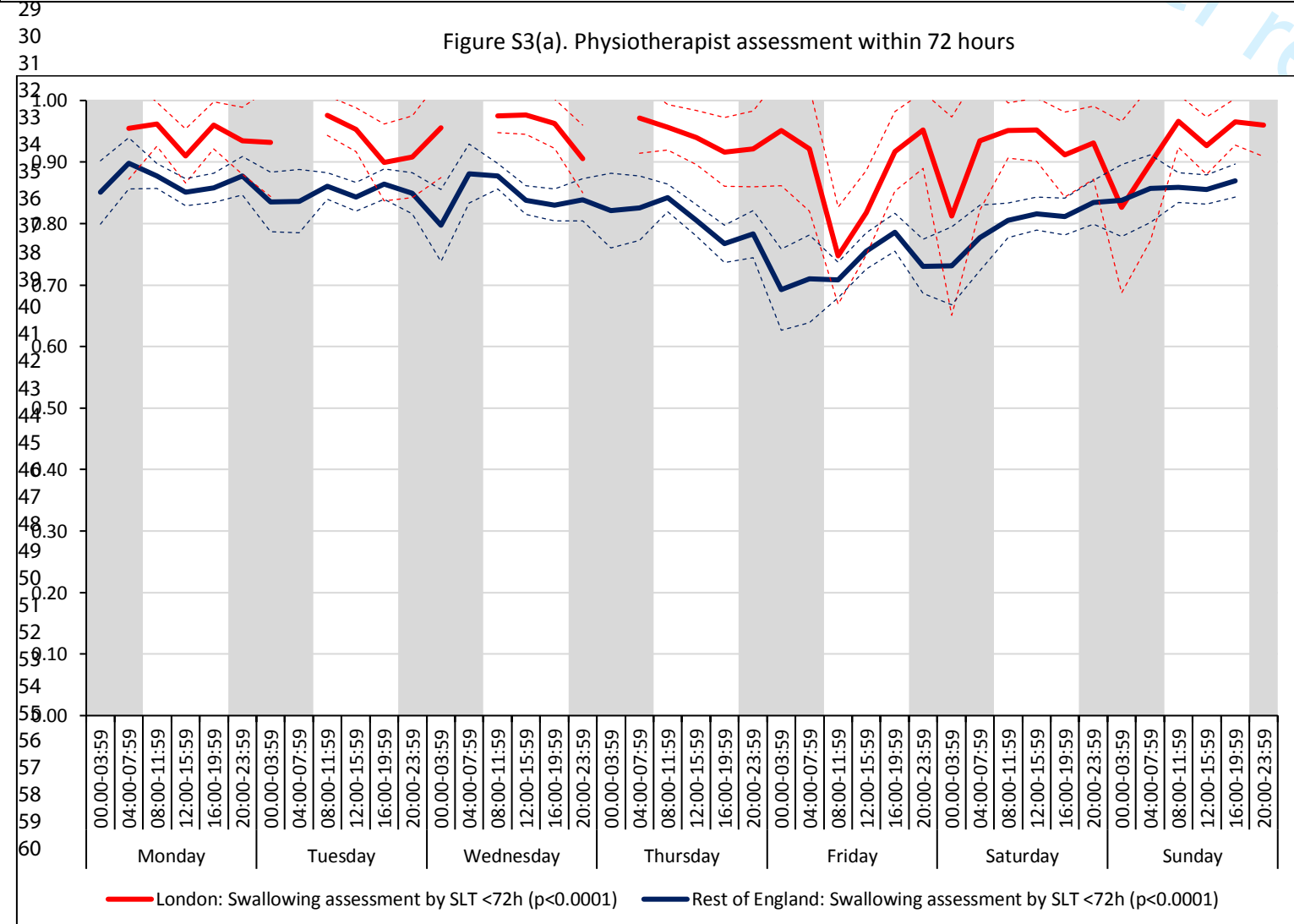
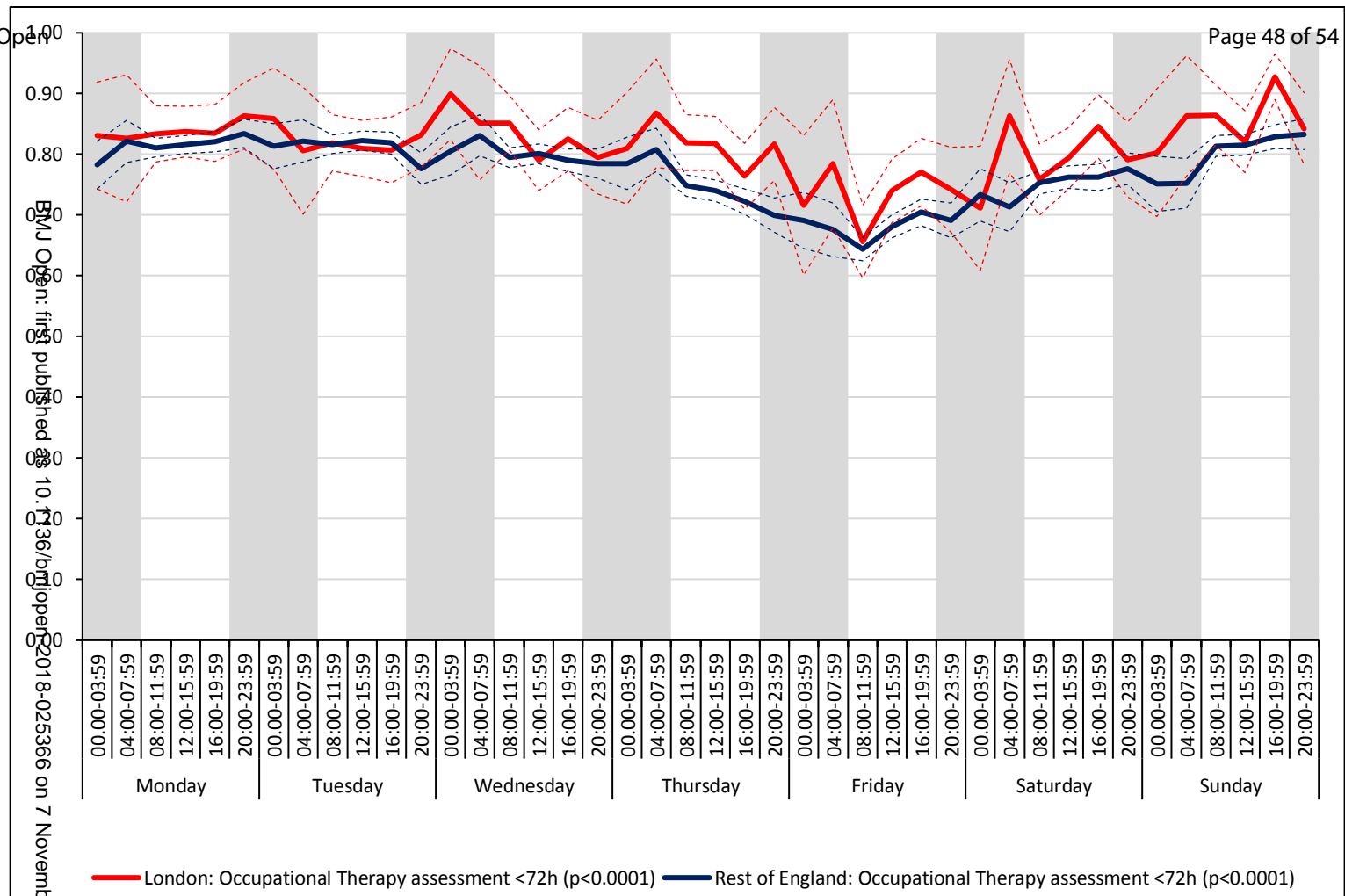
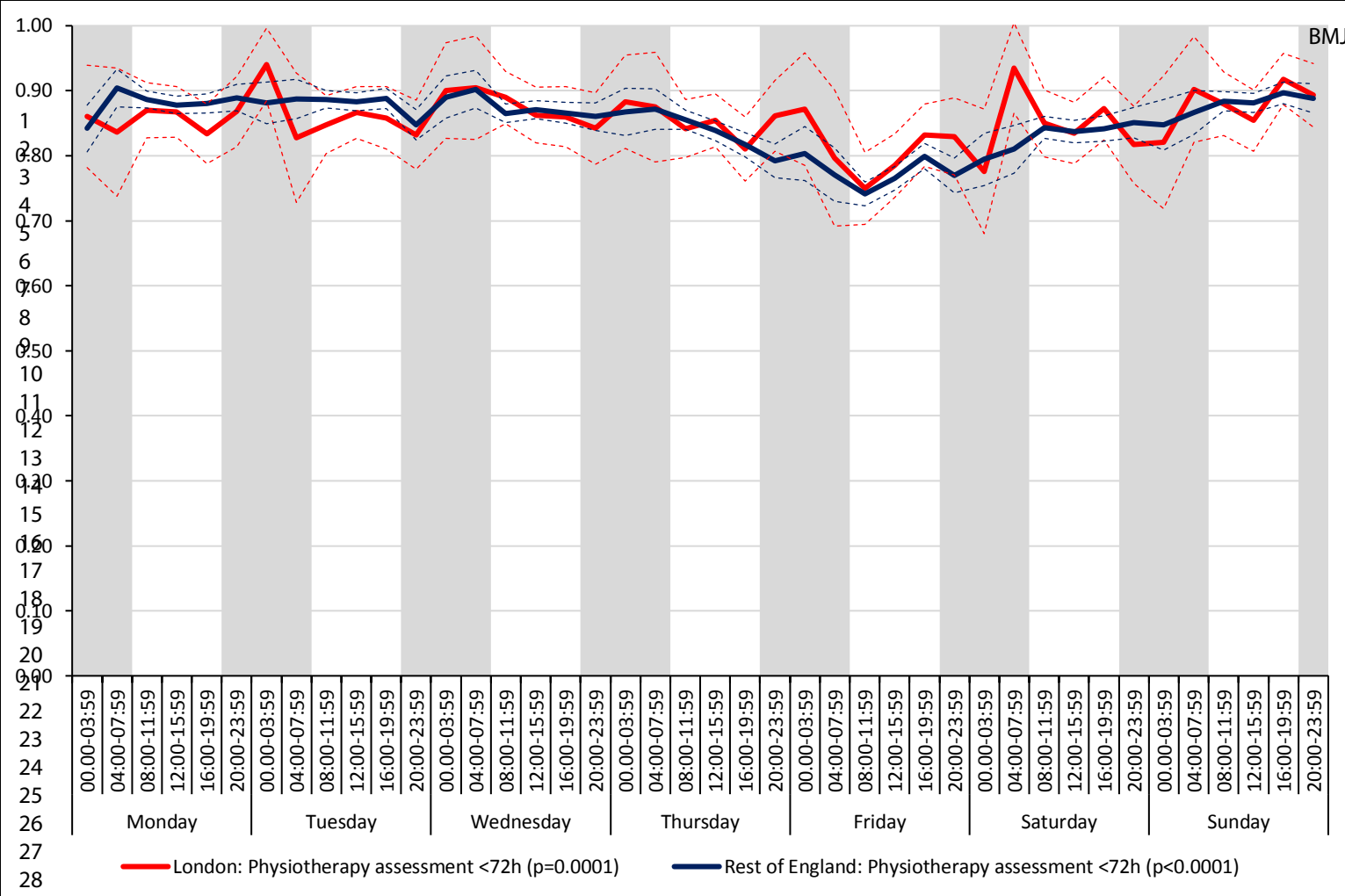


Figure S2(b). Admission to a stroke unit within four hours



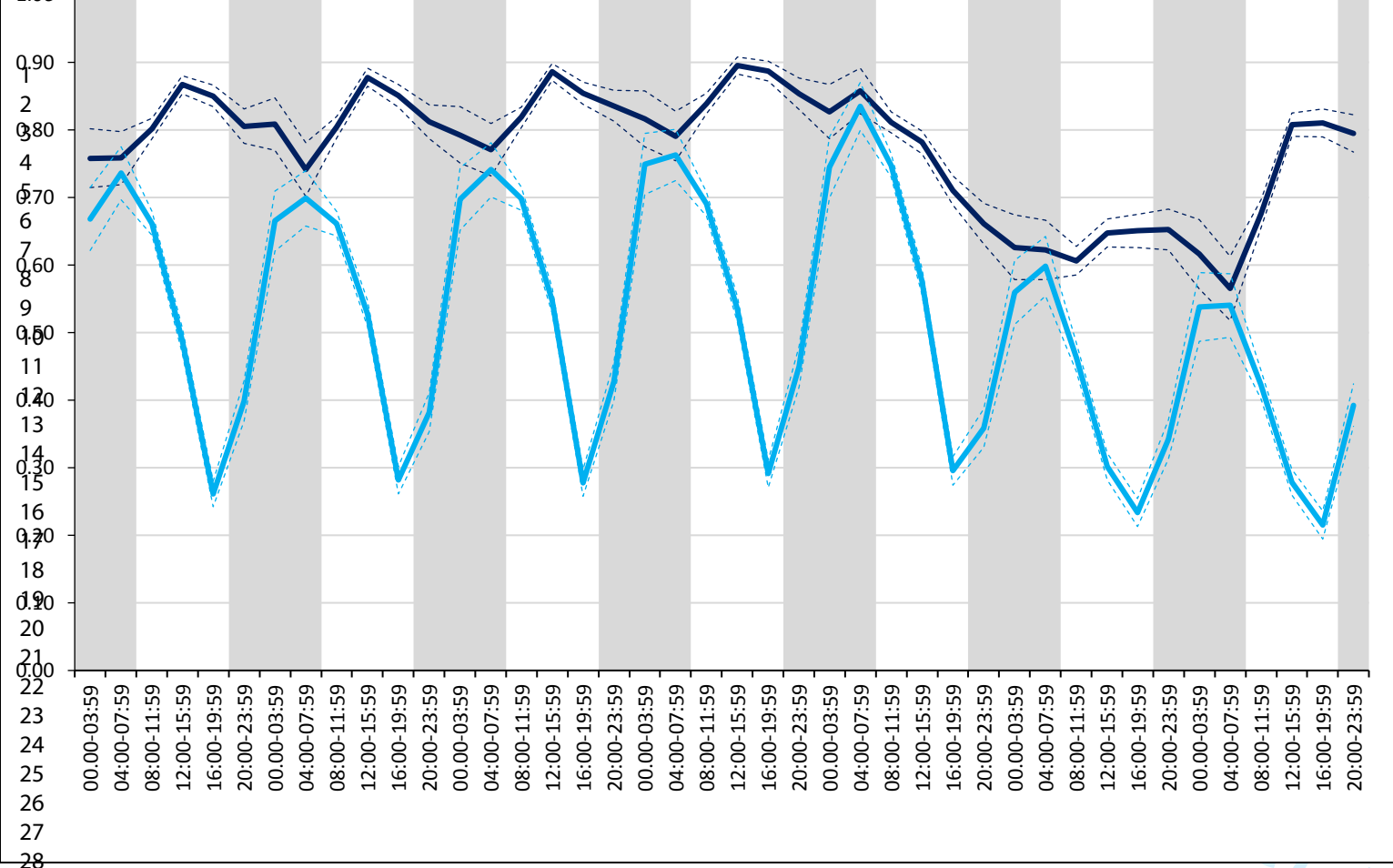


Figure S4(a). Assessment by a stroke consultant in Rest of England

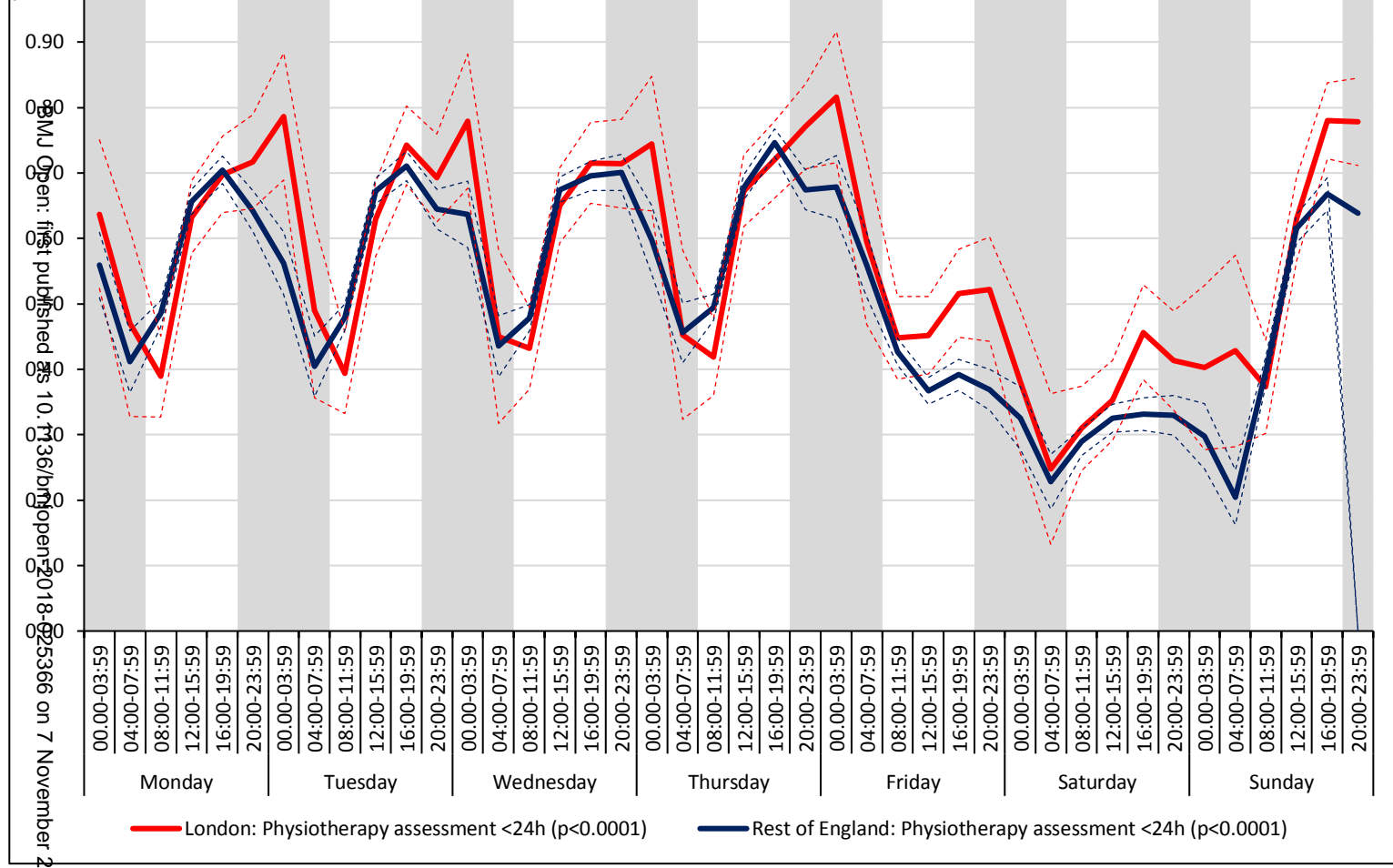


Figure S4(b). Physiotherapist assessment within 24 hours

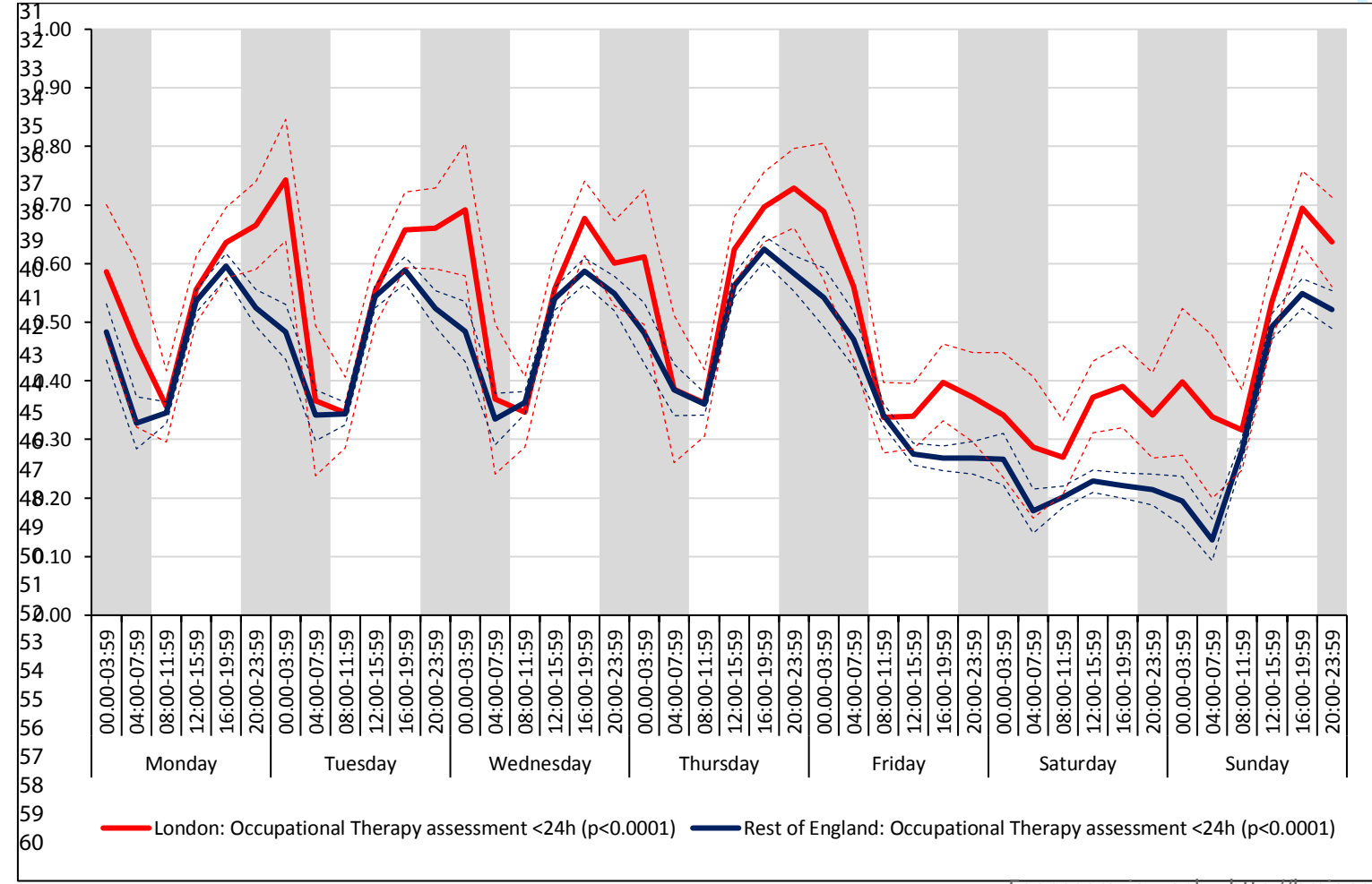


Figure S4(c). Occupational Therapist assessment within 24 hours

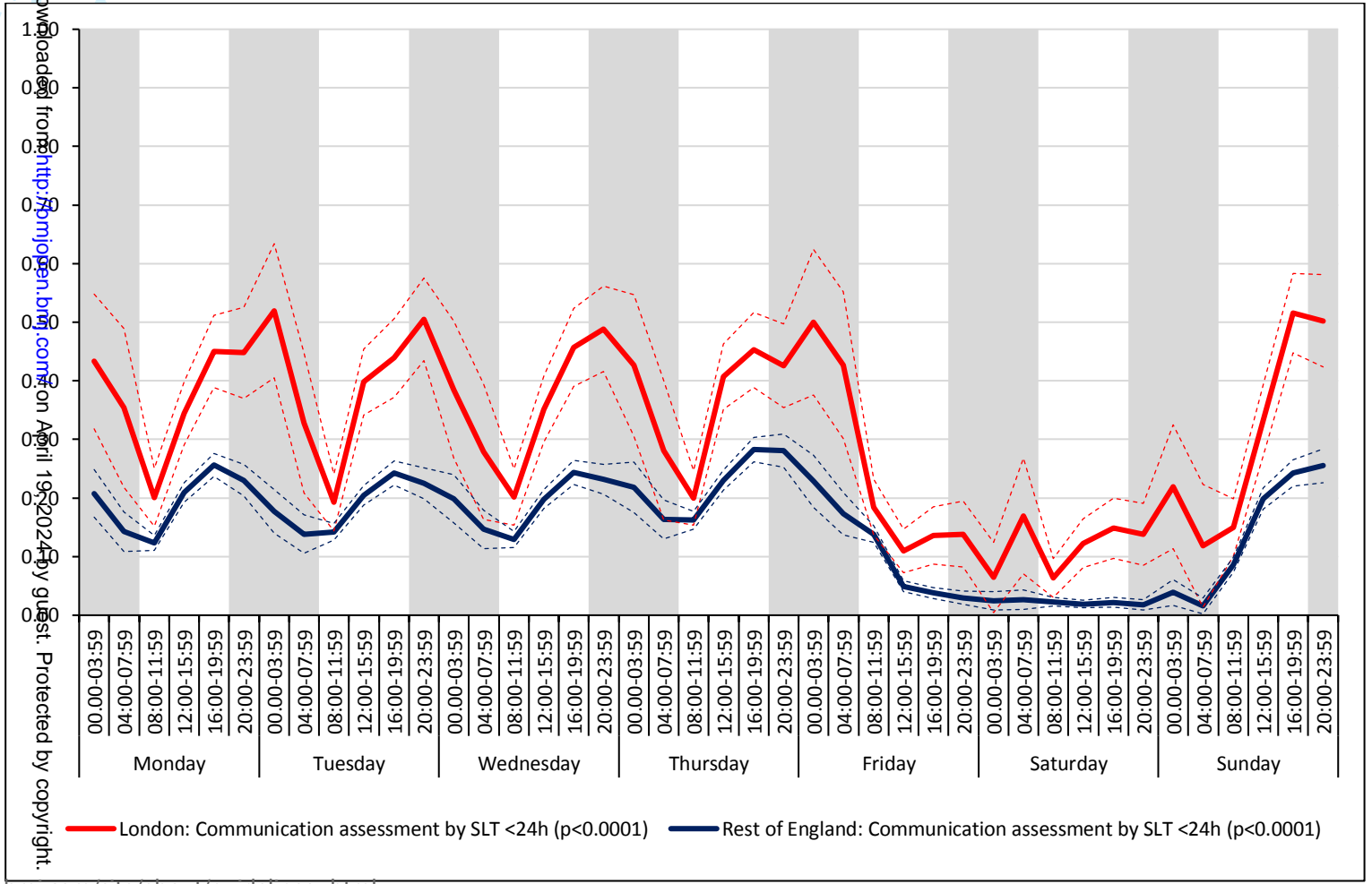


Figure S4(d). Communication assessment by a SaLT within 24 hours

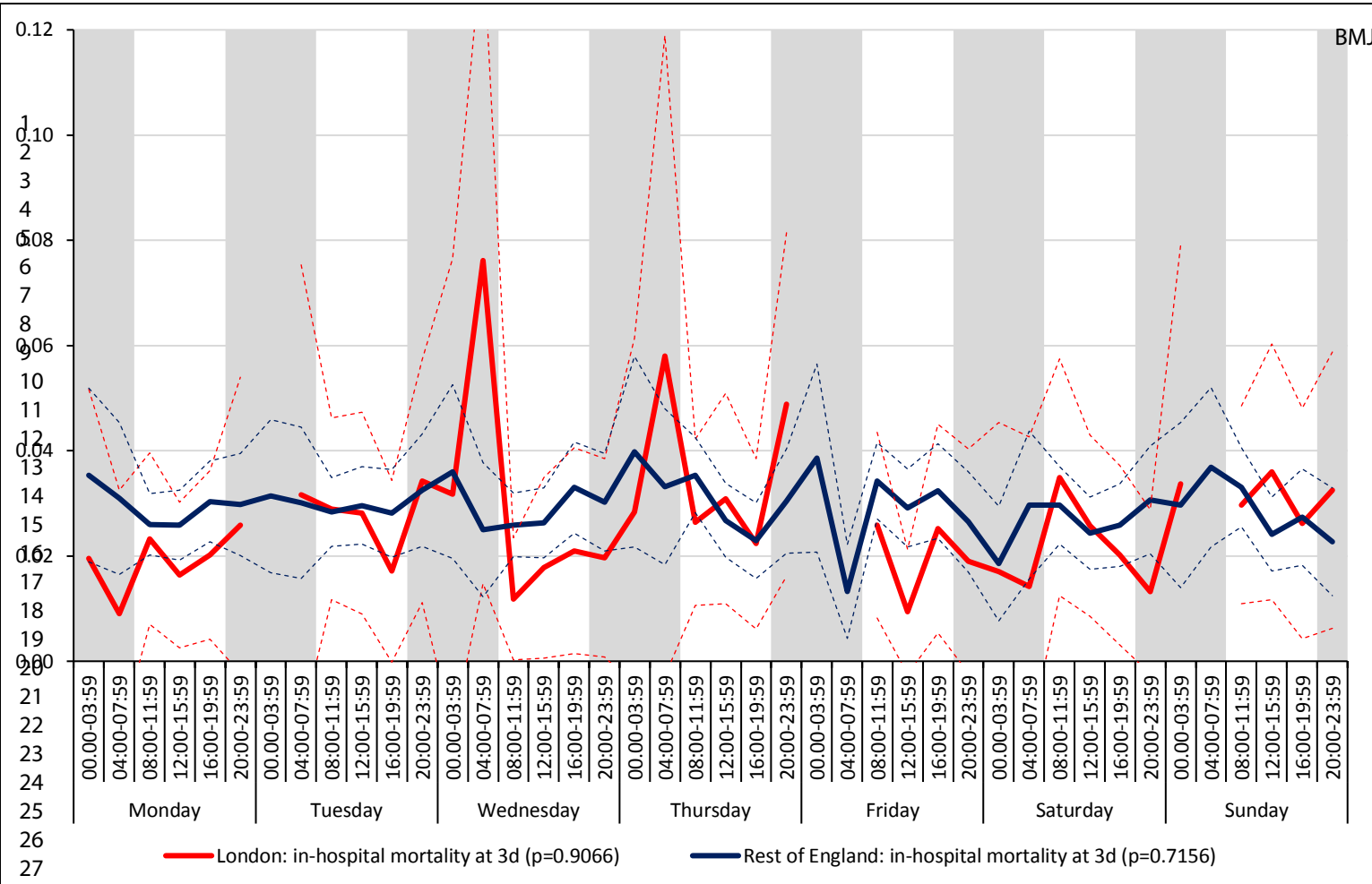


Figure S5(a). Mortality at three days

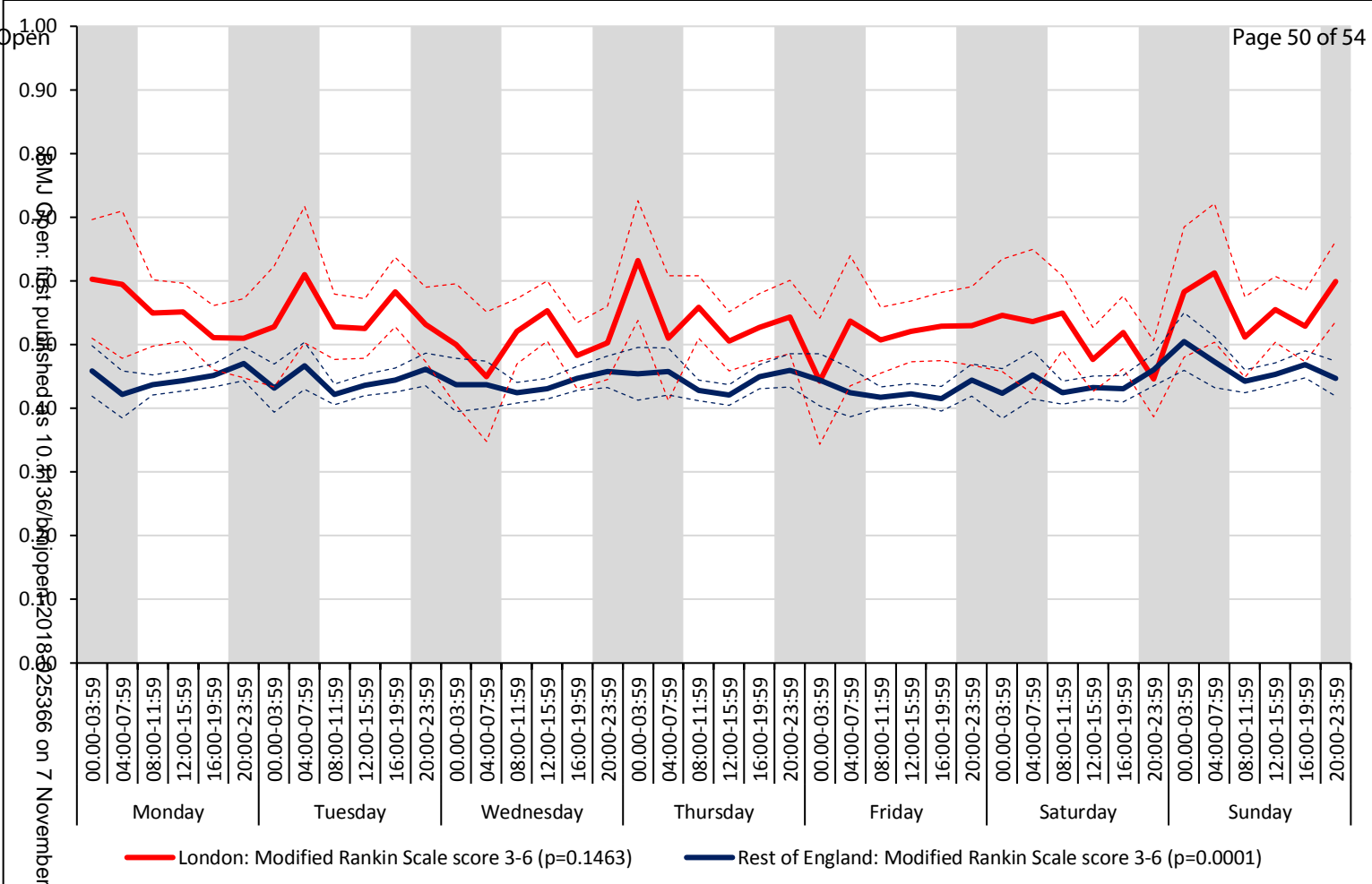


Figure S5(b). Modified Rankin Scale score 3-6

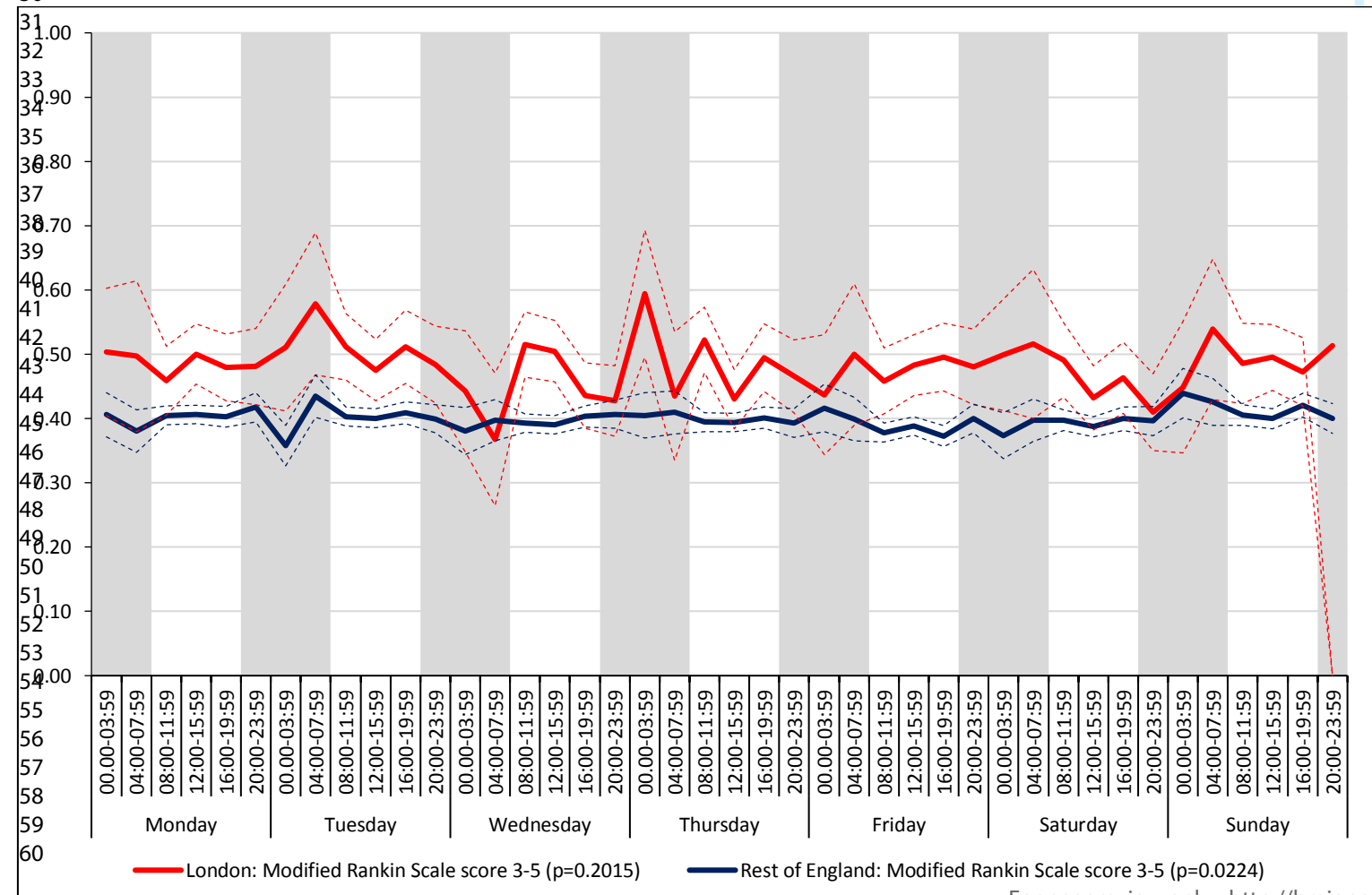


Figure S5(c). Modified Rankin Scale score 3-5

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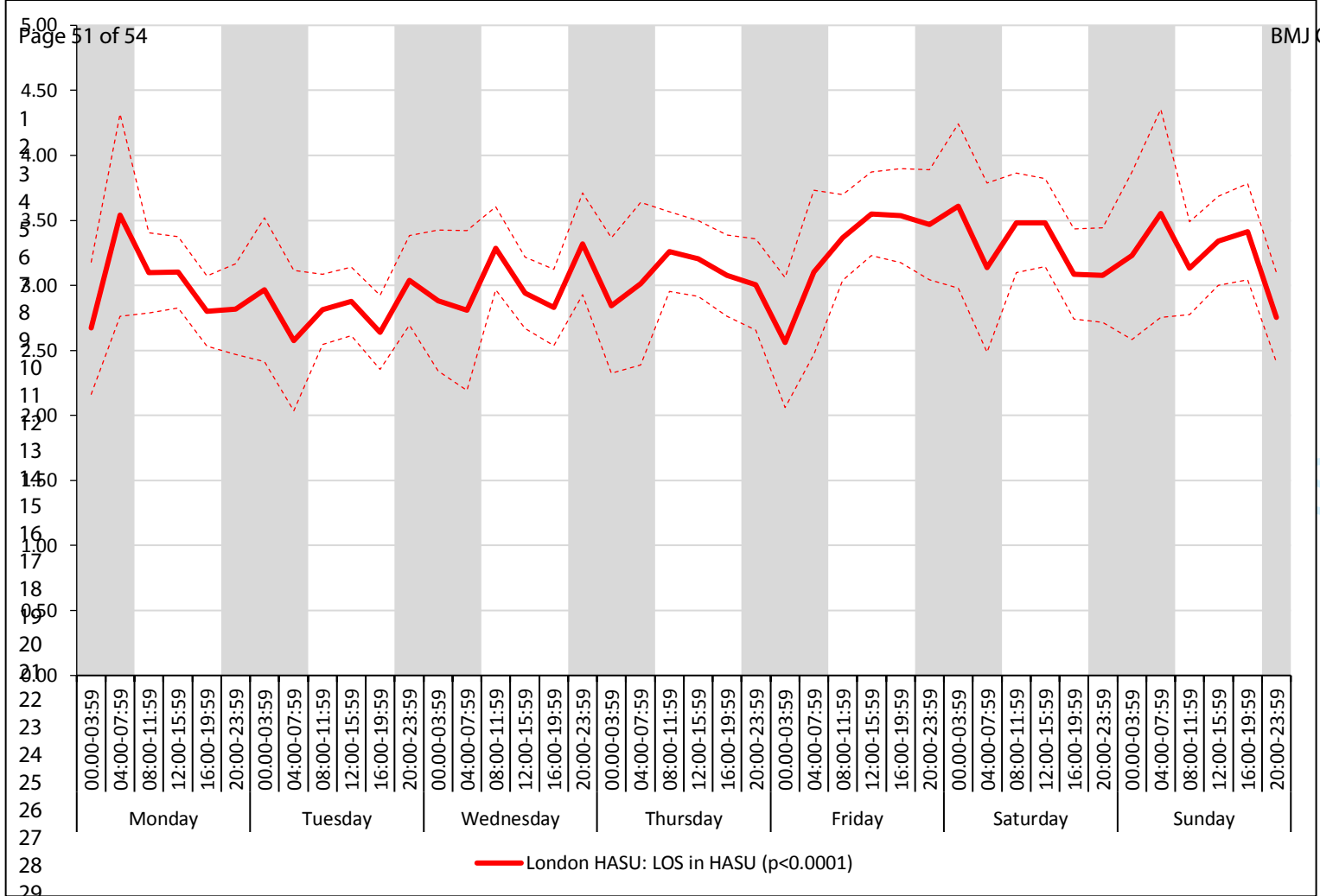


Figure S6(a). Length of stay in HASU

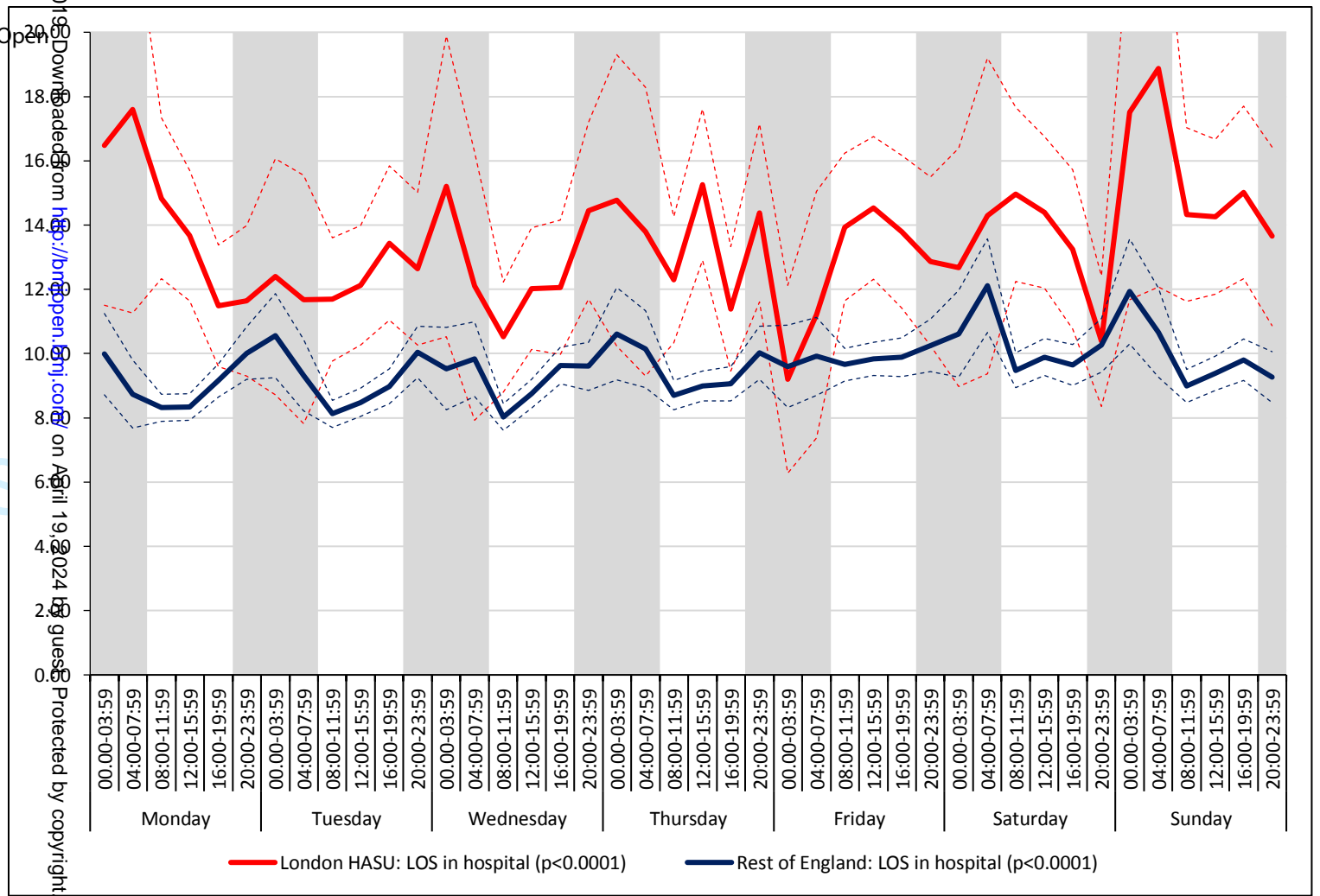


Figure S6(b). Length of stay in hospital

STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cohort studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(a) Indicate the study's design with a commonly used term in the title or the abstract	Title: P1; Abstract: P1-2
		(b) Provide in the abstract an informative and balanced summary of what was done and what was found	P1-2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	P3-4
Objectives	3	State specific objectives, including any prespecified hypotheses	P4, paragraph 3
Methods			
Study design	4	Present key elements of study design early in the paper	P4, paragraph 3; P5-6
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	P5, paragraph 1
Participants	6	(a) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up	P5, paragraph 1
		(b) For matched studies, give matching criteria and number of exposed and unexposed	Not applicable
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	P5, paragraph 2; P6, paragraphs 1-3; P7, paragraph 1
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	P5, paragraphs 1&2; P6, paragraphs 1&2
Bias	9	Describe any efforts to address potential sources of bias	P6, paragraph 3; P7, paragraph 1
Study size	10	Explain how the study size was arrived at	P5, paragraph 1; P6, paragraph 1
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	P5, paragraph 2 P6, paragraph 1-3; P7, paragraph 1

Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding	P6, paragraph 3; P7, paragraph 1
		(b) Describe any methods used to examine subgroups and interactions	Not applicable
		(c) Explain how missing data were addressed	Not applicable
		(d) If applicable, explain how loss to follow-up was addressed	Not applicable
		(e) Describe any sensitivity analyses	P7, paragraph 1; Supplementary Table 3
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	P8, paragraph 1; Supplementary Table 1
		(b) Give reasons for non-participation at each stage	Not applicable
		(c) Consider use of a flow diagram	Not applicable
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	P8, paragraph 1; Supplementary Table 1
		(b) Indicate number of participants with missing data for each variable of interest	Not applicable
		(c) Summarise follow-up time (eg, average and total amount)	Not applicable
Outcome data	15*	Report numbers of outcome events or summary measures over time	Supplementary Table 2
Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	Supplementary Table 2
		(b) Report category boundaries when continuous variables were categorized	Not applicable
		(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	Supplementary Table 2
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	Supplementary Table 3
Discussion			
Key results	18	Summarise key results with reference to study objectives	P11
Limitations			

Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	P12-13
Generalisability	21	Discuss the generalisability (external validity) of the study results	P13-15
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	P20, paragraph 1

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at <http://www.plosmedicine.org/>, Annals of Internal Medicine at <http://www.annals.org/>, and Epidemiology at <http://www.epidem.com/>). Information on the STROBE Initiative is available at www.strobe-statement.org.

BMJ Open

Variation in quality of acute stroke care by day and time of admission: prospective cohort study of weekday and weekend centralised hyperacute stroke unit care and non-centralised services

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2
3 TITLE: Variation in quality of acute stroke care by day and time of admission: prospective cohort
4 study of weekday and weekend centralised hyperacute stroke unit care and non-centralised
5 services
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Word count: 5704 (excluding tables); 6170 (with tables)

ABSTRACT

Objective: To investigate variations in quality of acute stroke care and outcomes by day and time of admission in London hyperacute stroke units compared with the rest of England.

Design: Prospective cohort study using anonymised patient-level data from the Sentinel Stroke National Audit Programme.

Setting: Acute stroke services in London hyperacute stroke units and the rest of England.

Participants: 68 239 patients with a primary diagnosis of stroke admitted between January and December 2014.

Interventions: Hub-and-spoke model for care of suspected acute stroke patients in London with performance standards designed to deliver uniform access to high-quality hyperacute stroke unit care across the week.

Main outcome measures: 16 indicators of quality of acute stroke care, mortality at three days after admission to the hospital, disability at the end of the inpatient spell, length of stay.

Results: There was no variation in quality of care by day and time of admission to the hospital across the week in terms of stroke nursing assessment, brain scanning, and thrombolysis in London hyperacute stroke units, nor was there variation in three-day mortality or disability at hospital discharge (all p-values>0.05). Other quality of care measures significantly varied by day and time of admission across the week in London (all p-values<0.01). In the rest of England there was variation in all measures by day and time of admission across the week (all p-values<0.01), except for mortality at three days (p-value>0.05).

Conclusions:

The London hyperacute stroke unit model achieved performance standards for “front door” stroke care across the week. The same benefits were not achieved by other models of care in the rest of England. There was no weekend effect for mortality in London or the rest of the

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3 England. Other aspects of care were not constant across the week in London hyperacute stroke
4 units, indicating some performance standards were perceived to be more important than others.
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9 **Article summary**

10 ***Strengths and weaknesses***

- 13 • We used a large national dataset containing detailed information on quality of stroke
14 care, outcomes, and patient characteristics.
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- 16 • We examined whether time of admission was related to quality of care using a
17 comprehensive set of indicators from across the acute stroke care pathway to reflect the
18 time-critical nature of acute stroke care.
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- 20 • Our outcomes were stroke short-term mortality and disability, buy we were unable to
21 measure long-term outcomes as these were not available in SSNAP.
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INTRODUCTION

There is conflicting evidence as to whether or not patients presenting with acute stroke symptoms receive lower quality of care and have worse outcomes if admitted to hospital outside of normal weekday working hours or at weekends (the “weekend effect”). Some studies have shown that acute stroke patients admitted at weekends have lower quality of care[1,2] and higher mortality[1–10], while others have shown the opposite[11–14]. Evaluation of these studies is further complicated by recent evidence that stroke incidence reporting at the weekend may be unreliable in older studies[15]. Recent work based upon data from the Stroke Sentinel National Audit Programme (SSNAP) dataset further shows that care quality and outcomes in acute stroke vary across the week, and concluded that binary comparisons of weekend versus weekday or in-hours versus out-of-hours processes and effects oversimplify more likely variations by day of week and time of day [16]. Further, no studies have investigated the impact of time of admission on disability following a stroke.

If there is lower quality of care and there are worse outcomes at the weekend these could be linked to reduced staffing levels[17]; for acute stroke care, nurse staffing levels at weekends has been shown to be a significant predictor of mortality[18], while evidence from the United States suggests that specialised stroke units, with round-the-clock availability of specialist stroke teams and rapid access to imaging and thrombolysis, reduce variation in quality of care and outcomes across the week[19–21].

In 2010 London centralised its acute stroke services using a hub-and-spoke network model [22] [23,24]. Out of 34 hospitals that had historically provided acute stroke care [25], 8 were selected as host sites for Hyperacute Stroke Units (HASUs). The HASU model involved the London Ambulance Service taking all patients with suspected stroke symptom onset within 48 hours to one of the eight HASUs[26]. HASUs receive patients with suspected stroke and routinely provide immediate assessment by specialised stroke assessment teams, access to immediate brain imaging, and the immediate delivery of intravenous thrombolysis where appropriate. Acute stroke

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3 patients seen at other medical facilities were similarly transferred as an emergency to a HASU.
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5 The aim of the HASUs was to provide specialised care for all acute stroke patients during the first
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7 72 hours after onset of stroke. After 72 hours, patients requiring ongoing inpatient treatment are
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9 transferred to one of the twenty-four Acute Stroke Units in London linked to HASUs. Eight of these
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11 were in the same hospital trust as a HASU[27].
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13 Performance standards for HASUs, linked to payments, were initially set by Healthcare for
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15 London[28] and subsequently the London Strategic Clinical Networks to maintain high quality of
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17 care across the HASU stay. Some standards were set to provide rapid access to time-critical
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19 “front door” measures, e.g., dysphagia screen within four hours of admission, brain scans within
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21 one hour, administration of thrombolysis to eligible patients[26] within 60 minutes). Other
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23 standards were set with less stringent time constraints (e.g., stroke specialist consultant physician
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25 assessment within 24 hours, physiotherapist assessment within 72 hours).
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28 On average across all patients, the quality of acute stroke care in London increased as a result
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30 of the centralisation and was significantly higher than elsewhere in England on all measures
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32 analysed [29], and mortality decreased[30]. Following these findings, the aim of this study was to
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34 investigate variations in the quality of acute stroke care and outcomes by day and time of
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36 admission in London HASUs and the rest of England. We used national audit data for all patients
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38 in England who had a stroke during a 12-month period recorded by the Sentinel Stroke National
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40 Audit Programme (SSNAP)[31]. We hypothesised that there would be less variation across the
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42 week in care quality measures within London HASUs compared with the variation in the rest of
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44 England, and that this would also translate into less variation in outcomes in London HASUs.
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53 **METHODS**

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Data and measures

We obtained anonymised patient-level data from the Sentinel Stroke National Clinical Audit Programme (SSNAP)[31], for all patients in England with a primary diagnosis of stroke (ischaemic stroke or primary intracerebral haemorrhage) between 1 January and 31 December 2014. SSNAP collects data on clinical characteristics, care quality (from the time of admission up to 6 months after stroke) and outcomes for all stroke patients admitted to acute care hospitals in England[32–34]. During our study period the case ascertainment in the SSNAP, which is calculated as the proportion of all acute stroke patients admitted to hospitals, for England was estimated to be 90%.[35] We excluded patients treated at hospitals in Wales from our analysis because for Wales the case ascertainment was estimated to be 60%[33].

The following quality of care indicators were measured from time of hospital admission (or onset of stroke symptoms for those who were already in hospital): brain scan within one hour and within 12 hours; dysphagia screen within four hours; assessment by a nurse trained in stroke management within 24 hours; administration of intravenous thrombolysis to eligible patients; door-to-needle time within one hour in patients receiving thrombolysis; assessment by a stroke specialist consultant physician within 12 hours* and within 24 hours; admission to a stroke unit within four hours; assessments by a Physiotherapist within 24 hours* and within 72 hours; by Occupational Therapist within 24 hours* and within 72 hours; and by Speech and Language Therapist within 24 hours* and within 72 hours. These measures are quality indicators routinely reported by SSNAP; we also included measures (marked with a *) with more stringent time constraints to reflect the time-critical nature of acute stroke care. Outcomes were measured as whether or not the patient died within three days and disability using the modified Rankin Scale (mRS) score 0-2 versus 3-6 (moderate, moderately severe or severe disability or death) at the end of the inpatient stay. We also analysed mRS score 0-2 versus 3-5 at the end of the inpatient stay, excluding patients who died. Mortality data beyond hospital discharge were not available in

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3 SSNAP; we therefore measured mortality up to three days after admission to minimise the number
4 of missed deaths. We analysed length of stay (LOS) in the HASU (in London only) and LOS in
5 hospital. The denominators used for each measure were consistent with the SSNAP key
6 indicators[36]. Most outcomes were measured for all patients, but there were exceptions: patients
7 who were medically unwell or refused to be screened were excluded from the dysphagia screen
8 measure; only patients with ischaemic stroke who met the Royal College of Physicians guideline
9 minimum threshold for thrombolysis were included in the thrombolysis rate; door-to-needle times
10 included only those who received thrombolysis with a final diagnosis of stroke; patients who were
11 persistently medically unwell, declined to be assessed or had no relevant deficit were excluded
12 from the therapy performance measures.
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14 To examine variations across the week we initially used a flexible specification of time of
15 admission, measured in six four-hour periods from 00:00 to 03:59, 04:00 to 07:59, 08:00 to 11:59,
16 12:00 to 15:59, 16:00 to 19:59, 20:00 to 23:59 for every day of the week (42 periods). We also
17 created a more restrictive measure to examine broad trends across the week: Monday to Friday
18 08:00 to 19:59; Monday to Friday 20:00 to 07.59; Saturday and Sunday 08:00 to 19:59; Saturday
19 and Sunday 20:00 to 07.59(four periods) following Bray et al.[16] who found variations across the
20 week with both specifications.
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24 **Statistical analysis**

25 We ran patient-level logistic regressions, regressing each measure against time period of
26 admission. For LOS we used parametric survival models (modelled as time to event of discharge)
27 assuming a lognormal survival distribution. We ran separate models for London and the rest of
28 England. In every model we controlled for sex, age (continuous variable), ethnic group (six
29 categories), type of stroke (infarction or primary intracerebral haemorrhage), comorbidities prior
30 to admission (five options), mRS before stroke (0 to 2, 3 to 5), level of consciousness on arrival
31 at the hospital (four categories), method of admission to the hospital (three categories), time from
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3 onset of stroke symptoms to admission (four categories), month of admission (12 categories),
4 and hospital Trust. When analysing mRS scores 0-2 versus 3-5 at the end of the inpatient spell
5 we additionally controlled for the number of days after admission at which the mRS score was
6 measured. We were unable to do this for the analysis of mRS score 0-2 versus 3-6 as date of
7 death was not available. We tested for statistically significant variations across the week using
8 Wald tests and reported the results as joint p-values under the null hypothesis that the regression
9 coefficients for every time period relative to the omitted time period were zero. We calculated the
10 average predicted probability of each outcome (predicted median LOS in the case of the LOS
11 variables) in each time period controlling for the covariates. Patients admitted with a diagnosis of
12 acute stroke in London who were not treated in a HASU were excluded (6% all London patients
13 in our dataset were not treated in a HASU). P-values<0.05 were considered to be statistically
14 significant. Data on National Institutes of Health Stroke Scale (NIHSS) score, a validated measure
15 of stroke severity on a scale from 0 (no stroke symptoms) to 42 (severe stroke), were available
16 for 93% patients in London HASUs and 77% patients in the rest of England. Due to the extent of
17 missing NIHSS data, in our main analysis we controlled for stroke severity using level of
18 consciousness on arrival at the hospital (one component of NIHSS); we then reran all analyses
19 controlling for NIHSS on arrival at the hospital on the smaller sample instead of level of
20 consciousness on arrival. The findings using NIHSS score on arrival were qualitatively the same
21 and are presented in the Supplementary Figures S1-S6.

22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 **Patient and public involvement**

46 Two stroke patient representatives contributed to the design of our study protocol and
47 development of the research questions; they also contributed to discussions of interim findings
48 presented at study steering committee meetings in June 2015 and July 2016, raising issues
49 related to variation in quality of care and mortality, which we incorporated into our analysis.
50 They were consulted on the methods for disseminating the outputs of this study and ensured
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3 that we were addressing questions and communicating lessons in a meaningful way. The
4 findings of this research will be disseminated to the relevant patient community in an accessible
5 way.
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9 **Results**

10 The study cohort comprised 68 239 patients (7094 from London HASUs, 61 145 from the rest of
11 England) from 208 hospitals (eight London HASUs, 200 hospitals from the rest of England). The
12 number of admissions varied across the week, with similar trends for London HASUs and the rest
13 of England: there were more admissions during the day than at night; more admissions in the day
14 during the week compared with during the day at the weekend; similar numbers of admissions
15 during the night each day; and the highest number of admissions was during the day on Monday
16 (Figure 1). In London HASUs the total number of admissions across all hospitals during the 12-
17 month period ranged from 47-297 across the 42 time periods; in the rest of England it ranged
18 from 398-2709. There was slightly higher proportion of men than women in London compared
19 with the rest of England, the mean age was slightly lower, and patients were less likely to be white
20 (all p-values<0.001; Table 1). There were also differences in the pattern of pre-existing
21 comorbidities, London HASUs case mix was characterised by a larger proportion of people having
22 congestive heart failure, hypertension and diabetes, while in the rest of England, patients were
23 more likely to have atrial fibrillation and previously have had a stroke or TIA (all p-values<0.001).
24 mRS before stroke was higher in London HASUs compared to the rest of England, suggesting
25 there were more people with at least moderate disability (<0.001). A higher proportion of patients
26 arrived to the hospital in an ambulance in London compared to the rest of England (<0.001). A
27 slightly higher proportion of patients was admitted to the hospital in London compared to the rest
28 of England within more than six hours from onset of stroke symptoms, but the proportion of the
29 patients with unknown time of symptoms' onset was also lower in London (<0.001).
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56 **Table 1. Patient characteristics**

	London HASUs (n=7094)	Rest of England (n=61 145)	Difference	P-value†
Sex				0.0001
Male	3719 (52%)	30 536 (50%)	2%	
Female	3375 (48%)	30 609 (50%)	-2%	
Age, years (mean (std.dev.))	72 (15)	75 (13)	-3 years	<0.0001
Ethnic group				<0.0001
White	4332 (61%)	56 221 (92%)	-31%	
Mixed	72 (1%)	141 (<1%)	<1%	
Black	650 (9%)	1272 (2%)	7%	
Asian	505 (7%)	362 (<1%)	6%	
Other	526 (7%)	358 (<1%)	6%	
Not available	1009 (14%)	2791 (5%)	9%	
Type of stroke				0.0531
Infarction	6252 (88%)	54 355 (89%)	-1%	
Primary Intracerebral Haemorrhage	842 (12%)	6790 (11%)	1%	
Comorbidities prior to admission				
Congestive Heart Failure	439 (6%)	3204 (5%)	1%	0.0008
Hypertension	4284 (60%)	32 447 (53%)	7%	<0.0001
Atrial fibrillation	1229 (17%)	12 655 (21%)	-4%	<0.0001
Diabetes	1705 (24%)	12 024 (20%)	4%	<0.0001
Stroke/TIA	1688 (24%)	16 752 (27%)	-4%	<0.0001
mRS score before stroke				<0.0001
Slight or no disability (0-2)	5552 (78%)	49 574 (81%)	-3%	
At least moderate disability (3-5)	1542 (22%)	11 571 (19%)	3%	
Level of consciousness on arrival at the hospital**				0.0263

Alert	5991 (84%)	51 230 (84%)	0%	
Not alert; but respond to minor stimulation	663 (9%)	5724 (9%)	0%	
Not alert; requires repeated stimulation	281 (4%)	2438 (4%)	0%	
Unresponsive	159 (2%)	1753 (3%)	-1%	
NIHSS on arrival at the hospital, score (median (IQR))	5 (2-11)	4 (2-9)	1 IQR	<0.0001
Method of admission to the hospital				<0.0001
Already inpatient	173 (2%)	3288 (5%)	-3%	
Ambulance	5966 (84%)	47 096 (77%)	7%	
Walk-in	955 (14%)	10 761 (18%)	-4%	
Time from onset of stroke symptoms to admission				<0.0001
<180 minutes	2741 (39%)	24 233 (40%)	-1%	
180-359 minutes	759 (11%)	5871 (10%)	1%	
≥360 minutes	1516 (21%)	10 773 (18%)	3%	
Time of onset not known	2078 (29%)	20 268 (33%)	4%	

Note. Figures are n (%) except for age, which is mean (std.dev.), and NIHSS on arrival at the hospital, which is median (IQR). mRS = modified Rankin Scale. IQR = interquartile range. The sample with NIHSS scores on arrival was n=6571 in London HASUs and n=47 126 in the rest of England. ** Level of consciousness scores taken from admission NIHSS score (Question 1a). † P-value threshold adjusted for multiple testing is 0.0038

There was no significant variation in care quality across the 42 time periods in any of the measures relating to brain scanning, stroke nursing care and thrombolysis in London HASUs (all p-values>0.05), but there was significant variation in these measures in the rest of England (all p-values<0.001; Figure 2). For each measure in the rest of England there was variation by time of day every day, with the likelihood of receiving these interventions worse for patients admitted at night.

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3 For all the other quality of care measures there was significant variation by time period of
4 admission across the week both in London and the rest of England (all p-values <0.001). There
5 were three patterns of variation. (1) Variation by time of day but not day of the week was
6 observed for assessment by a stroke specialist consultant physician within 12 hours and within
7 24 hours in London HASUs and admission to a stroke unit within four hours in London and the
8 rest of England (Figure 3). With this pattern similar variations during the day were found each
9 day of the week. (2) Variation by day of the week but not time of day was observed for
10 assessments by a Physiotherapist, Occupational Therapist, and Speech and Language
11 Therapist within 72 hours in London HASUs and the rest of England (Figure 4). With this pattern
12 care quality was worse for patients admitted on Friday. (3) Variation by time of day and day of
13 the week was observed for assessment by a stroke specialist consultant physician within 12
14 hours and within 24 hours in the rest of England and for therapist assessments within 24 hours
15 in London HASUs and the rest of England (Figure 5). With this pattern, there was variation
16 during the day on Monday to Friday and care quality was worse at weekends.

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There was no significant variation in outcomes across the 42 time periods in London HASUs (all
p-values>0.05; Figure 6a). In the rest of England there was significant variation in disability (p-
value<0.001 for mRS scores 0-6, and p-value=0.022 for mRS scores 0-5), Figures 6b and 6c)
but not mortality (p-value>0.05); mRS scores at the end of the inpatient episode varied by time
of admission on every day and were worse among patients admitted at night. It is worth noting
that, based on the point estimates in each period, it appears there is more variation in mRS
scores in London HASUs. One reason why the variation in London HASUs was not statistically
significant might be because of the larger uncertainty at each time point.

There was significant variation in LOS across the 42 time periods in London HASUs and the
rest of England both in terms of HASU LOS and total inpatient LOS (p-value<0.001 for London
HASUs LOS, p-value=0.005 for total LOS in London hospitals and p-values<0.001 for LOS in
the rest of England hospitals; Figure 7). Median HASU LOS in London varied between 2.6 and

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3 3.6 days across the 42 time periods. It was difficult to detect a trend by day and time of
4 admission in London HASU LOS and inpatient LOS. In the rest of England median inpatient
5 LOS was longer among those admitted at night.
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9 Results using the four time period specification (Table 2) were broadly similar to those with the
10 42 time periods, but pooling time periods meant that the extent of variation during the week for
11 some of the quality of care measures was reduced (for unadjusted figures and p-values, see
12 Supplementary Table 1 and Supplementary Table 2 respectively). In these analyses there was
13 no significant variation in London in quality of care measures linked to specialist stroke nurse
14 assessments, rapid access to brain scans and administration of thrombolysis to eligible patients
15 for London HASUs, nor was there in the outcome measures. With the exception of mortality at
16 three days and mRS scores 3-5 at the end of the inpatient spell, all of these measured varied
17 significantly in the rest of England. LOS varied significantly for London HASUs and the rest of
18 England; for London HASUs pooling time periods more clearly indicates longer LOS among
19 patents admitted at the weekend; for the rest of England the trends were as in the 42 time
20 period model, with longer LOS among patients admitted at night.
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24 Results were similar when controlling for NIHSS score on arrival at hospital instead of level of
25 consciousness on the smaller sample of patients with non-missing NIHSS data: results with p-
26 values<0.05 and trends across the week were unchanged (Figures S1-S6 and Table 3 in the
27 Supplementary materials).
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Table 2. Quality of care and outcomes across four periods in the week

	London HASUs					Rest of England				
	Weekday	Weekend	Weekday	Weekend	p-value†	Weekday	Weekend	Weekday	Weekend	p-value†
	08:00-19:59	08:00-19:59	20:00-07:59	20:00-07:59		08:00-19:59	08:00-19:59	20:00-07:59	20:00-07:59	
Quality of care measures that do not vary across the week in London HASUs										
Brain scan within one hour	0.60 (0.58-0.61)	0.61 (0.58-0.63)	0.63 (0.60-0.65)	0.65 (0.61-0.68)	0.0344	0.44 (0.44-0.45)	0.41 (0.40-0.41)	0.40 (0.39-0.40)	0.39 (0.38-0.41)	<0.0001
Brain scan within 12 hours	0.97 (0.96-0.97)	0.96 (0.95-0.97)	0.95 (0.94-0.96)	0.95 (0.93-0.96)	0.0093	0.90 (0.90-0.90)	0.88 (0.87-0.89)	0.84 (0.83-0.84)	0.83 (0.82-0.84)	<0.0001
Dysphagia screen within four hours	0.74 (0.72-0.75)	0.75 (0.73-0.77)	0.77 (0.75-0.79)	0.79 (0.76-0.82)	0.0029	0.70 (0.70-0.71)	0.65 (0.64-0.66)	0.60 (0.59-0.61)	0.58 (0.56-0.59)	<0.0001
Assessment by a nurse trained in stroke management within 24 hours	0.96 (0.95-0.96)	0.94 (0.93-0.96)	0.95 (0.94-0.96)	0.95 (0.94-0.97)	0.1872	0.89 (0.88-0.89)	0.85 (0.85-0.86)	0.86 (0.86-0.87)	0.83 (0.82-0.84)	<0.0001
Administration of intravenous thrombolysis to eligible patients	0.88 (0.86-0.90)	0.88 (0.84-0.92)	0.86 (0.82-0.91)	0.88 (0.82-0.95)	0.9327	0.81 (0.80-0.82)	0.80 (0.78-0.82)	0.76 (0.74-0.78)	0.76 (0.72-0.79)	<0.0001
Door-to-needle time within one hour in patients receiving thrombolysis	0.84 (0.81-0.87)	0.89 (0.85-0.93)	0.79 (0.74-0.84)	0.84 (0.77-0.91)	0.0269	0.60 (0.59-0.62)	0.48 (0.45-0.50)	0.38 (0.35-0.40)	0.37 (0.33-0.41)	<0.0001
Quality of care: measures that vary significantly across the week										
Assessment by a stroke specialist consultant physician within 12 hours	0.39 (0.38-0.40)	0.30 (0.27-0.32)	0.63 (0.61-0.66)	0.64 (0.60-0.68)	<0.0001	0.48 (0.48-0.49)	0.30 (0.29-0.31)	0.51 (0.51-0.52)	0.42 (0.41-0.44)	<0.0001
Assessment by a stroke specialist consultant physician within 24 hours	0.90 (0.89-0.91)	0.87 (0.85-0.89)	0.90 (0.88-0.91)	0.92 (0.90-0.94)	0.0043	0.80 (0.79-0.80)	0.65 (0.65-0.66)	0.75 (0.74-0.75)	0.62 (0.61-0.64)	<0.0001
Admission to a stroke unit within four hours	0.62 (0.60-0.63)	0.64 (0.61-0.66)	0.67 (0.65-0.70)	0.70 (0.67-0.74)	<0.0001	0.63 (0.63-0.63)	0.59 (0.58-0.60)	0.55 (0.54-0.56)	0.53 (0.52-0.55)	<0.0001

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1	Physiotherapist assessment within 72 hours	0.83 (0.82-0.84)	0.86 (0.84-0.88)	0.85 (0.83-0.87)	0.84 (0.81-0.87)	0.0693	0.82 (0.81-0.82)	0.83 (0.82-0.84)	0.81 (0.81-0.82)	0.82 (0.80-0.83)	0.0010
2	Occupational Therapist assessment within 72 hours	0.79 (0.78-0.80)	0.82 (0.80-0.84)	0.81 (0.79-0.82)	0.80 (0.76-0.83)	0.0967	0.73 (0.73-0.74)	0.75 (0.75-0.76)	0.73 (0.72-0.74)	0.73 (0.72-0.74)	<0.0001
3	Swallow assessment by a SLT within 72 hours	0.92 (0.91-0.93)	0.93 (0.91-0.95)	0.93 (0.91-0.95)	0.91 (0.88-0.95)	0.5838	0.80 (0.80-0.81)	0.81 (0.80-0.82)	0.79 (0.78-0.80)	0.80 (0.78-0.82)	0.0946
4	Communication assessment by a SLT within 72 hours	0.53 (0.51-0.54)	0.56 (0.54-0.59)	0.55 (0.53-0.58)	0.52 (0.48-0.56)	0.0739	0.33 (0.32-0.33)	0.36 (0.35-0.37)	0.34 (0.33-0.35)	0.34 (0.32-0.35)	<0.0001
5	Physiotherapist assessment within 24 hours	0.56 (0.54-0.57)	0.47 (0.45-0.50)	0.65 (0.63-0.68)	0.48 (0.44-0.52)	<0.0001	0.54 (0.54-0.55)	0.41 (0.40-0.41)	0.53 (0.52-0.54)	0.35 (0.34-0.37)	<0.0001
6	Occupational Therapist assessment within 24 hours	0.49 (0.47-0.50)	0.42 (0.40-0.45)	0.58 (0.55-0.60)	0.41 (0.37-0.45)	<0.0001	0.43 (0.42-0.43)	0.31 (0.30-0.31)	0.42 (0.42-0.43)	0.26 (0.25-0.27)	<0.0001
7	Communication assessment by a SLT within 24 hours	0.29 (0.28-0.31)	0.22 (0.20-0.24)	0.39 (0.37-0.42)	0.23 (0.20-0.27)	<0.0001	0.17 (0.17-0.17)	0.10 (0.09-0.10)	0.19 (0.18-0.20)	0.08 (0.07-0.09)	<0.0001
8	Outcome measures										
9	Mortality at three days	0.03 (0.02-0.03)	0.03 (0.02-0.04)	0.03 (0.02-0.04)	0.02 (0.01-0.03)	0.3310	0.04 (0.04-0.05)	0.04 (0.04-0.04)	0.05 (0.04-0.05)	0.05 (0.04-0.05)	0.1055
10	mRS score 3-6	0.55 (0.53-0.56)	0.55 (0.52-0.57)	0.55 (0.52-0.57)	0.56 (0.53-0.59)	0.8672	0.48 (0.48-0.48)	0.49 (0.48-0.50)	0.51 (0.50-0.51)	0.51 (0.50-0.52)	<0.0001
11	mRS score 3-5*	0.49 (0.47-0.50)	0.47 (0.45-0.50)	0.48 (0.45-0.50)	0.48 (0.44-0.51)	0.7497	0.40 (0.39-0.40)	0.40 (0.39-0.41)	0.40 (0.39-0.41)	0.40 (0.39-0.41)	0.3746
12	Length of stay										
13	Length of stay in HASU (days)	3.1 (3.0-3.2)	3.4 (3.2-3.5)	3.0 (2.9-3.1)	3.1 (2.9-3.3)	0.0007					
14	Length of stay in hospital (days)	10.8 (10.2-11.3)	12.1 (11.1-13.1)	10.8 (10.0-11.7)	11.5 (10.2-12.9)	0.0359	8.5 (8.4-8.6)	9.2 (9.0-9.4)	9.7(9.4-9.9)	10.1 (9.6-10.5)	<0.0001

Note.

Figures are average predicted probabilities (95% confidence intervals) of each measure in each time period controlling for the covariates. SLT = Speech and Language Therapist. mRS = modified Rankin Scale. * Patients who died were not included. † P-value threshold adjusted for multiple testing is 0.0025 for London HASUs and 0.0024 for the rest of England.

DISCUSSION

Principal findings

In our study, we found no evidence for an admission effect across the week on early outcomes in acute stroke patients admitted to a London HASU: three-day mortality and modified Rankin Scale score at hospital discharge did not vary by day and time of admission in London HASUs. This is consistent with a recent study based on administrative data in the UK [9] that found a steady reduction in in-hospital mortality difference between weekday and weekend stroke admissions in 2008-2014 across England and that this difference is no longer statistically significant in 2014).

There was also no variation by day and time of admission across the week in terms of rapid access to brain scanning, stroke nursing care and thrombolysis in London HASUs. Other quality of care measures did significantly vary across the week in London HASUs, and three patterns of variation were detected: by time of day but not day of the week; by day of the week but not time of day; and, by time of day and day of the week. LOS was longer among patients admitted to London HASUs at the weekend. In the rest of England there was variation in all measures by day and time of admission across the week, except for mortality at three days. We hypothesised there would be less variation across the week in care quality measures in London HASUs compared with the rest of England, and that this would translate into less variation in outcomes in London HASUs. The lower variation in care quality measures across the week in London HASUs was confirmed, but only with respect to “front door” measures of acute stroke care. With respect to the health outcomes: there was no variation in mortality at three days and disability at hospital discharge by day and time of admission across the week in London HASUs. This is consistent with previous studies showing that timely access to thrombolysis is associated with

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3 good stroke outcomes[37]. In the rest of England there was no variation in three-day mortality
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5 by day and time of admission across the week (but there was in terms of disability after
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7 discharge), suggesting the lack of variation in outcomes in London HASUs may not be
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9 exclusively attributed to the lack of variation in “front door” quality of care.
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12 13 **Strengths and weaknesses**

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18 The main strength of our study is the large national dataset we have used containing detailed
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20 information on quality of care, outcomes, and patient characteristics. We have examined
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22 whether time of admission was related to quality of care using a comprehensive set of indicators
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24 from across the acute stroke care pathway. Most of the measures were from a pre-existing set
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26 of national acute stroke care indicators, and those that were added had more stringent time
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28 constraints to reflect the time-critical nature of acute stroke care. Our outcomes were stroke
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30 mortality and disability, where previous studies have focused on mortality[2,4,5,7–10]. The rich
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32 set of patient characteristics in the dataset meant we could control for patient factors likely to
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34 affect quality of care and outcomes that vary by day and time of admission across the week and
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36 between London and the rest of England. There are several weaknesses. First, while case
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38 ascertainment in SSNAP was 90% during the time period of our study, these data might not be
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40 representative of all stroke patients. For example, not all hospitals receiving acute stroke
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42 patients in England participated in SSNAP, and the results may not be representative of
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44 hospitals who did not participate. Second, while analyses of hospital administrative data to
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46 investigate weekend effects in stroke have been undermined by evidence of variations in
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48 inaccurate coding across the week[15], in SSNAP data are inputted voluntarily by hospitals and
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50 we cannot exclude the possibility of inaccurate or selective reporting. Particularly problematic for
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52 our study would be if this bias was more likely to occur in London or the rest of England and/or if
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54 it was more likely to vary by time of admission. Third, we were unable to measure long-term
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3 outcomes as these were not available in SSNAP. Mortality data in SSNAP are currently only
4 available for patients who are in hospital and therefore to reduce the risk of bias we measured
5 mortality at three days after admission when most patients will still be admitted. Three-day
6 mortality has been used in previous studies to evaluate the centralisation of acute stroke
7 services in London[30], but the focus in our study on in-hospital mortality only is a further
8 limitation. Similarly, long-term disability data are not reliably collected in SSNAP, and so this
9 was measured by mRS at the end of the inpatient spell. Fourth, while the richness of our
10 dataset means we have been able to control for confounding factors we cannot exclude the
11 possibility of confounding due to unobserved patient characteristics or staffing levels. Fifth, while
12 the sample size of our study is large in both London and the rest of England, when evaluating
13 quality of care and outcomes across the week the number of observations in each time period
14 was considerably smaller in London. We cannot exclude the possibility that the smaller number
15 of patients in London resulted in wider confidence intervals around the adjusted predicted
16 probabilities in each time period making it less likely to show significant variation in the
17 measures evaluated.
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34 35 36 37 ***Comparison with other studies*** 38

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41 There is a large literature examining weekend effects in health care across a range of clinical
42 areas[38]. In acute stroke there is conflicting evidence as to whether patients admitted at
43 weekends have higher or lower quality of care and better or worse outcomes[1–8], but recent
44 analyses have shown that care quality and outcomes in acute stroke vary across the week, and
45 that comparing weekend versus weekday or in-hours versus out-of-hours effects is flawed as it
46 does not take into account variations by day of the week and time of day[16]. This study, using
47 the same dataset as ours but from an earlier time period and analysing the whole of England
48 and Wales, found that quality of care varied across the entire week, not only between weekends
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3 and weekdays, with a number quality of care measures showing different patterns of variation
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5 over the week. While the findings mirrored our own for the rest of England, one noticeable
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7 difference was in mortality: Bray et al. reported that patients admitted overnight on weekdays
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9 had lower odds of survival (0.90, 95% confidence interval 0.82-0.99) compared to those
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11 admitted during the day at weekdays; this difference might be because our survival measure is
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13 not the same (three versus 30 days) and/or because our extract of the SSNAP dataset is more
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15 recent. What our study adds is analyses of variation in quality of care and outcomes in London
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17 HASUs separately following the centralisation of acute stroke services in London in 2010, which
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19 has been shown to increase the quality of care and outcomes on average across the
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21 week[29,30]. Our findings were further expanded in Black GB, Ramsay AIG, et al. (2019) that
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23 aimed to identify factors influencing this variation[39].
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28 ***Implications***

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32 There are several implications of our study. The first is that London HASUs appear to operate a
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34 uniform service across the week with respect to some but not all aspects of acute stroke care.
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36 Performance standards originally set by Healthcare for London stipulated that London HASUs
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38 should operate a 24/7 service with respect to first assessment by a stroke nurse, rapid access
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40 to brain scans and administration of thrombolysis to eligible patients; our findings show that
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42 London HASUs do operate a 24/7 service with respect to these measures. However, for other
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44 less time-critical measures, such as senior stroke physician assessment within 24 hours and
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46 therapist assessments within 72 hours, we found significant variation by day and time of
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48 admission across the week in London HASUs. This suggests that some performance standards
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50 like “front door” interventions may be emphasised more than others and analysis of qualitative
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52 data collected in Black GB, Ramsay AIG, et al. (2019) complemented our findings[39]. The
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54 second implication is that there are differences in acute stroke care between London HASUs
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3 and the rest of England across the week, with less variation in quality of care and outcomes in
4 London HASUs. The main differences were observed in nursing care, brain scanning and
5 thrombolysis provision, and also with the type of variation observed for stroke consultant care.
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7 For these measures, our results show that the centralised model in London is more effective at
8 providing constant care across the week. In terms of comparing London and the rest of
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10 England, four further issues are worth bearing in mind. First, our study focuses on patients
11 admitted to London HASUs only, not other hospitals in London; our data suggest that 6% of
12 acute stroke patients in London are not treated in a HASU. However, some of these patients will
13 not have been eligible for HASU care because of greatly delayed presentation or identification
14 of stroke, and others will have had a stroke after surgical procedures or in another context which
15 precluded their admission to a HASU. Our focus on London HASUs was deliberate as the aim
16 of our study was to evaluate the HASU model, but it means that our findings for London HASUs
17 should not be generalised to all patients in London. Indeed, there is evidence that quality of care
18 is lower for acute stroke patients in London not treated in a HASU compared with those who are
19 [29]. Second, and conversely, HASUs operate in many other parts of England using different
20 models of care[31,40]. In Greater Manchester, for instance, HASUs have also been shown to
21 have higher quality of care than the rest of England excluding London[29]. Hence the
22 differences observed between London HASUs and the rest of England cannot be interpreted as
23 a direct comparison of HASU versus non-HASU care, though if HASU-based care outside
24 London was removed from the rest of England then the differences observed in this study are
25 likely to be the same or greater. The third issue is that the London model may not apply to
26 services operating in rural settings – in particular the greater travel times in rural areas make
27 centralisation challenging[41]. This means that potential benefits of the London model in terms
28 of 24/7 care are unlikely to be achieved nationwide. The fourth issue is that the centralisation of
29 acute stroke services in London was estimated to occur at an additional cost of £20 million,
30 allocated to cover the increased cost per bed day in a HASU[28]. With this additional level of
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3 funding it might be expected that the quality of care in London should improve, though whether
4 it should produce less variation in quality of care and outcomes across the week in London
5 compared with the rest of England depends on the relative levels of funding in both areas.
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9 There is some evidence that the reorganisation in London was cost-effective[42,43], but further
10 analyses accounting for the size of the up-front investment, the relatively high costs per day of
11 hyperacute stroke care, the impact on mortality and disability, and the lifetime costs incurred by
12 the NHS, social services and families caring for stroke survivors at different levels of disability
13 would be helpful.
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22 ***Future research***

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26 Further research would be beneficial to evaluate the impact of stroke admission at different
27 times of the week on longer-term mortality and disability outcomes, and to investigate the
28 relationship between quality of care and outcomes and if this relationship varies by time of
29 admission. Further research would also be useful to investigate the reasons for the differences
30 in variation found between London HASUs and the rest of England, and why for some
31 standards care in London HASUs was constant across the week, irrespective of day and time of
32 admission, but for others it was not. Performing follow-up studies to monitor attainment of key
33 quality indicators and outcomes, complementary to the SSNAP clinical audit annual
34 reports[33,44], would also be beneficial in order to get an overall picture of national trends and
35 dynamics over time, and look in detail at underlying reasons for that to understand what
36 amendments to clinical guideline for stroke care ought to be proposed in the future. Also,
37 accounting for the organisational factors at the stroke unit level could explain an important part
38 of the variation in quality of acute stroke care and outcomes by day and time of admission in
39 London HASUs and the rest of England. This research would help to further inform how acute
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stroke services ought to be designed in future to maximise patient outcomes in a cost-effective manner.

References

- 1 Turner M, Barber M, Dodds H, *et al*. Stroke patients admitted within normal working hours are more likely to achieve process standards and to have better outcomes. *J Neurol Neurosurg Psychiatry* 2016;**87**:138–43. doi:10.1136/jnnp-2015-311273
- 2 Palmer WL, Bottle A, Davie C, *et al*. Dying for the Weekend. *Arch Neurol* 2012;**69**. doi:10.1001/archneurol.2012.1030
- 3 Tung Y-C, Chang G-M, Chen Y-H. Associations of physician volume and weekend admissions with ischemic stroke outcome in Taiwan: a nationwide population-based study. *Med Care* 2009;**47**:1018–25. doi:10.1097/MLR.0b013e3181a81144
- 4 Saposnik G, Baibergenova A, Bayer N, *et al*. Weekends: A dangerous time for having a stroke? *Stroke* 2007;**38**:1211–5. doi:10.1161/01.STR.0000259622.78616.ea
- 5 Fang J, Saposnik G, Silver FL, *et al*. Association between weekend hospital presentation and stroke fatality. *Neurology* 2010;**75**:1589–96. doi:10.1212/WNL.0b013e3181fb84bc
- 6 Patel AA, Mahajan A, Benjo A, *et al*. A Nationwide Analysis of Outcomes of Weekend Admissions for Intracerebral Hemorrhage Shows Disparities Based on Hospital Teaching Status. *The Neurohospitalist* 2016;**6**:51–8. doi:10.1177/1941874415601164
- 7 Reeves MJ, Smith E, Fonarow G, *et al*. Off-hour admission and in-hospital stroke case fatality in the get with the guidelines-stroke program. *Stroke* 2009;**40**:569–76. doi:10.1161/STROKEAHA.108.519355
- 8 Crowley RW, Yeoh HK, Stukenborg GJ, *et al*. Influence of weekend versus weekday hospital admission on mortality following subarachnoid hemorrhage. *J Neurosurg* 2009;**111**:60–6. doi:10.3171/2008.11.JNS081038
- 9 Balinskaite V, Bottle A, Shaw LJ, *et al*. Reorganisation of stroke care and impact on mortality in patients admitted during weekends: a national descriptive study based on administrative data. *BMJ Qual Saf* 2017;:bmjqs – 2017–006681. doi:10.1136/bmjqs-2017-006681
- 10 Walker AS, Mason A, Quan TP, *et al*. Mortality risks associated with emergency admissions during weekends and public holidays: an analysis of electronic health records. *Lancet* 2017;**390**:62–72. doi:10.1016/S0140-6736(17)30782-1
- 11 Concha OP, Gallego B, Hillman K, *et al*. Do variations in hospital mortality Patterns after weekend admission Reflect reduced quality of care or Different patient cohorts? A population-based study. *BMJ Qual Saf* 2014;**23**:215–22. doi:10.1136/bmjqs-2013-002218
- 12 Luyt CE, Combes A, Aegerter P, *et al*. Mortality among patients admitted to intensive care units during weekday day shifts compared with 'off' hours. *Crit Care Med* 2007;**35**:3–11. doi:10.1097/01.CCM.0000249832.36518.11
- 13 Brunot V, Landreau L, Corne P, *et al*. Mortality associated with night and weekend admissions to ICU with on-site intensivist coverage: Results of a nine-year cohort study (2006-2014). *PLoS One* 2016;**11**:1–16. doi:10.1371/journal.pone.0168548

- 1
2
3 14 Aylin P, Alexandrescu R, Jen MH, *et al.* Day of week of procedure and 30 day mortality
4 for elective surgery: Retrospective analysis of hospital episode statistics. *BMJ*
5 2013;**346**:1–8. doi:10.1136/bmj.f2424
6
7 15 Li L, Rothwell PM. Biases in detection of apparent ‘weekend effect’ on outcome with
8 administrative coding data: population based study of stroke. *Bmj* 2016;i2648.
9 doi:10.1136/bmj.i2648
10
11 16 Bray BD, Cloud GC, James MA, *et al.* Weekly variation in health-care quality by day and
12 time of admission: a nationwide, registry-based, prospective cohort study of acute stroke
13 care. *Lancet* 2016;**388**:170–7. doi:10.1016/S0140-6736(16)30443-3
14
15 17 Goddard a F, Lees P. Higher senior staffing levels at weekends and reduced mortality.
16 *BMJ* 2012;**344**:e67–e67. doi:10.1136/bmj.e67
17
18 18 Bray BD, Ayis S, Campbell J, *et al.* Associations between stroke mortality and weekend
19 working by stroke specialist physicians and registered nurses: Prospective multicentre
20 cohort study. *PLoS Med* 2015;**11**. doi:10.1371/journal.pmed.1001705
21
22 19 Albright KC, Raman R, Ernstrom K, *et al.* Can comprehensive stroke centers erase the
23 ‘weekend effect’? *Cerebrovasc Dis* 2009;**27**:107–13. doi:10.1159/000177916
24
25 20 Albright KC, Savitz SI, Raman R, *et al.* Comprehensive stroke centers and the ‘Weekend
26 Effect’: The SPOTRIAS experience on behalf of the SPOTRIAS investigators.
27 *Cerebrovasc Dis* 2012;**34**:424–9. doi:10.1159/000345077
28
29 21 McKinney JS, Deng Y, Kasner SE, *et al.* Comprehensive stroke centers overcome the
30 weekend versus weekday gap in stroke treatment and mortality. *Stroke* 2011;**42**:2403–9.
31 doi:10.1161/STROKEAHA.110.612317
32
33 22 Statistics O for N. 2011 Census: Key Statistics for England and Wales, March 2011.
34 2012;:1–34.<http://www.ons.gov.uk/ons/rel/census/2011-census/key-statistics-for-local-authorities-in-england-and-wales/stb-2011-census-key-statistics-for-england-and-wales.html>
35
36 23 Morris S, Hunter RM, Ramsay AIG, *et al.* Impact of centralising acute stroke services in
37 English metropolitan areas on mortality and length of hospital stay: difference-in-
38 differences analysis. *BMJ* 2014;**349**:g4757. doi:10.1136/bmj.g4757
39
40 24 Turner S, Ramsay A, Perry C, *et al.* Lessons for major system change: Centralization of
41 stroke services in two metropolitan areas of England. *J Heal Serv Res Policy*
42 2016;**21**:156–65. doi:10.1177/1355819615626189
43
44 25 Davie C, Hunter RM, Mountford J, *et al.* London ’ s Hyperacute Stroke Units Improve
45 Outcomes and Lower Costs. 2013.
46
47 26 NHS London Strategic Clinical Networks. Stroke acute commissioning and tariff
48 guidance. 2014.
49
50 27 Fulop N, Boaden R, Hunter R, *et al.* Innovations in major system reconfiguration in
51 England: a study of the effectiveness, acceptability and processes of implementation of
52 two models of stroke care. *Implement Sci* 2013;**8**:5. doi:10.1186/1748-5908-8-5
53
54 28 Healthcare for London. The shape of things to come: Appendix 7d - finance
55 commissioning assurance. *London Healthc London* 2009;:1–87.
56
57 29 Ramsay AIG, Morris S, Hoffman A, *et al.* Effects of centralizing acute stroke services on
58 stroke care provision in two large metropolitan areas in England. *Stroke* 2015;**46**:2244–
59 51. doi:10.1161/STROKEAHA.115.009723
60

- 1
2
3 30 Morris S, Hunter RM, Ramsay a. IG, *et al.* Impact of centralising acute stroke services in
4 English metropolitan areas on mortality and length of hospital stay: difference-in-
5 differences analysis. *Bmj* 2014;**349**:g4757–g4757. doi:10.1136/bmj.g4757
6
7 31 Royal College of Physicians. Sentinel Stroke National Audit Programme (SSNAP):
8 Clinical audit first pilot public report. 2013;:1–48.
9
10 32 Royal College of Physicians. First SSNAP Annual Report. How good is stroke care?
11 2014.
12
13 33 Royal College of Physicians. Is stroke care improving ? The Second SSNAP Annual
14 Report. 2015;:32.
15
16 34 Royal College of Physicians. 3rd SSNAP Annual Report for 2015/2016 ‘Mind the Gap!’
17 *Third Ssn Annu Rep* 2016;:1–219. doi:10.1787/9789264038950-en
18
19 35 Royal College of Physicians. *Sentinel Stroke National Audit Programme (SSNAP) Clinical*
20 *Audit*. 2015.
21
22 36 Royal College of Physicians. National clinical guideline for stroke. *London R Coll*
23 *Physicians* 2008;:232.
24
25 37 Emberson J, Lees KR, Lyden P, *et al.* Effect of treatment delay, age, and stroke severity
26 on the effects of intravenous thrombolysis with alteplase for acute ischaemic stroke: A
27 meta-analysis of individual patient data from randomised trials. *Lancet* 2014;**384**:1929–
28 35. doi:10.1016/S0140-6736(14)60584-5
29
30 38 Godlee F. What to do about the ‘weekend effect’. *Bmj* 2015;**4840**:h4840.
31 doi:10.1136/bmj.h4840
32
33 39 Black GB, Ramsay AIG, Baim-Lance A, Eng J, Melnychuk M, Xanthopoulou P, Brown
34 MM, Morris S, Rudd AG, Simister R FN. What does it take to provide clinical interventions
35 with temporal consistency? A qualitative study of London hyperacute stroke units. 2019.
36
37 40 Royal College of Physicians. Sentinel Stroke National Audit Programme (SSNAP) Acute
38 organisational audit proforma. 2012;:1–35.
39
40 41 Allen M, Pearn K, Villeneuve E, *et al.* Feasibility of a hyper-acute stroke unit model of
41 care across England: a modelling analysis. *BMJ Open* 2017;**7**:e018143.
42 doi:10.1136/bmjopen-2017-018143
43
44 42 Hunter RM, Fulop NJ, Boaden RJ, *et al.* The potential role of cost-utility analysis in the
45 decision to implement major system change in acute stroke services in metropolitan
46 areas in England. *Heal Res Policy Syst* 2018;**16**:1–14. doi:10.1186/s12961-018-0301-5
47
48 43 Hunter RM, Davie C, Rudd A, *et al.* Impact on Clinical and Cost Outcomes of a
49 Centralized Approach to Acute Stroke Care in London: A Comparative Effectiveness
50 Before and After Model. *PLoS One* 2013;**8**:1–9. doi:10.1371/journal.pone.0070420
51
52 44 Royal College of Physicians. *Sentinel Stroke National Audit Programme (SSNAP) Clinical*
53 *audit August-November 2016 Public Report*. 2016.
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5 carried out the statistical analysis of data and SM drafted the manuscript. MM, SM, NJF, RS,
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38 [and-checklists/copyright-open-access-and-permission-reuse](http://www.bmj.com/about-bmj/resources-authors/forms-policies-and-checklists/copyright-open-access-and-permission-reuse)). The terms of such Open Access
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14 important aspects of the study have been omitted; and that any discrepancies from the study as
15
16 planned (and, if relevant, registered) have been explained.
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Figure legends

Figure 1. Number of admissions in London and Rest of England across the 42 time periods in the week

Note.

Left-hand y-axis relates to London HASUs, right-hand y-axis to the Rest of England. Shaded areas indicate 20:00-07:59 each day of the week.

Figure 2. Quality of care across the 42 time periods in the week: measures linked to performance standards for London HASUs

(a) Brain scan within one hour

(b) Brain scan within 12 hours

(c) Dysphagia screen within four hours

(d) Assessment by a nurse trained in stroke management within 24 hours

(e) Administration of intravenous thrombolysis to eligible patients

(f) Door-to-needle time within one hour in patients receiving thrombolysis

Note.

Figures are average predicted probabilities of each outcome in each time period controlling for the covariates. Dashed lines represent lower and upper 95% confidence limits. Shaded areas indicate 20:00-07:59 each day of the week. P-values indicate significant variation ($p < 0.05$) or not for each measure over the week in each region. Gaps in the solid line indicate that all patients in that time period achieved that outcome.

Figure 3. Quality of care across the 42 time periods in the week: variation by time of day but not day of the week

(a) Assessment by a stroke specialist consultant physician within 12 and 24 hours in

London HASUs

(b) Admission to a stroke unit within four hours

Note.

Figures are average predicted probabilities of each outcome in each time period controlling for the covariates. Dashed lines represent lower and upper 95% confidence limits. Shaded areas indicate 20:00-07:59 each day of the week. P-values indicate significant variation ($p < 0.05$) or not for each measure over the week in each region. Figure 3(a) includes two measures for London HASUs.

Figure 4. Quality of care across the 42 time periods in the week: variation by day of the week but not time of day

(a) Physiotherapist assessment within 72 hours

(b) Occupational Therapist assessment within 72 hours

(c) Swallow assessment by a Speech and Language Therapist within 72 hours

(d) Communication assessment by a Speech and Language Therapist within 72 hours

Note.

Figures are average predicted probabilities of each outcome in each time period controlling for the covariates. Dashed lines represent lower and upper 95% confidence limits. Shaded areas indicate 20:00-07:59 each day of the week. P-values indicate significant variation ($p < 0.05$) or not for each measure over the week in each region. Gaps in the solid line indicate that no patients in that time period achieved that outcome. SLT = Speech and Language Therapist.

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5 **Figure 5. Quality of care across the 42 time periods in the week: variation by time of day**
6 **and day of the week**
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9 **(a) Assessment by a stroke specialist consultant physician within 12 and 24 hours in**

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11 **Rest of England**

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13 **(b) Physiotherapist assessment within 24 hours**

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15 **(c) Occupational Therapist assessment within 24 hours**

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17 **(d) Communication assessment by a Speech and Language Therapist within 24 hours**
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22 Note.

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24 Figures are average predicted probabilities of each outcome in each time period controlling for
25 the covariates. Dashed lines represent lower and upper 95% confidence limits. Shaded areas
26 indicate 20:00-07:59 each day of the week. P-values indicate significant variation ($p < 0.05$) or
27 not for each measure over the week in each region. Figure 5(a) includes two measures for Rest
28 of England. SLT = Speech and Language Therapist.
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37 **Figure 6. Outcomes across the 42 time periods in the week**

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39 **(a) Mortality at three days**

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41 **(b) Modified Rankin Scale score 3-6**

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43 **(c) Modified Rankin Scale score 3-5***
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47 Note.

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49 Figures are average predicted probabilities of each outcome in each time period controlling for
50 the covariates. Dashed lines represent lower and upper 95% confidence limits. Shaded areas
51 indicate 20:00-07:59 each day of the week. P-values indicate significant variation ($p < 0.05$) or
52 not for each measure over the week in each region. Gaps in the solid line indicate that no
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3 patients in that time period achieved that outcome. Note the scaling of the y-axis in Figure 6(a)
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5 is not from zero to one.
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9 **Figure 7. Length of stay across the 42 time periods in the week**

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11 **(a) Length of stay in HASU**

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13 **(b) Length of stay in hospital**

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15 Note.

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18 Figures are average predicted probabilities of each outcome in each time period controlling for
19 the covariates. Dashed lines represent lower and upper 95% confidence limits. Shaded areas
20 indicate 20:00-07:59 each day of the week. P-values indicate significant variation ($p < 0.05$) or
21 not for each measure over the week in each region.
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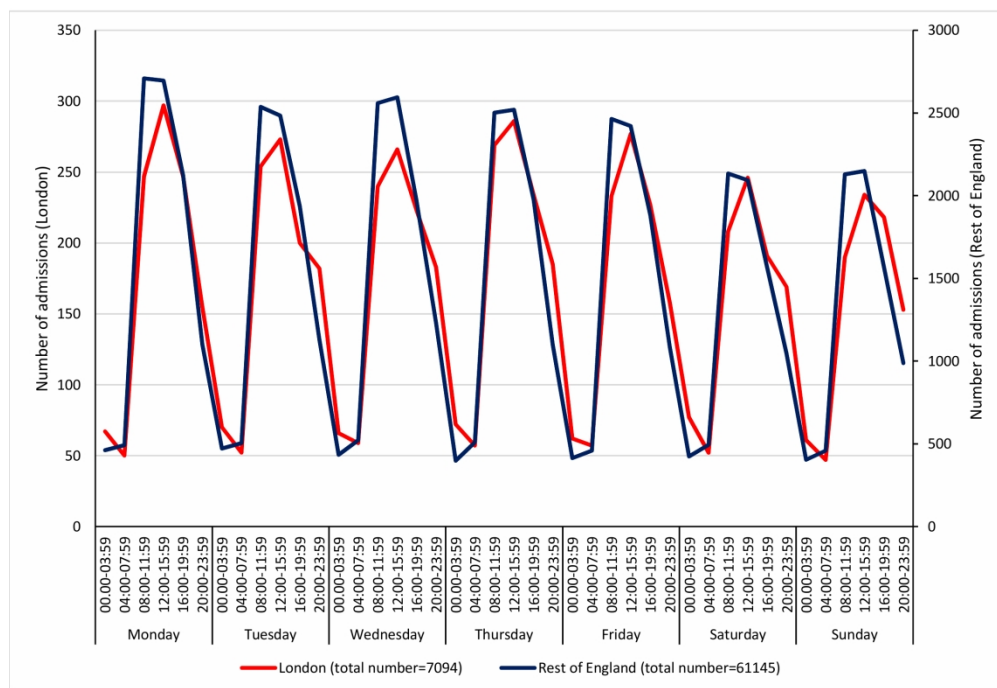


Figure 1. Number of admissions

Figure 1. Number of admissions

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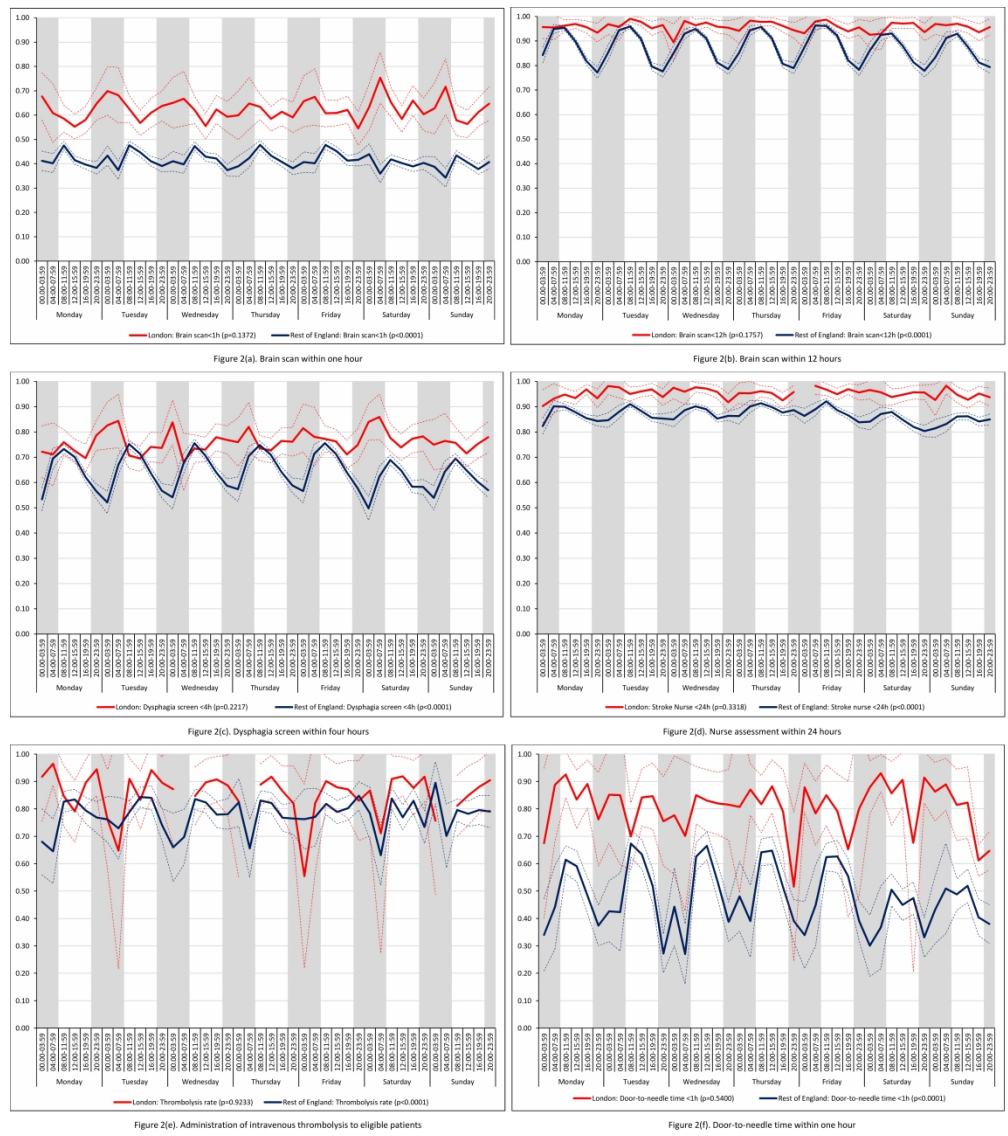


Figure 2. Quality of care across the 42 time periods in the week: measures linked to performance standards for London HASUs

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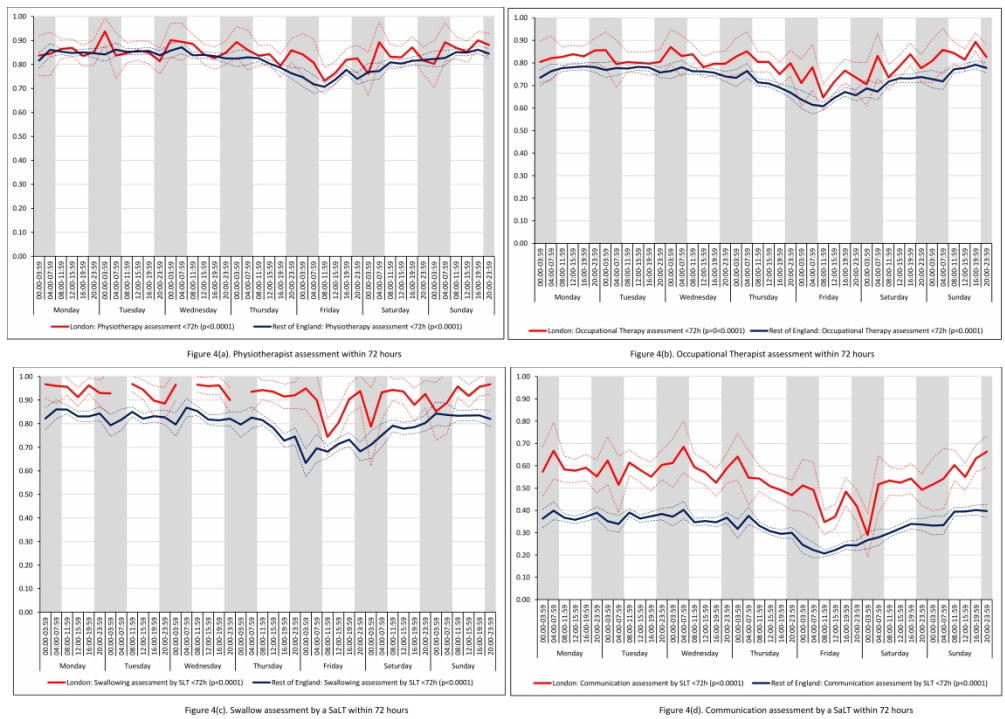


Figure 4. Quality of care across the 42 time periods in the week: variation by day of the week but not time of day

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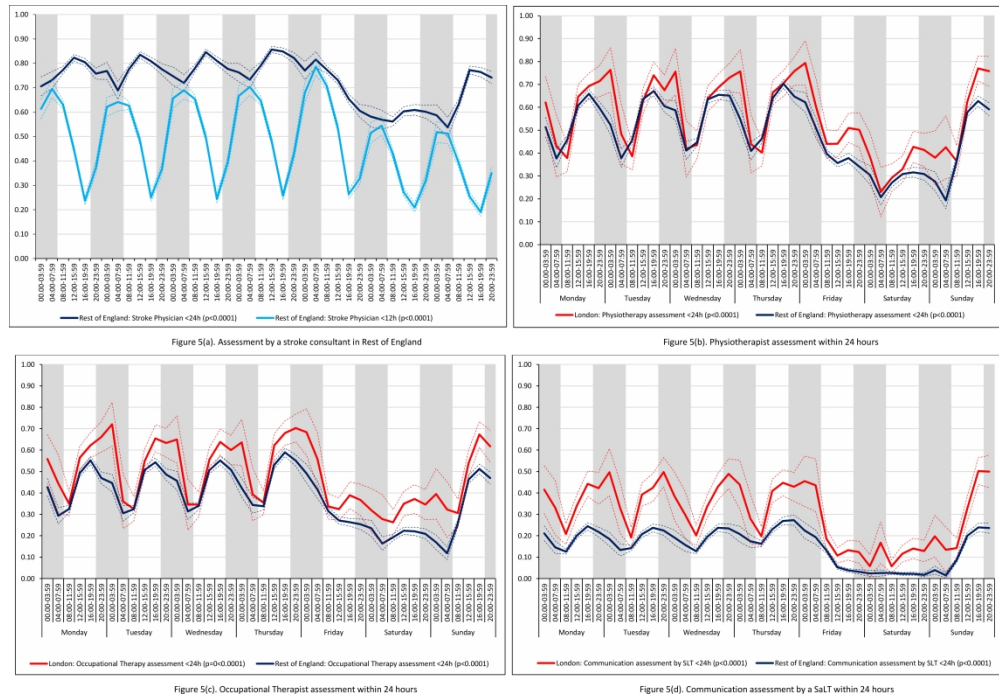


Figure 5. Quality of care across the 42 time periods in the week: variation by time of day and day of the week

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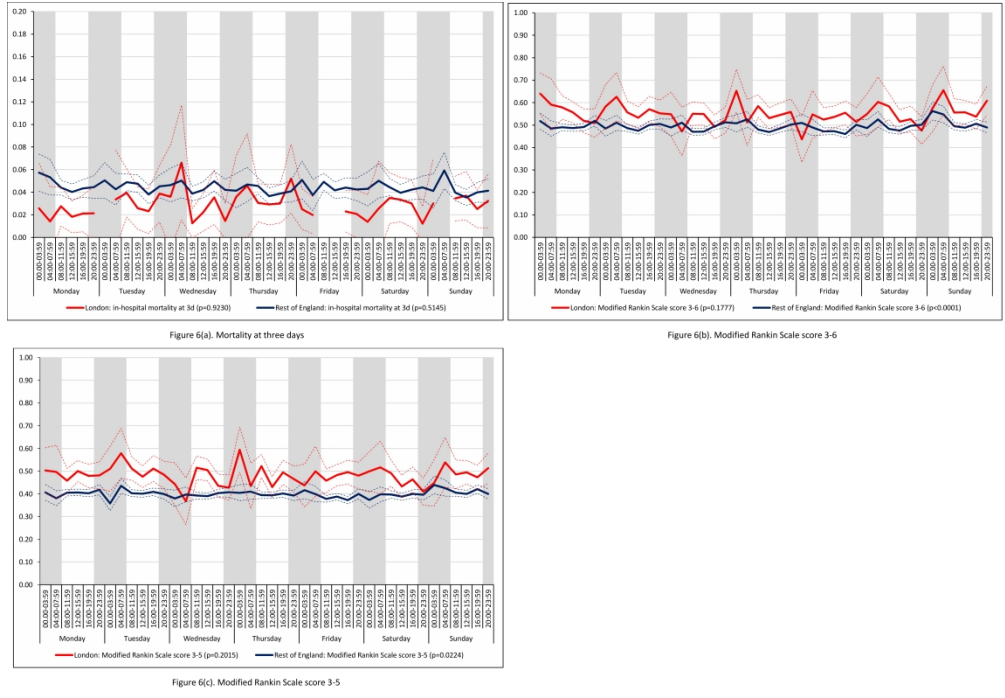


Figure 6. Outcomes across the 42 time periods in the week

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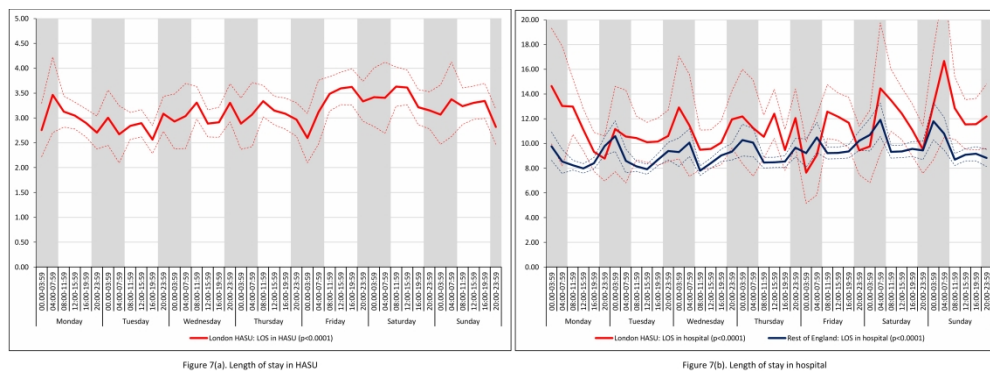


Figure 7. Length of stay across the 42 time periods in the week

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Supplementary Tables

Supplementary Table 1. Quality of care and outcomes across four periods in the week unadjusted figures

	London HASUs					Rest of England				
	Weekday	Weekend	Weekday	Weekend	p-value†	Weekday	Weekend	Weekday	Weekend	p-value†
	08:00-19:59	08:00-19:59	20:00-07:59	20:00-07:59		08:00-19:59	08:00-19:59	20:00-07:59	20:00-07:59	
Quality of care measures that do not vary across the week in London HASUs										
Brain scan within one hour	0.58 (0.57-0.60)	0.62 (0.59-0.64)	0.61 (0.58-0.63)	0.63 (0.59-0.67)	0.0443	0.42 (0.41-0.43)	0.41 (0.40-0.42)	0.42 (0.41-0.43)	0.43 (0.42-0.45)	0.2145
Brain scan within 12 hours	0.95 (0.95-0.96)	0.96 (0.94-0.97)	0.93 (0.91-0.94)	0.92 (0.90-0.94)	0.0000	0.88 (0.88-0.89)	0.88 (0.87-0.88)	0.84 (0.83-0.84)	0.84 (0.83-0.85)	0.0000
Dysphagia screen within four hours	0.74 (0.72-0.75)	0.76 (0.73-0.78)	0.77 (0.74-0.79)	0.78 (0.74-0.81)	0.0359	0.69 (0.69-0.70)	0.66 (0.65-0.66)	0.61 (0.60-0.62)	0.60 (0.58-0.62)	0.0000
Assessment by a nurse trained in stroke management within 24 hours	0.96 (0.95-0.96)	0.95 (0.94-0.96)	0.95 (0.93-0.96)	0.95 (0.94-0.97)	0.4109	0.88 (0.88-0.89)	0.86 (0.85-0.86)	0.86 (0.85-0.86)	0.84 (0.82-0.85)	0.0000
Administration of intravenous thrombolysis to eligible patients	0.88 (0.85-0.90)	0.87 (0.83-0.92)	0.87 (0.83-0.91)	0.88 (0.81-0.95)	0.9905	0.80 (0.79-0.81)	0.79 (0.77-0.81)	0.74 (0.72-0.77)	0.75 (0.72-0.79)	0.0000
Door-to-needle time within one hour in patients receiving thrombolysis	0.84 (0.81-0.87)	0.88 (0.84-0.93)	0.79 (0.74-0.85)	0.85 (0.78-0.92)	0.0677	0.60 (0.59-0.62)	0.48 (0.45-0.51)	0.38 (0.35-0.41)	0.36 (0.32-0.41)	0.0000
Quality of care: measures that vary significantly across the week										
Assessment by a stroke specialist consultant physician within 12 hours	0.39 (0.37-0.40)	0.30 (0.28-0.33)	0.63 (0.60-0.65)	0.65 (0.61-0.69)	0.0000	0.47 (0.47-0.48)	0.30 (0.30-0.31)	0.52 (0.51-0.53)	0.44 (0.42-0.45)	0.0000
Assessment by a stroke specialist consultant physician within 24 hours	0.90 (0.89-0.91)	0.87 (0.86-0.89)	0.90 (0.88-0.91)	0.92 (0.90-0.94)	0.0173	0.79 (0.79-0.80)	0.66 (0.65-0.67)	0.74 (0.73-0.75)	0.63 (0.62-0.65)	0.0000
Admission to a stroke unit within four hours	0.62 (0.60-0.63)	0.65 (0.62-0.67)	0.68 (0.66-0.70)	0.71 (0.67-0.74)	0.0000	0.62 (0.62-0.63)	0.60 (0.59-0.61)	0.55 (0.54-0.56)	0.55 (0.53-0.57)	0.0000
Physiotherapist assessment within 72 hours	0.83 (0.82-0.84)	0.86 (0.84-0.88)	0.85 (0.83-0.87)	0.84 (0.81-0.87)	0.0538	0.82 (0.82-0.82)	0.83 (0.82-0.84)	0.80 (0.79-0.81)	0.81 (0.79-0.82)	0.0000
Occupational Therapist assessment within 72 hours	0.79 (0.77-0.80)	0.82 (0.79-0.84)	0.81 (0.79-0.83)	0.80 (0.77-0.84)	0.0993	0.74 (0.73-0.74)	0.75 (0.74-0.76)	0.71 (0.70-0.72)	0.72 (0.71-0.74)	0.0000
Swallow assessment by a SLT within 72 hours	0.92 (0.90-0.93)	0.94 (0.92-0.96)	0.93 (0.91-0.95)	0.93 (0.89-0.96)	0.3473	0.80 (0.79-0.80)	0.81 (0.80-0.82)	0.79 (0.78-0.81)	0.80 (0.79-0.82)	0.1258
Communication assessment by a SLT within 72 hours	0.53 (0.51-0.55)	0.57 (0.55-0.60)	0.54 (0.52-0.57)	0.50 (0.46-0.55)	0.0191	0.32 (0.32-0.33)	0.36 (0.35-0.37)	0.34 (0.33-0.35)	0.34 (0.32-0.35)	0.0000

Physiotherapist assessment within 24 hours	0.56 (0.55-0.58)	0.47 (0.44-0.50)	0.65 (0.63-0.68)	0.49 (0.45-0.53)	0.0000	0.54 (0.54-0.55)	0.40 (0.40-0.41)	0.52 (0.51-0.53)	0.35 (0.33-0.36)	0.0000
Occupational Therapist assessment within 24 hours	0.49 (0.47-0.50)	0.42 (0.39-0.45)	0.58 (0.56-0.61)	0.43 (0.39-0.47)	0.0000	0.43 (0.42-0.43)	0.30 (0.30-0.31)	0.41 (0.40-0.42)	0.26 (0.25-0.27)	0.0000
Communication assessment by a SLT within 24 hours	0.29 (0.28-0.31)	0.23 (0.20-0.25)	0.39 (0.36-0.41)	0.22 (0.19-0.25)	0.0000	0.17 (0.17-0.17)	0.10 (0.09-0.10)	0.19 (0.18-0.20)	0.08 (0.07-0.09)	0.0000
Outcome measures										
Mortality at three days	0.02 (0.02-0.03)	0.04 (0.03-0.05)	0.03 (0.02-0.03)	0.02 (0.01-0.03)	0.0547	0.04 (0.04-0.04)	0.04 (0.04-0.04)	0.06 (0.05-0.06)	0.06 (0.05-0.06)	0.0000
mRS score 3-6	0.55 (0.53-0.56)	0.58 (0.55-0.60)	0.52 (0.50-0.55)	0.54 (0.50-0.58)	0.0553	0.46 (0.46-0.47)	0.50 (0.49-0.51)	0.54 (0.53-0.55)	0.54 (0.53-0.56)	0.0000
mRS score 3-5*	0.48 (0.46-0.49)	0.51 (0.48-0.54)	0.46 (0.43-0.49)	0.47 (0.43-0.52)	0.1024	0.38 (0.37-0.38)	0.41 (0.40-0.42)	0.44 (0.43-0.45)	0.44 (0.42-0.46)	0.0000
Length of stay										
Length of stay in HASU (days)	3.0 (2.9-3.1)	3.3 (3.2-3.5)	2.9 (2.7-3.0)	3.0 (2.8-3.2)	0.0000					
Length of stay in hospital (days)	7.8 (7.4-8.1)	9.2 (8.5-10.0)	7.6 (7.0-8.2)	8.0 (7.0-9.0)	0.0016	6.6 (6.5-6.6)	7.5 (7.3-7.7)	8.4 (8.2-8.6)	8.7 (8.3-9.1)	0.0000

Note.
 Figures are average predicted probabilities (95% confidence intervals) of each measure in each time period controlling for the covariates. SLT = Speech and Language Therapist. mRS = modified Rankin Scale. * Patients who died were not included. †P-value threshold adjusted for multiple testing is 0.0025 for London HASUs and 0.0024 for the rest of England.

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Supplementary Table 2A. Quality of care and outcomes across four periods in the week (p-values comparison between Wald test and Likelihood-ratio test)

	London HASUs						Rest of England					
	Weekday	Weekend	Weekday	Weekend	p-value [†]	p-value [†]	Weekday	Weekend	Weekday	Weekend	p-value [†]	p-value [†]
	08:00-19:59	08:00-19:59	20:00-07:59	20:00-07:59	Wald	Likelihood-ratio test	08:00-19:59	08:00-19:59	20:00-07:59	20:00-07:59	Wald	Likelihood-ratio test
Quality of care measures that do not vary across the week in London HASUs												
Brain scan within one hour	0.60 (0.58-0.61)	0.61 (0.58-0.63)	0.63 (0.60-0.65)	0.65 (0.61-0.68)	0.0344	0.0336	0.44 (0.44-0.45)	0.41 (0.40-0.41)	0.40 (0.39-0.40)	0.39 (0.38-0.41)	0.0000	0.0000
Brain scan within 12 hours	0.97 (0.96-0.97)	0.96 (0.95-0.97)	0.95 (0.94-0.96)	0.95 (0.93-0.96)	0.0093	0.0110	0.90 (0.90-0.90)	0.88 (0.87-0.89)	0.84 (0.83-0.84)	0.83 (0.82-0.84)	0.0000	0.0000
Dysphagia screen within four hours	0.74 (0.72-0.75)	0.75 (0.73-0.77)	0.77 (0.75-0.79)	0.79 (0.76-0.82)	0.0029	0.0026	0.70 (0.70-0.71)	0.65 (0.64-0.66)	0.60 (0.59-0.61)	0.58 (0.56-0.59)	0.0000	0.0000
Assessment by a nurse trained in stroke management within 24 hours	0.96 (0.95-0.96)	0.94 (0.93-0.96)	0.95 (0.94-0.96)	0.95 (0.94-0.97)	0.1872	0.1896	0.89 (0.88-0.89)	0.85 (0.85-0.86)	0.86 (0.86-0.87)	0.83 (0.82-0.84)	0.0000	0.0000
Administration of intravenous thrombolysis to eligible patients	0.88 (0.86-0.90)	0.88 (0.84-0.92)	0.86 (0.82-0.91)	0.88 (0.82-0.95)	0.9327	0.9341	0.81 (0.80-0.82)	0.80 (0.78-0.82)	0.76 (0.74-0.78)	0.76 (0.72-0.79)	0.0000	0.0000
Door-to-needle time within one hour in patients receiving thrombolysis	0.84 (0.81-0.87)	0.89 (0.85-0.93)	0.79 (0.74-0.84)	0.84 (0.77-0.91)	0.0269	0.0233	0.60 (0.59-0.62)	0.48 (0.45-0.50)	0.38 (0.35-0.40)	0.37 (0.33-0.41)	0.0000	0.0000
Quality of care: measures that vary significantly across the week												
Assessment by a stroke specialist consultant physician	0.39 (0.38-.40)	0.30 (0.27-0.32)	0.63 (0.61-0.66)	0.64 (0.60-0.68)	0.0000	0.0000	0.48 (0.48-0.49)	0.30 (0.29-0.31)	0.51 (0.51-0.52)	0.42 (0.41-0.44)	0.0000	0.0000

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within 12 hours												
Assessment by a stroke specialist consultant physician within 24 hours	0.90 (0.89-0.91)	0.87 (0.85-0.89)	0.90 (0.88-0.91)	0.92 (0.90-0.94)	0.0043	0.0048	0.80 (0.79-0.80)	0.65 (0.65-0.66)	0.75 (0.74-0.75)	0.62 (0.61-0.64)	0.0000	0.0000
Admission to a stroke unit within four hours	0.62 (0.60-0.63)	0.64 (0.61-0.66)	0.67 (0.65-0.70)	0.70 (0.67-0.74)	0.0000	0.0000	0.63 (0.63-0.63)	0.59 (0.58-0.60)	0.55 (0.54-0.56)	0.53 (0.52-0.55)	0.0000	0.0000
Physiotherapist assessment within 72 hours	0.83 (0.82-0.84)	0.86 (0.84-0.88)	0.85 (0.83-0.87)	0.84 (0.81-0.87)	0.0693	0.0666	0.82 (0.81-0.82)	0.83 (0.82-0.84)	0.81 (0.81-0.82)	0.82 (0.80-0.83)	0.0010	0.0009
Occupational Therapist assessment within 72 hours	0.79 (0.78-0.80)	0.82 (0.80-0.84)	0.81 (0.79-0.82)	0.80 (0.76-0.83)	0.0967	0.0936	0.73 (0.73-0.74)	0.75 (0.75-0.76)	0.73 (0.72-0.74)	0.73 (0.72-0.74)	0.0000	0.0000
Swallow assessment by a SLT within 72 hours	0.92 (0.91-0.93)	0.93 (0.91-0.95)	0.93 (0.91-0.95)	0.91 (0.88-0.95)	0.5838	0.5795	0.80 (0.80-0.81)	0.81 (0.80-0.82)	0.79 (0.78-0.80)	0.80 (0.78-0.82)	0.0946	0.0946
Communication assessment by a SLT within 72 hours	0.53 (0.51-0.54)	0.56 (0.54-0.59)	0.55 (0.53-0.58)	0.52 (0.48-0.56)	0.0739	0.0735	0.33 (0.32-0.33)	0.36 (0.35-0.37)	0.34 (0.33-0.35)	0.34 (0.32-0.35)	0.0000	0.0000
Physiotherapist assessment within 24 hours	0.56 (0.54-0.57)	0.47 (0.45-0.50)	0.65 (0.63-0.68)	0.48 (0.44-0.52)	0.0000	0.0000	0.54 (0.54-0.55)	0.41 (0.40-0.41)	0.53 (0.52-0.54)	0.35 (0.34-0.37)	0.0000	0.0000
Occupational Therapist assessment within 24 hours	0.49 (0.47-0.50)	0.42 (0.40-0.45)	0.58 (0.55-0.60)	0.41 (0.37-0.45)	0.0000	0.0000	0.43 (0.42-0.43)	0.31 (0.30-0.31)	0.42 (0.42-0.43)	0.26 (0.25-0.27)	0.0000	0.0000
Communication assessment by a SLT within 24 hours	0.29 (0.28-0.31)	0.22 (0.20-0.24)	0.39 (0.37-0.42)	0.23 (0.20-0.27)	0.0000	0.0000	0.17 (0.17-0.17)	0.10 (0.09-0.10)	0.19 (0.18-0.20)	0.08 (0.07-0.09)	0.0000	0.0000
Outcome measures												
Mortality at three days	0.03 (0.02-0.03)	0.03 (0.02-0.04)	0.03 (0.02-0.04)	0.02 (0.01-0.03)	0.3310	0.3298	0.04 (0.04-0.05)	0.04 (0.04-0.04)	0.05 (0.04-0.05)	0.05 (0.04-0.05)	0.1055	0.1030
mRS score 3-6	0.55 (0.53-0.55)	0.55 (0.52-0.55)	0.55 (0.52-0.55)	0.56 (0.53-0.56)	0.8672	0.8673	0.48 (0.48-0.48)	0.49 (0.48-0.49)	0.51 (0.50-0.51)	0.51 (0.50-0.51)	0.0000	0.0000

	0.56)	0.57)	0.57)	0.59)			0.48)	0.50)	0.51)	0.52)		
mRS score 3-5*	0.49 (0.47-0.50)	0.47 (0.45-0.50)	0.48 (0.45-0.50)	0.48 (0.44-0.51)	0.7497	0.7494	0.40 (0.39-0.40)	0.40 (0.39-0.41)	0.40 (0.39-0.41)	0.40 (0.39-0.41)	0.3746	0.3750
Length of stay												
Length of stay in HASU (days)	3.1 (3.0-3.2)	3.4 (3.2-3.5)	3.0 (2.9-3.1)	3.1 (2.9-3.3.)	0.0007	0.0008						
Length of stay in hospital (days)	10.8 (10.2-11.3)	12.1 (11.1-13.1)	10.8 (10.0-11.7)	11.5 (10.2-12.9)	0.0359	0.0359	8.5 (8.4-8.6)	9.2 (9.0-9.4)	9.7(9.4-9.9)	10.1 (9.6-10.5)	0.0000	0.0000

Note.

Figures are average predicted probabilities (95% confidence intervals) of each measure in each time period controlling for the covariates. SLT = Speech and Language Therapist. mRS = modified Rankin Scale. * Patients who died were not included. †P-value threshold adjusted for multiple testing is 0.0025 for London HASUs and 0.0024 for the rest of England.

Supplementary Table 3. Quality of care and outcomes across four periods in the week controlling for HSS score on arrival

	London HASUs					Rest of England				
	Weekday	Weekend	Weekday	Weekend	†p-value	Weekday	Weekend	Weekday	Weekend	†p-value
	08:00-19:59	08:00-19:59	20:00-07:59	20:00-07:59		08:00-19:59	08:00-19:59	20:00-07:59	20:00-07:59	
Quality of care measures that do not vary across the week in London HASUs										
Brain scan within one hour	0.60 (0.59-0.62)	0.61 (0.59-0.64)	0.63 (0.61-0.66)	0.65 (0.62-0.69)	0.0256	0.47 (0.46-0.47)	0.43 (0.42-0.44)	0.41 (0.41-0.42)	0.41 (0.40-0.43)	0.0000
Brain scan within 12 hours	0.97 (0.97-0.98)	0.97 (0.96-0.98)	0.95 (0.94-0.96)	0.94 (0.92-0.96)	0.0012	0.91 (0.91-0.92)	0.89 (0.89-0.90)	0.85 (0.84-0.86)	0.85 (0.84-0.86)	0.0000
Dysphagia screen within four hours	0.74 (0.73-0.76)	0.76 (0.74-0.79)	0.78 (0.76-0.81)	0.80 (0.77-0.84)	0.0003	0.74 (0.73-0.74)	0.68 (0.68-0.69)	0.64 (0.63-0.65)	0.61 (0.60-0.63)	0.0000
Assessment by a nurse trained in stroke management within 24 hours	0.96 (0.96-0.97)	0.95 (0.94-0.96)	0.95 (0.94-0.96)	0.96 (0.95-0.98)	0.1191	0.92 (0.92-0.93)	0.89 (0.89-0.90)	0.90 (0.90-0.91)	0.88 (0.87-0.89)	0.0000
Administration of intravenous thrombolysis to eligible patients	0.89 (0.86-0.91)	0.89 (0.85-0.93)	0.88 (0.83-0.92)	0.87 (0.81-0.94)	0.9436	0.83 (0.82-0.84)	0.83 (0.81-0.84)	0.78 (0.76-0.80)	0.79 (0.75-0.82)	0.0000
Door-to-needle time within one hour in patients receiving thrombolysis	0.84 (0.81-0.87)	0.89 (0.85-0.93)	0.79 (0.74-0.85)	0.85 (0.78-0.92)	0.0673	0.62 (0.60-0.63)	0.48 (0.46-0.51)	0.39 (0.36-0.42)	0.38 (0.33-0.42)	0.0000
Quality of care: measures that vary significantly across the week										
Assessment by a stroke specialist consultant physician within 12 hours	0.39 (0.38-.40)	0.29 (0.27-0.31)	0.64 (0.62-0.67)	0.65 (0.62-0.69)	0.0000	0.52 (0.52-0.53)	0.33 (0.32-0.34)	0.55 (0.54-0.56)	0.46 (0.44-0.47)	0.0000
Assessment by a stroke specialist consultant physician within 24 hours	0.90 (0.89-0.91)	0.88 (0.86-0.89)	0.90 (0.89-0.92)	0.94 (0.92-0.96)	0.0005	0.84 (0.83-0.84)	0.70 (0.69-0.71)	0.79 (0.78-0.80)	0.67 (0.65-0.68)	0.0000
Admission to a stroke unit within four hours	0.62 (0.61-0.64)	0.65 (0.62-0.68)	0.69 (0.66-0.71)	0.71 (0.67-0.74)	0.0000	0.67 (0.67-0.68)	0.63 (0.62-0.64)	0.59 (0.58-0.60)	0.57 (0.56-0.59)	0.0000
Physiotherapist assessment within 72 hours	0.84 (0.83-0.85)	0.87 (0.85-0.89)	0.86 (0.84-0.88)	0.85 (0.82-0.88)	0.1845	0.85 (0.85-0.85)	0.86 (0.86-0.87)	0.85 (0.84-0.85)	0.85 (0.84-0.86)	0.0022
Occupational Therapist assessment within 72 hours	0.80 (0.79-0.81)	0.83 (0.81-0.85)	0.82 (0.80-0.84)	0.81 (0.78-0.84)	0.0707	0.77 (0.77-0.77)	0.79 (0.78-0.80)	0.77 (0.76-0.78)	0.77 (0.76-0.78)	0.0005
Swallow assessment by a SLT within 72 hours	0.93 (0.91-0.94)	0.95 (0.93-0.97)	0.94 (0.92-0.96)	0.91 (0.87-0.85)	0.2298	0.83 (0.82-0.83)	0.84 (0.83-0.85)	0.82 (0.81-0.83)	0.82 (0.80-0.84)	0.1677

Communication assessment by a SLT within 72 hours	0.54 (0.52-0.55)	0.57 (0.54-0.60)	0.56 (0.54-0.59)	0.53 (0.49-0.57)	0.1069	0.33 (0.32-0.33)	0.36 (0.35-0.37)	0.33 (0.32-0.34)	0.34 (0.32-0.36)	0.0000
Physiotherapist assessment within 24 hours	0.57 (0.55-0.58)	0.49 (0.46-0.51)	0.66 (0.64-0.69)	0.49 (0.45-0.53)	0.0000	0.57 (0.57-0.58)	0.43 (0.42-0.44)	0.57 (0.56-0.58)	0.38 (0.36-0.39)	0.0000
Occupational Therapist assessment within 24 hours	0.49 (0.48-0.51)	0.43 (0.41-0.46)	0.59 (0.56-0.61)	0.42 (0.38-0.46)	0.0000	0.45 (0.45-0.46)	0.33 (0.32-0.33)	0.46 (0.45-0.47)	0.28 (0.27-0.30)	0.0000
Communication assessment by a SLT within 24 hours	0.30 (0.28-0.31)	0.22 (0.20-0.25)	0.40 (0.38-0.43)	0.24 (0.20-0.27)	0.0000	0.17 (0.17-0.18)	0.10 (0.09-0.10)	0.19 (0.18-0.20)	0.08 (0.07-0.09)	0.0000
Outcome measures										
Mortality at three days	0.02 (0.02-0.03)	0.03 (0.02-0.04)	0.03 (0.02-0.04)	0.02 (0.01-0.03)	0.2987	0.03 (0.03-0.03)	0.03 (0.02-0.03)	0.03 (0.03-0.03)	0.03 (0.02-0.03)	0.6904
mRS score 3-6	0.53 (0.52-0.54)	0.52 (0.50-0.55)	0.53 (0.51-0.55)	0.54 (0.510-0.57)	0.8754	0.43 (0.43-0.44)	0.44 (0.43-0.45)	0.45 (0.44-0.46)	0.46 (0.44-0.47)	0.0000
mRS score 3-5*	0.49 (0.47-0.50)	0.47 (0.45-0.50)	0.48 (0.45-0.50)	0.48 (0.44-0.51)	0.7497	0.40 (0.39-0.40)	0.40 (0.39-0.41)	0.40 (0.39-0.41)	0.40 (0.39-0.41)	0.3746
Length of stay										
Length of stay in HASU (days)	3.1 (3.0-3.2)	3.3 (3.2-3.5)	3.0 (2.9-3.1)	3.1 (2.9-3.3)	0.0080					
Length of stay in hospital (days)	12.8 (12.1-13.6)	14.4 (13.2-15.6)	13.2 (12.2-14.3)	13.2 (11.7-14.7)	0.0562	8.9 (8.7-9.0)	9.5 (9.3-9.8)	9.9 (9.6-10.2)	10.4 (10.0-10.9)	0.0000

Note.

Figures are average predicted probabilities (95% confidence intervals) of each measure in each time period controlling for the covariates. SLT = Speech and Language Therapist. mRS = modified Rankin Scale. * Patients who died were not included. †P-value threshold adjusted for multiple testing is 0.0025 for London HASUs and 0.0024 for the rest of England.

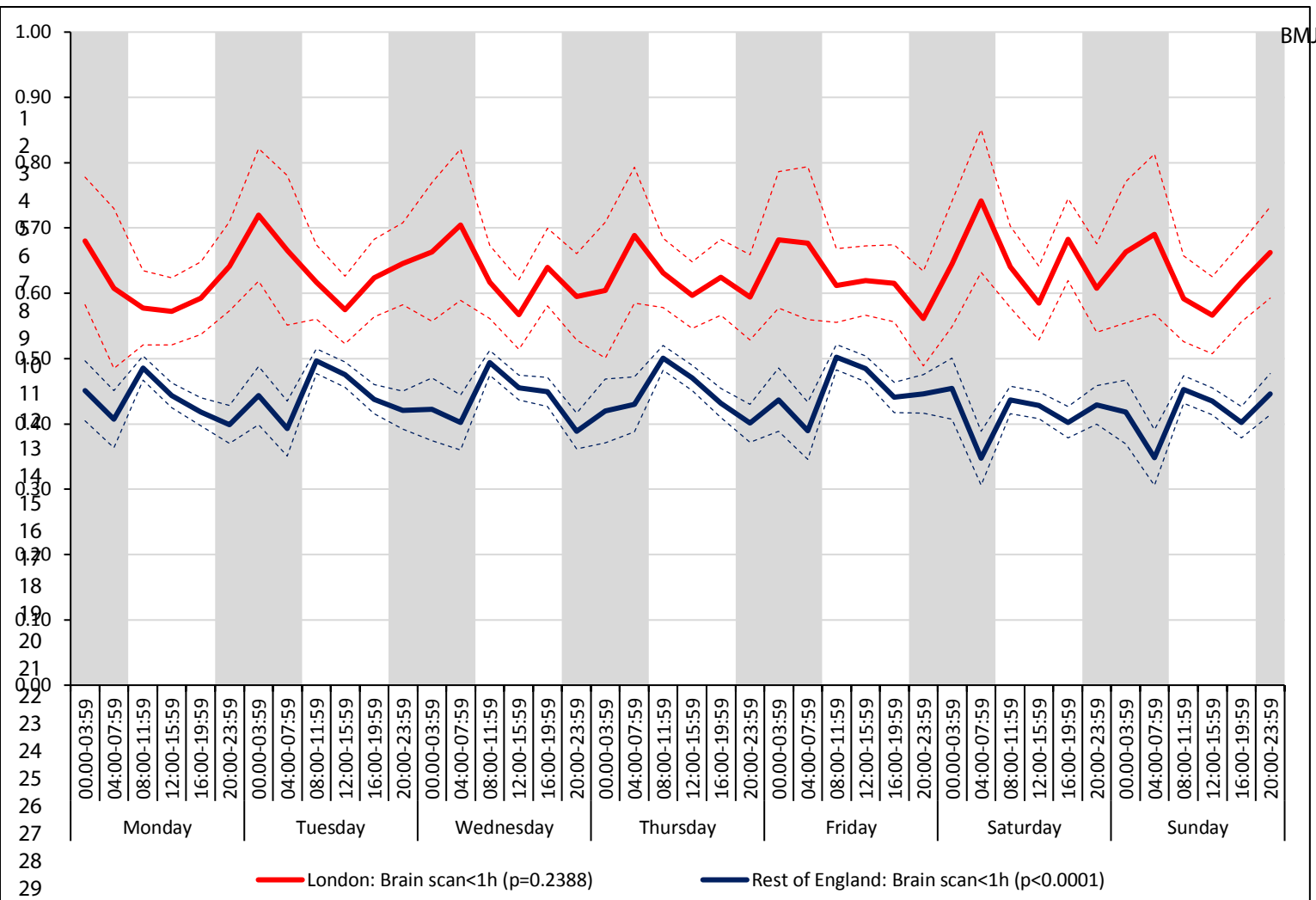


Figure S1(a). Brain scan within one hour

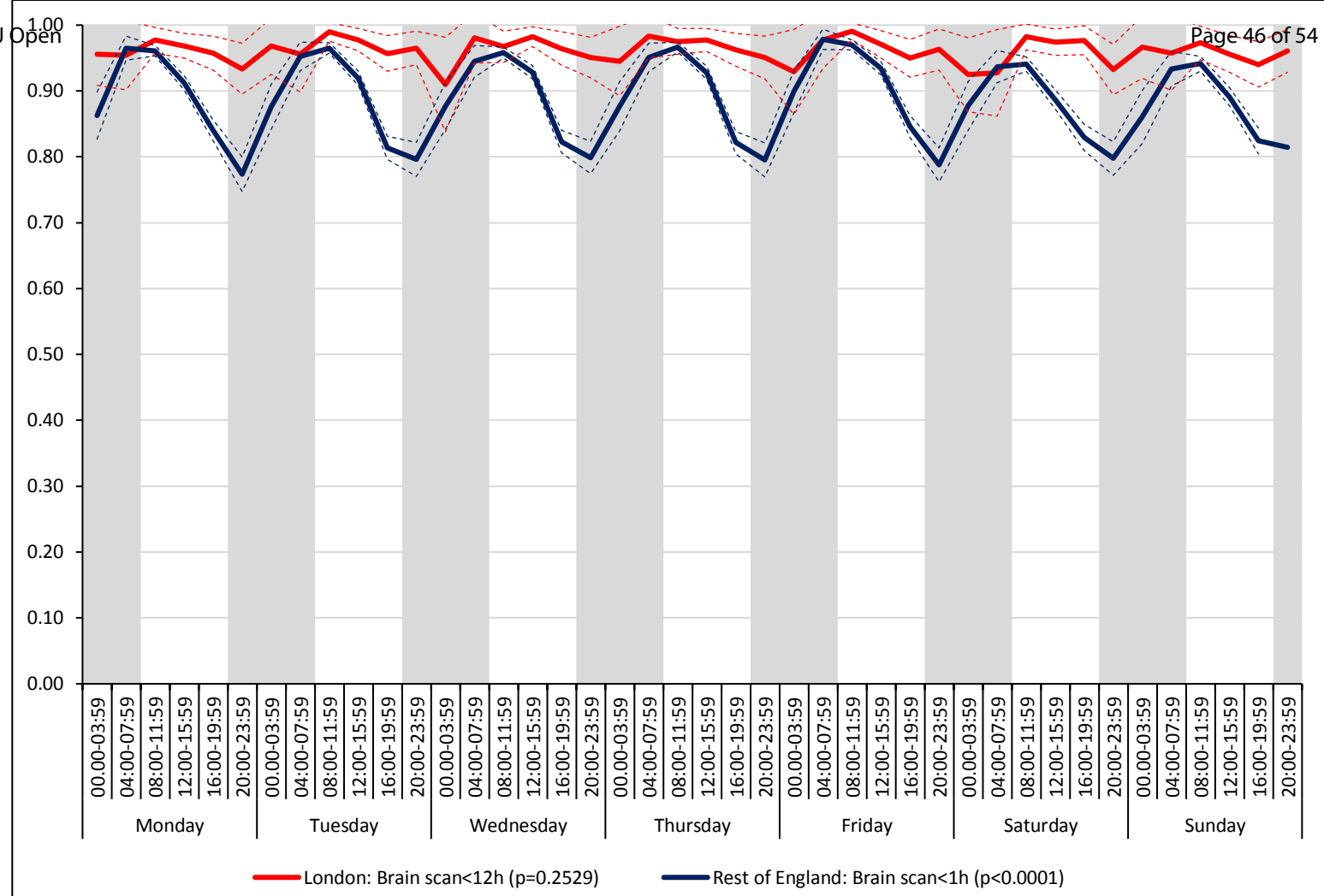


Figure S1(b). Brain scan within 12 hours

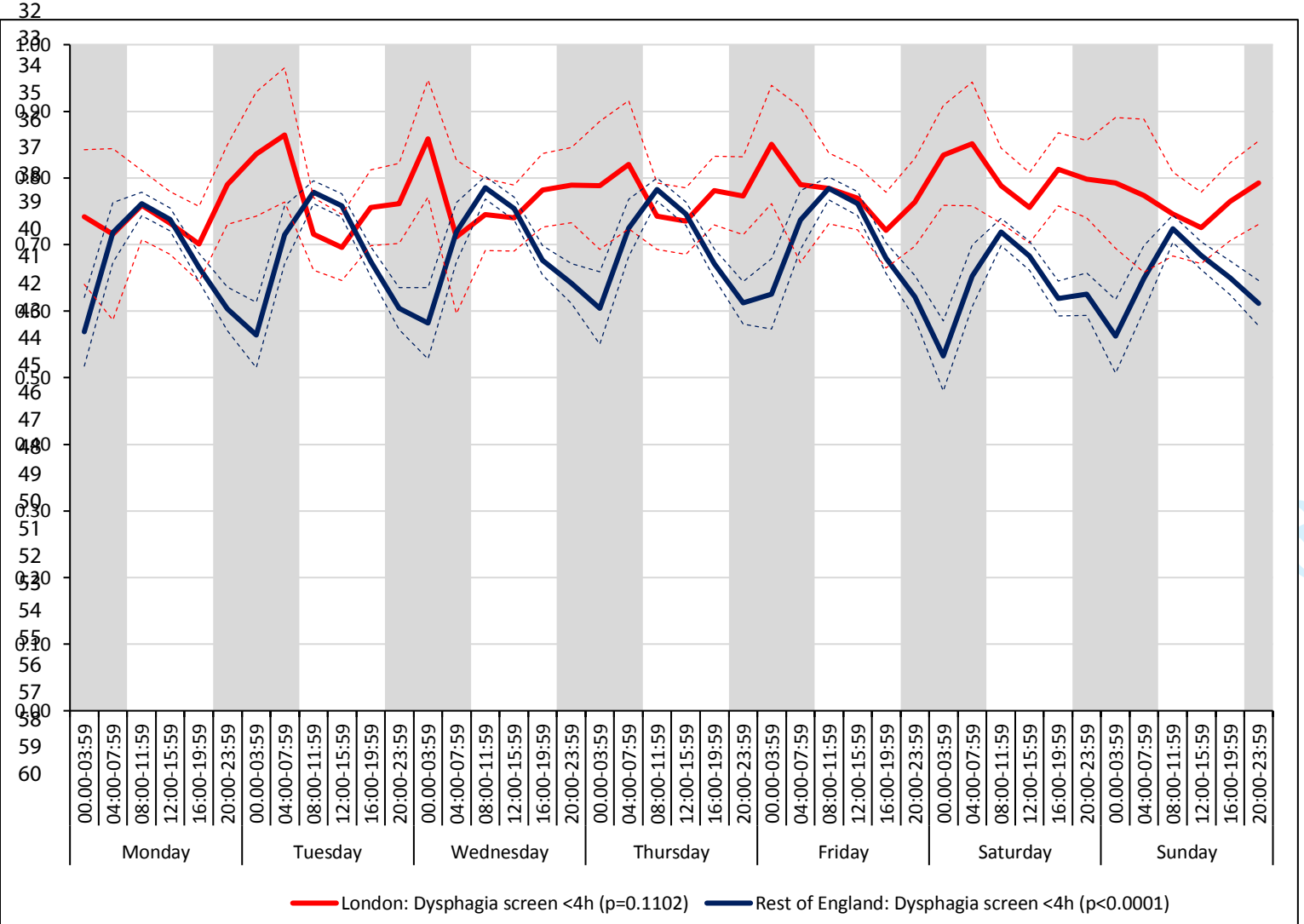


Figure S1(c). Dysphagia screen within four hours

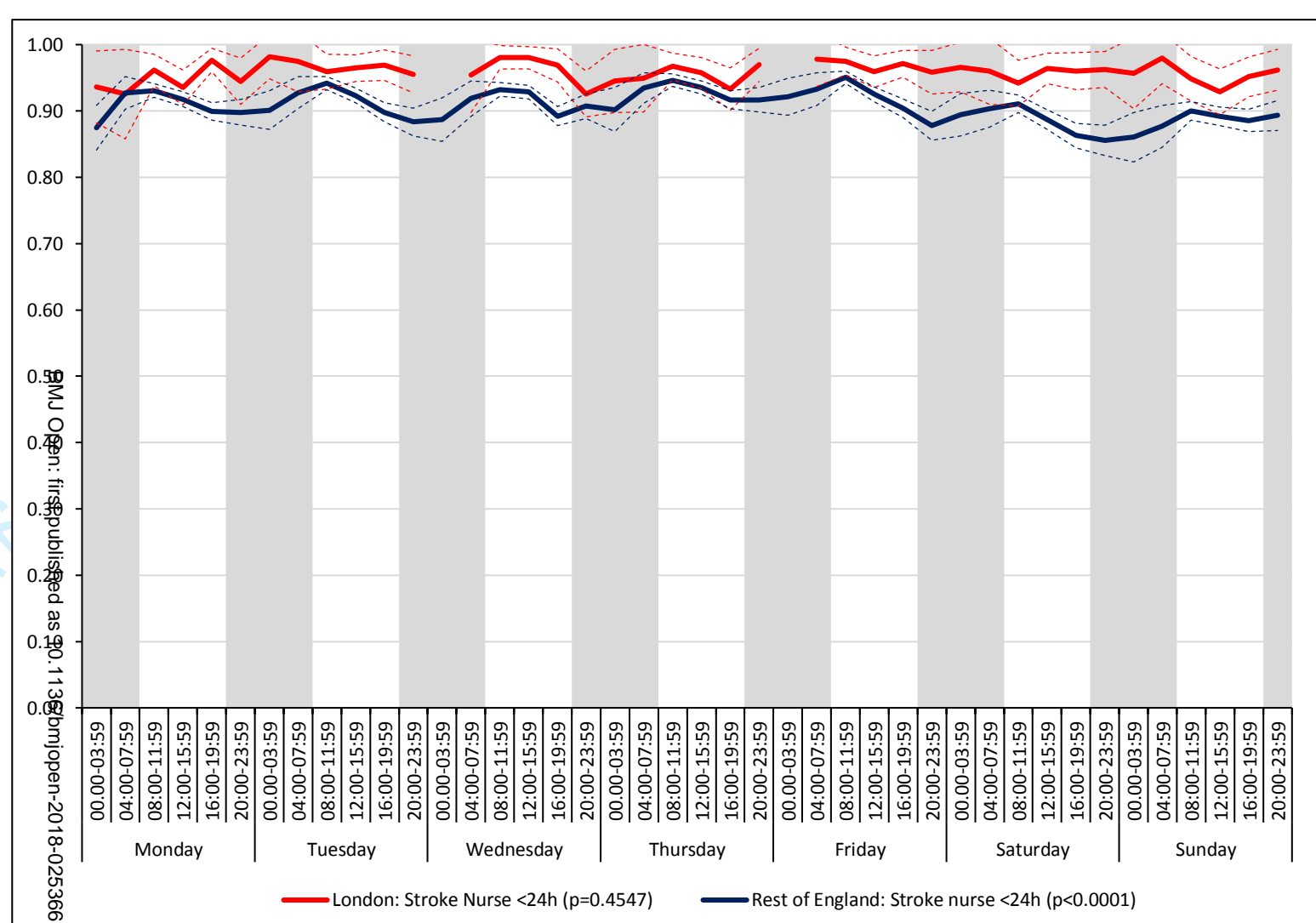


Figure S1(d). Nurse assessment within 24 hours

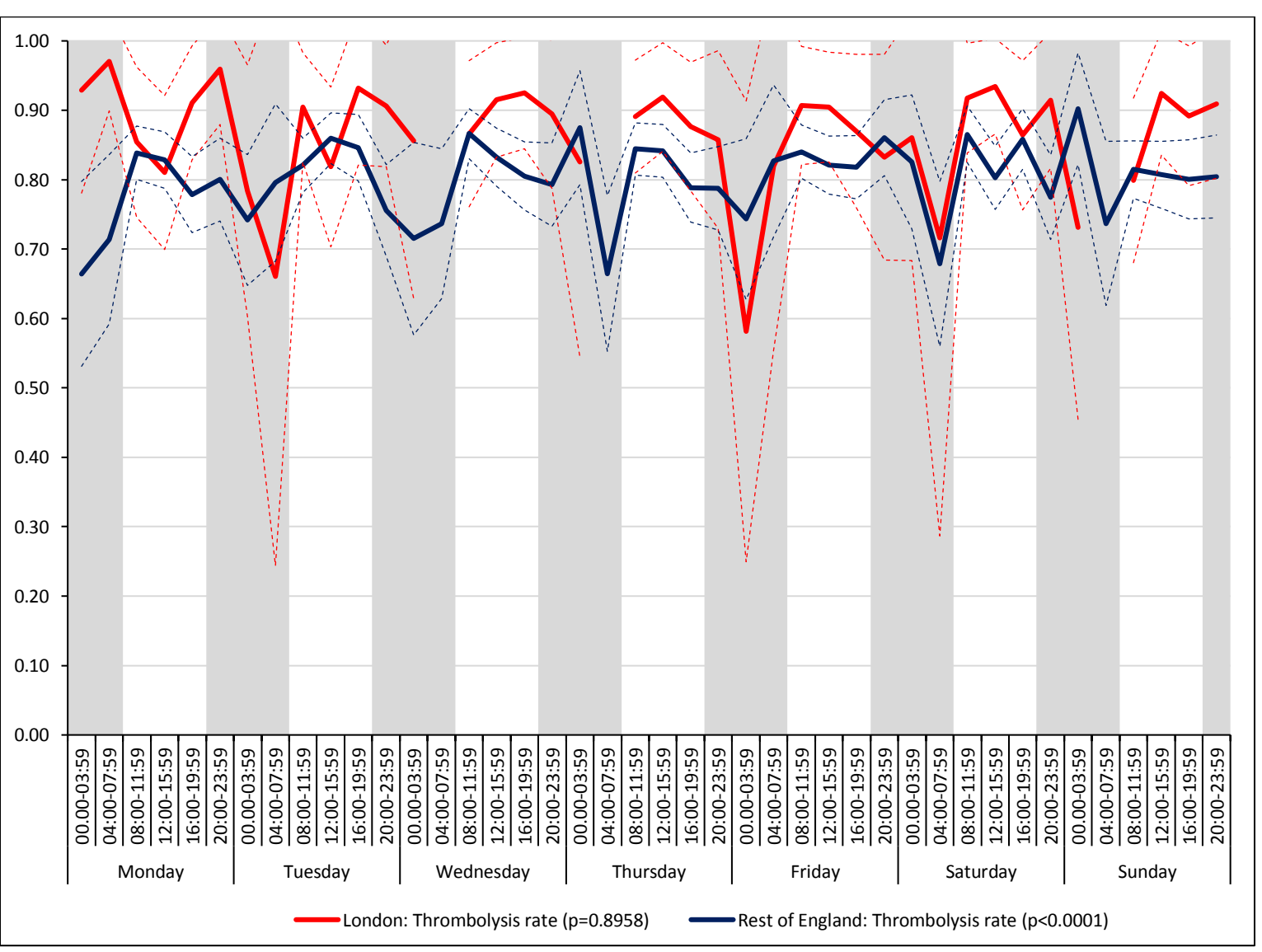


Figure S1(e). Administration of intravenous thrombolysis to eligible patients

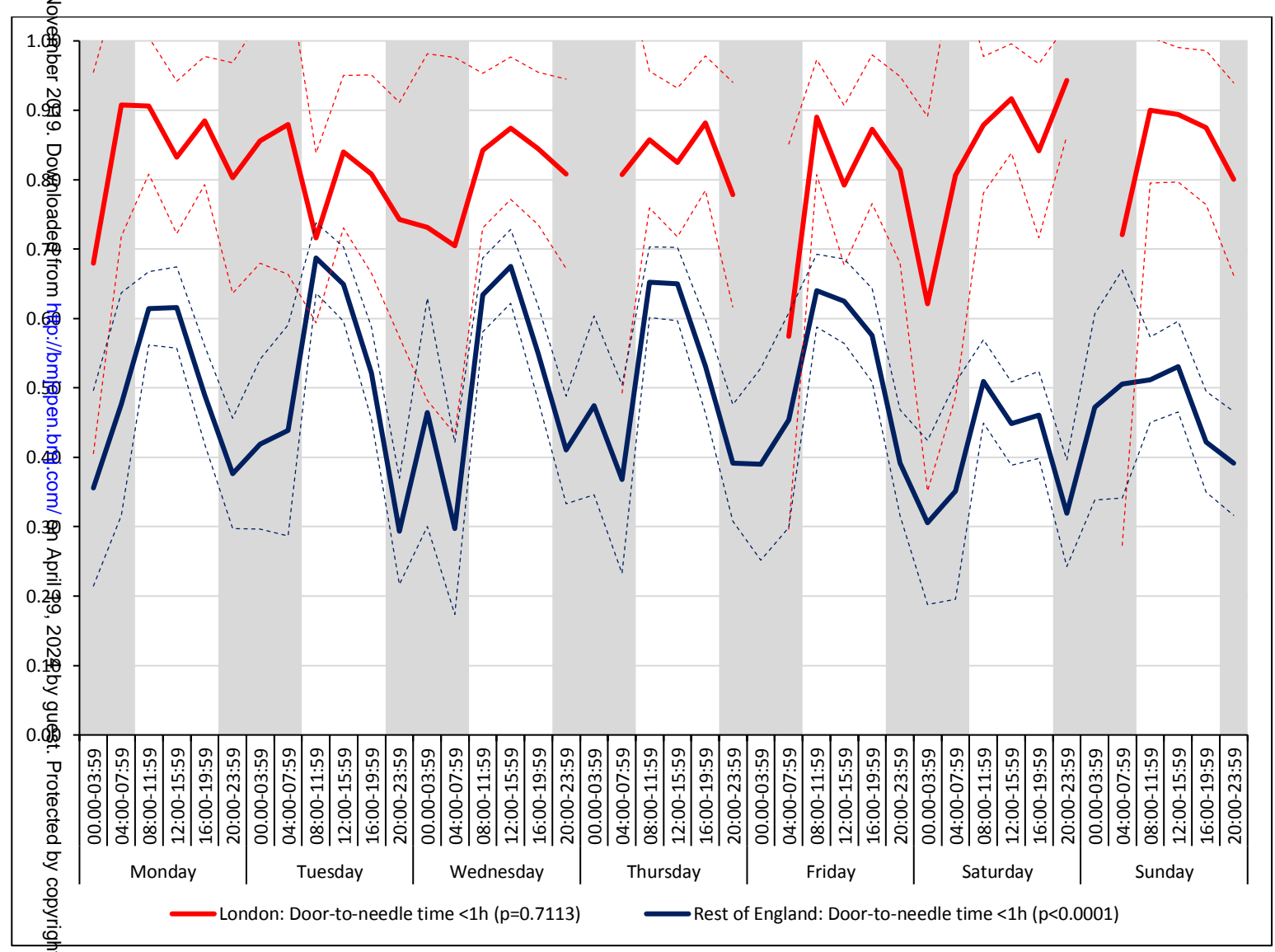


Figure S1(f). Door-to-needle time within one hour

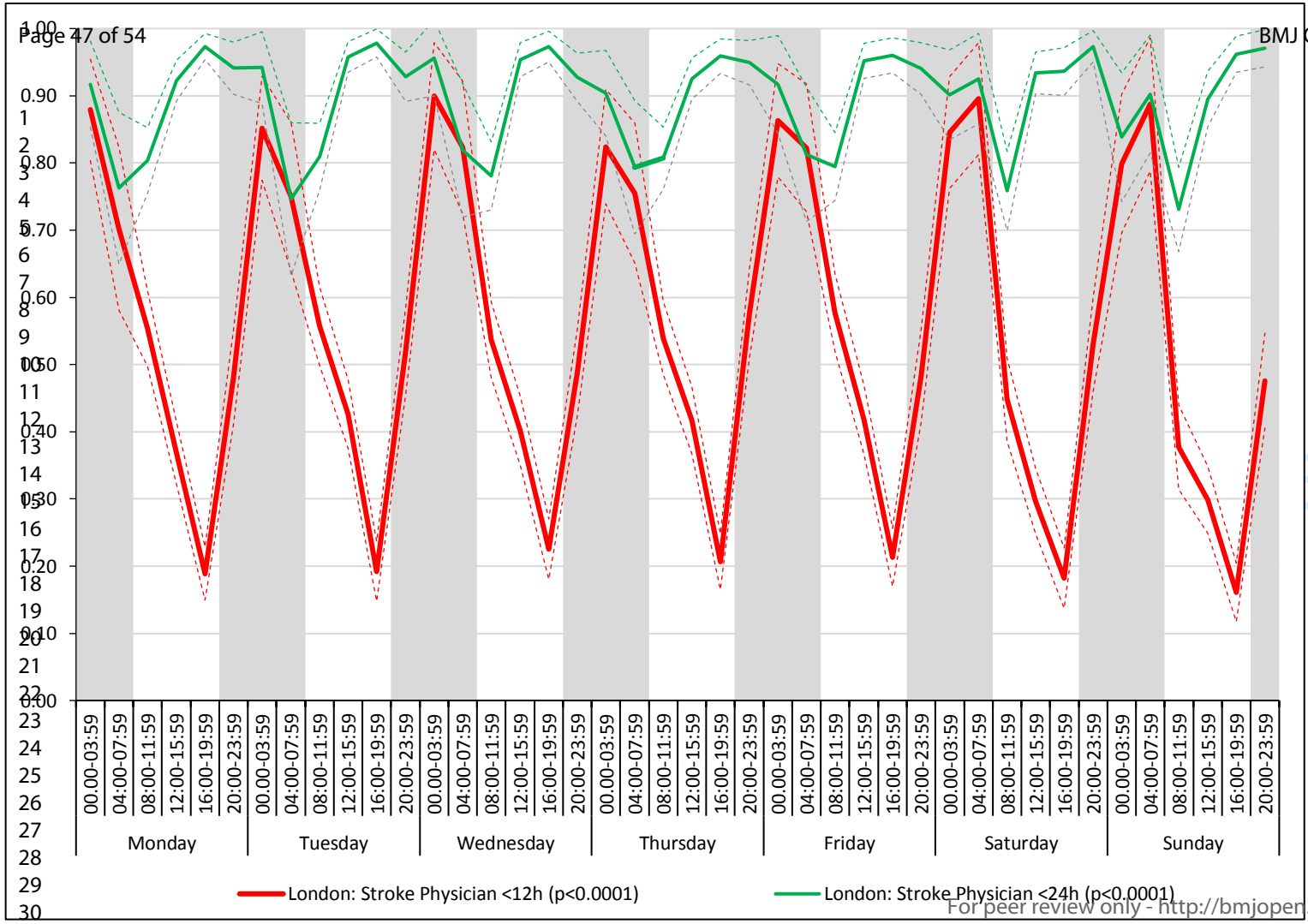


Figure S2(a). Assessment by a stroke consultant in London HASUs

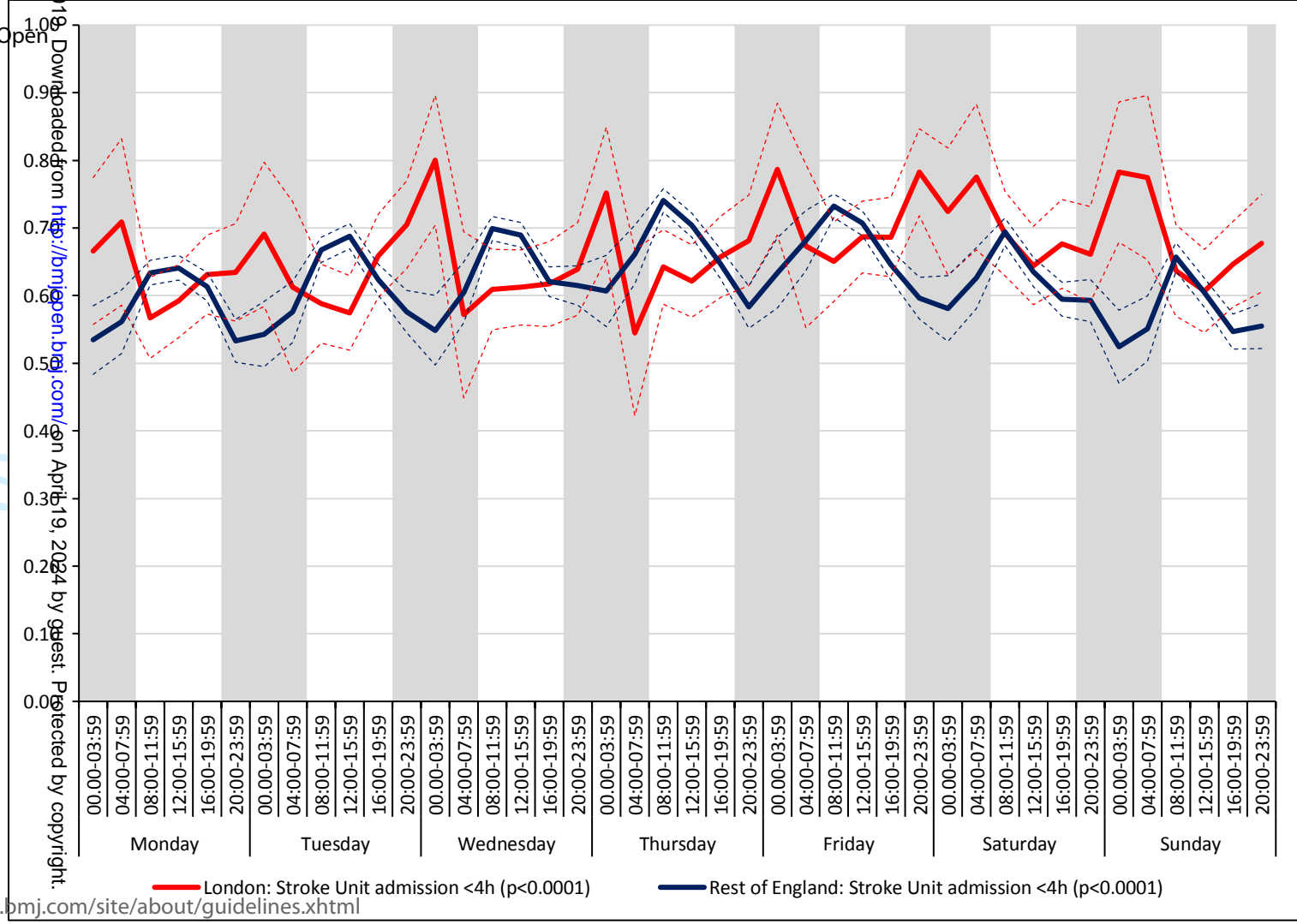


Figure S2(b). Admission to a stroke unit within four hours

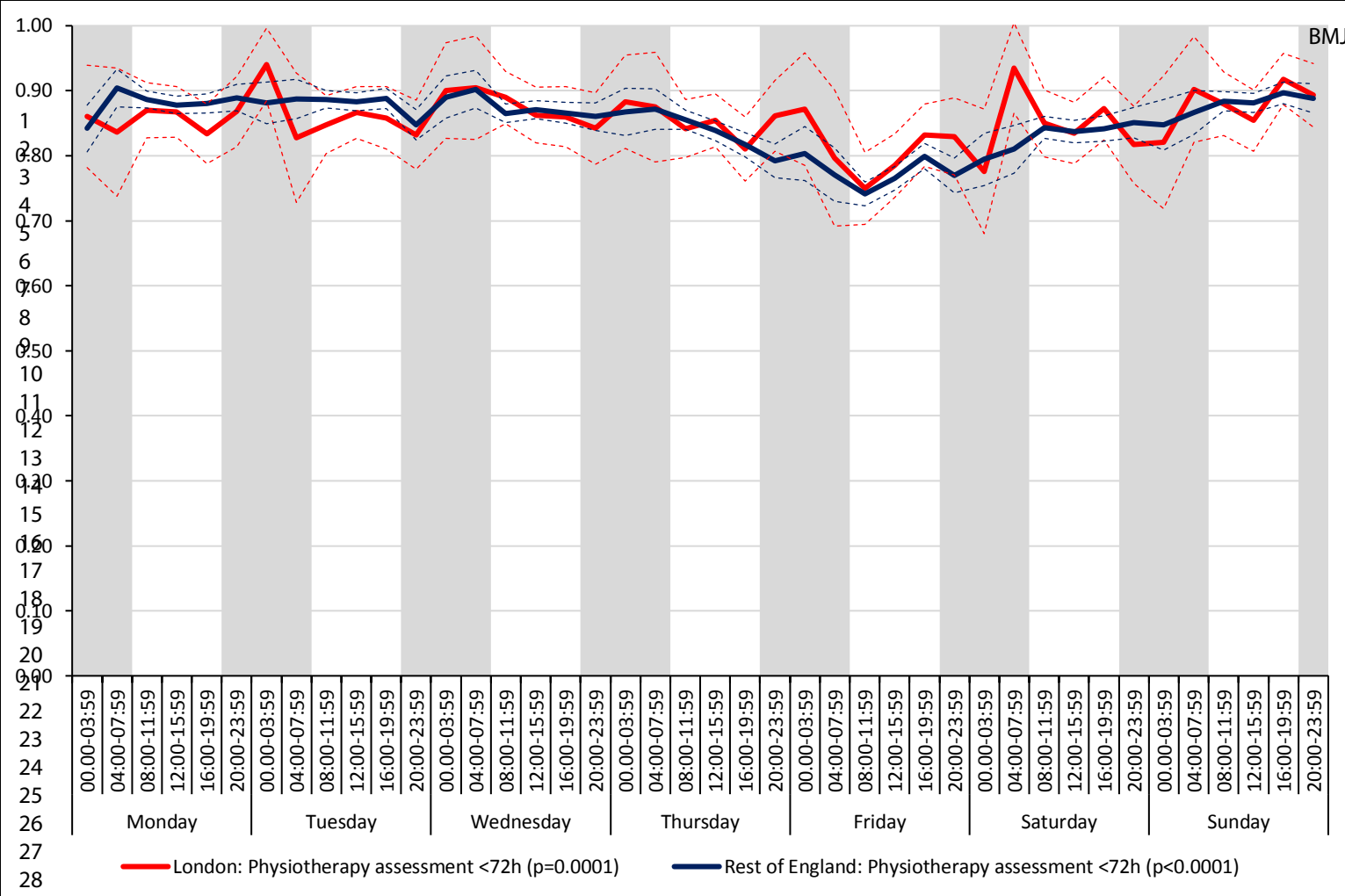


Figure S3(a). Physiotherapist assessment within 72 hours

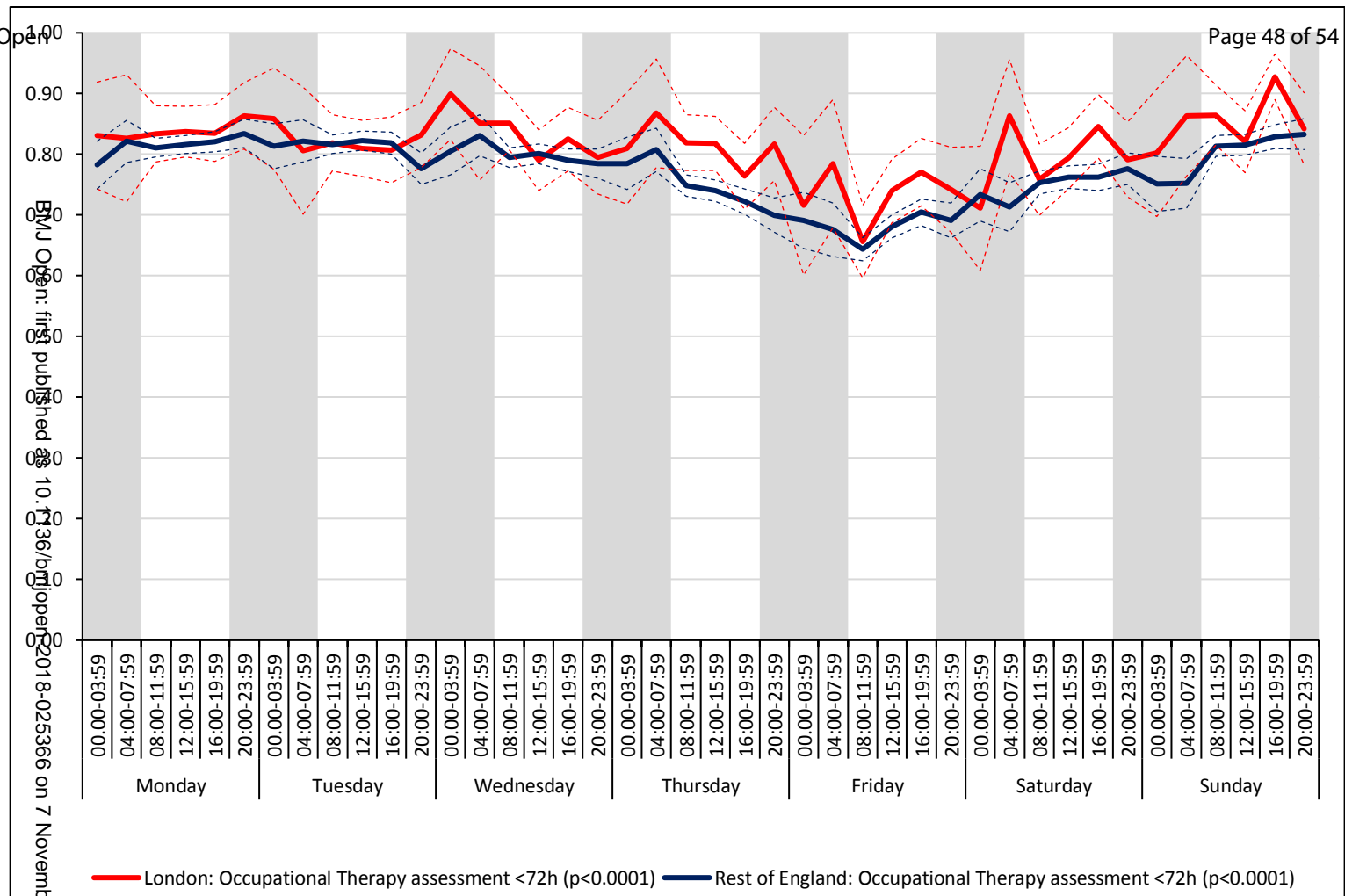


Figure S3(b). Occupational Therapist assessment within 72 hours

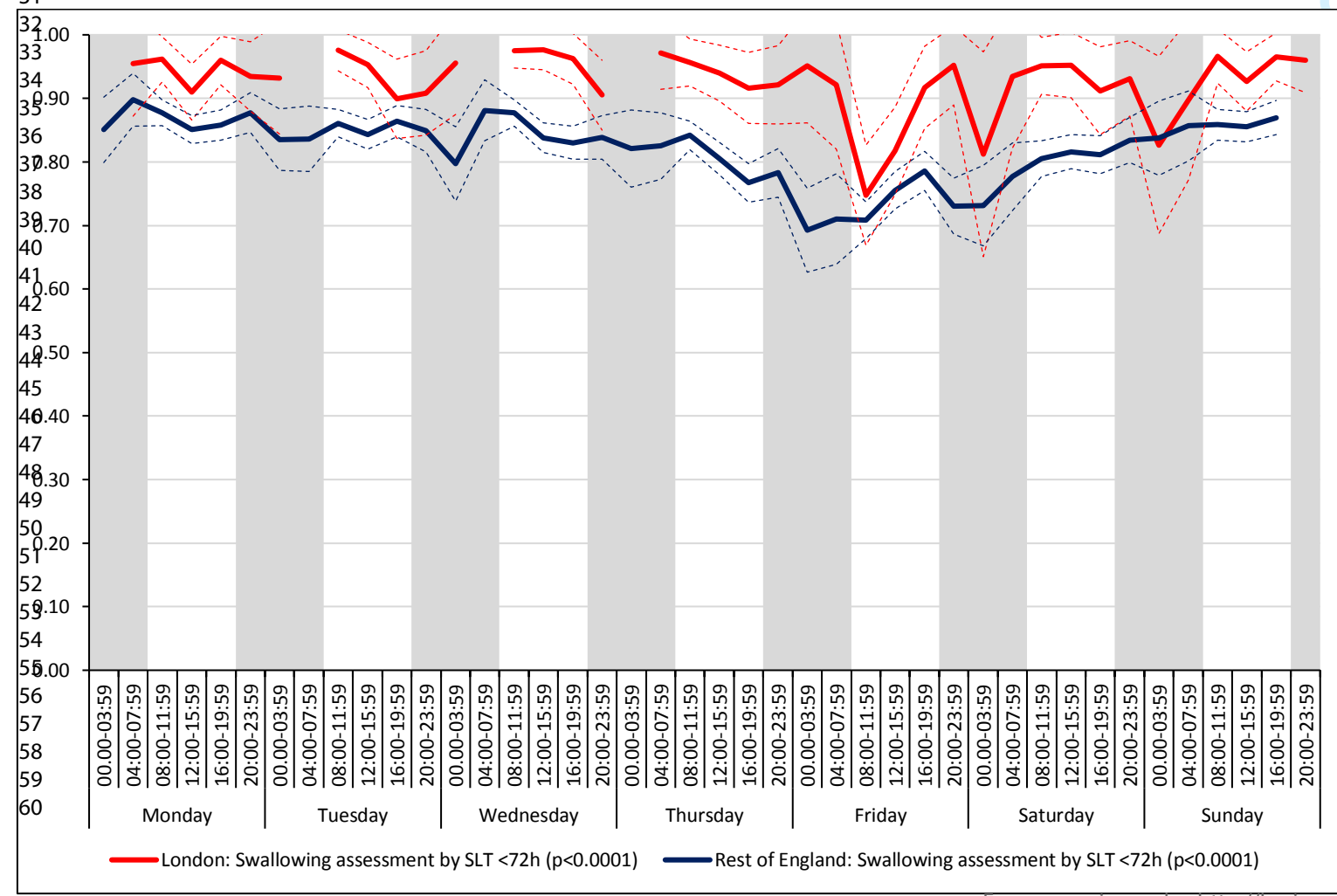


Figure S3(c). Swallow assessment by a SaLT within 72 hours

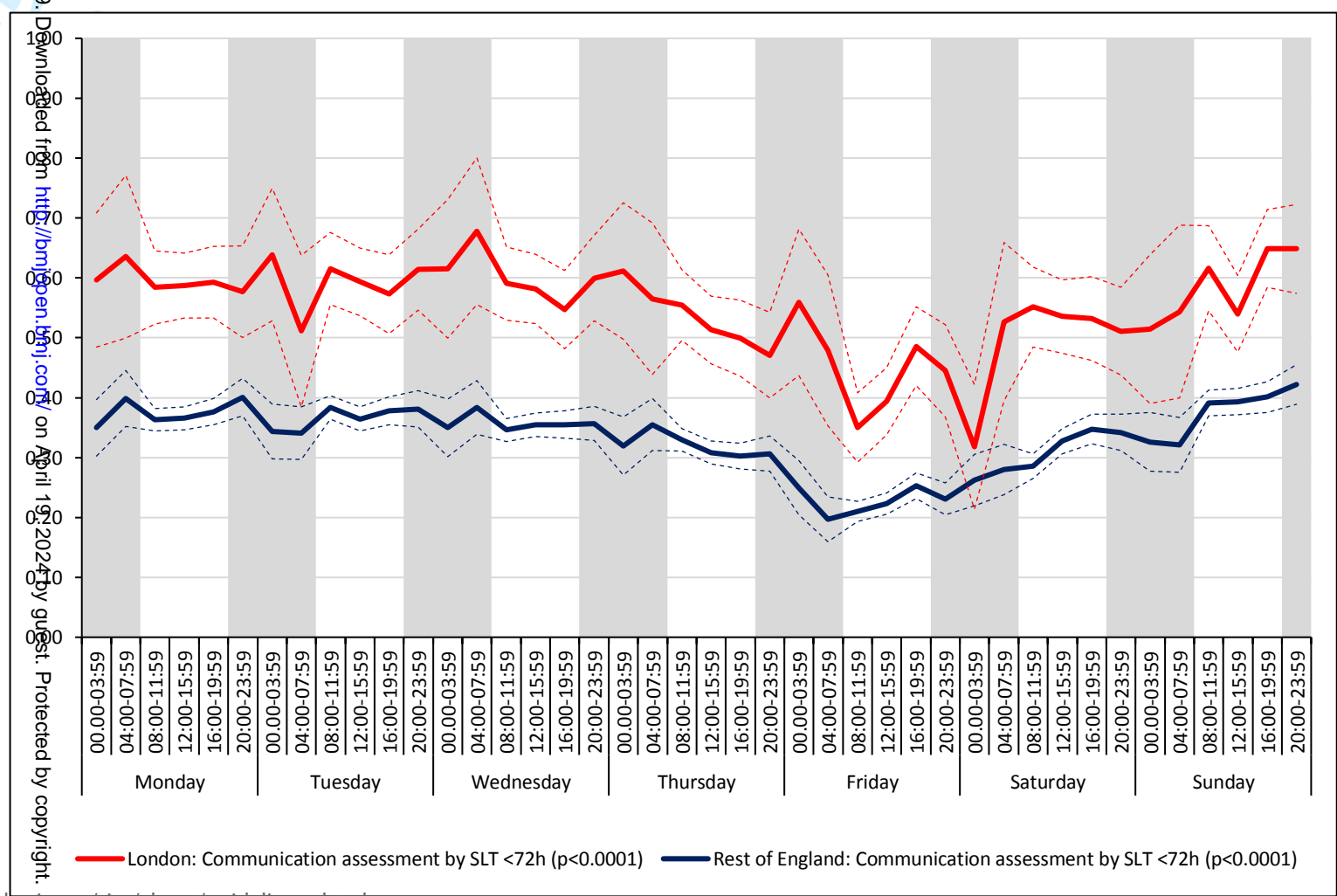


Figure S3(d). Communication assessment by a SaLT within 72 hours

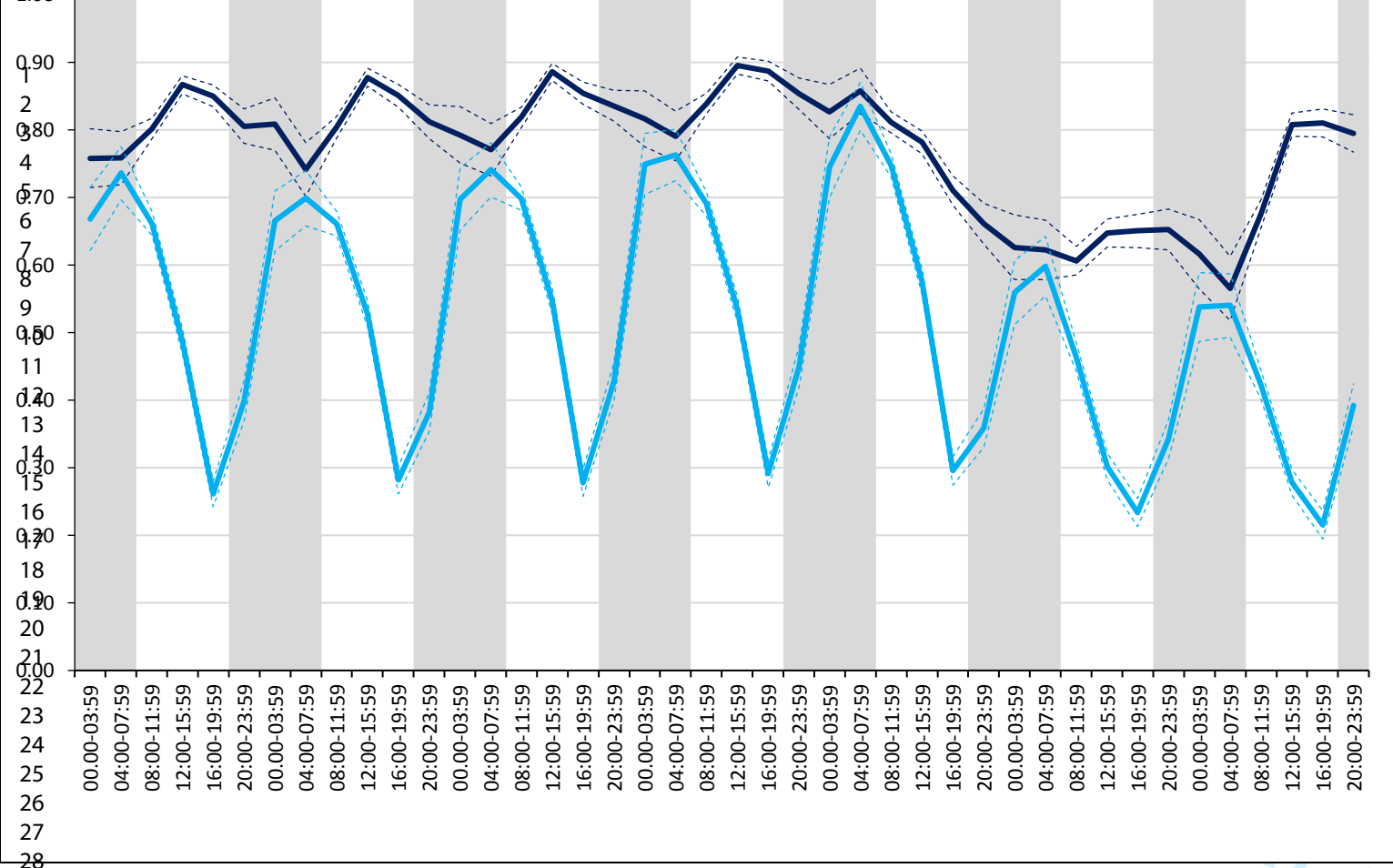


Figure S4(a). Assessment by a stroke consultant in Rest of England

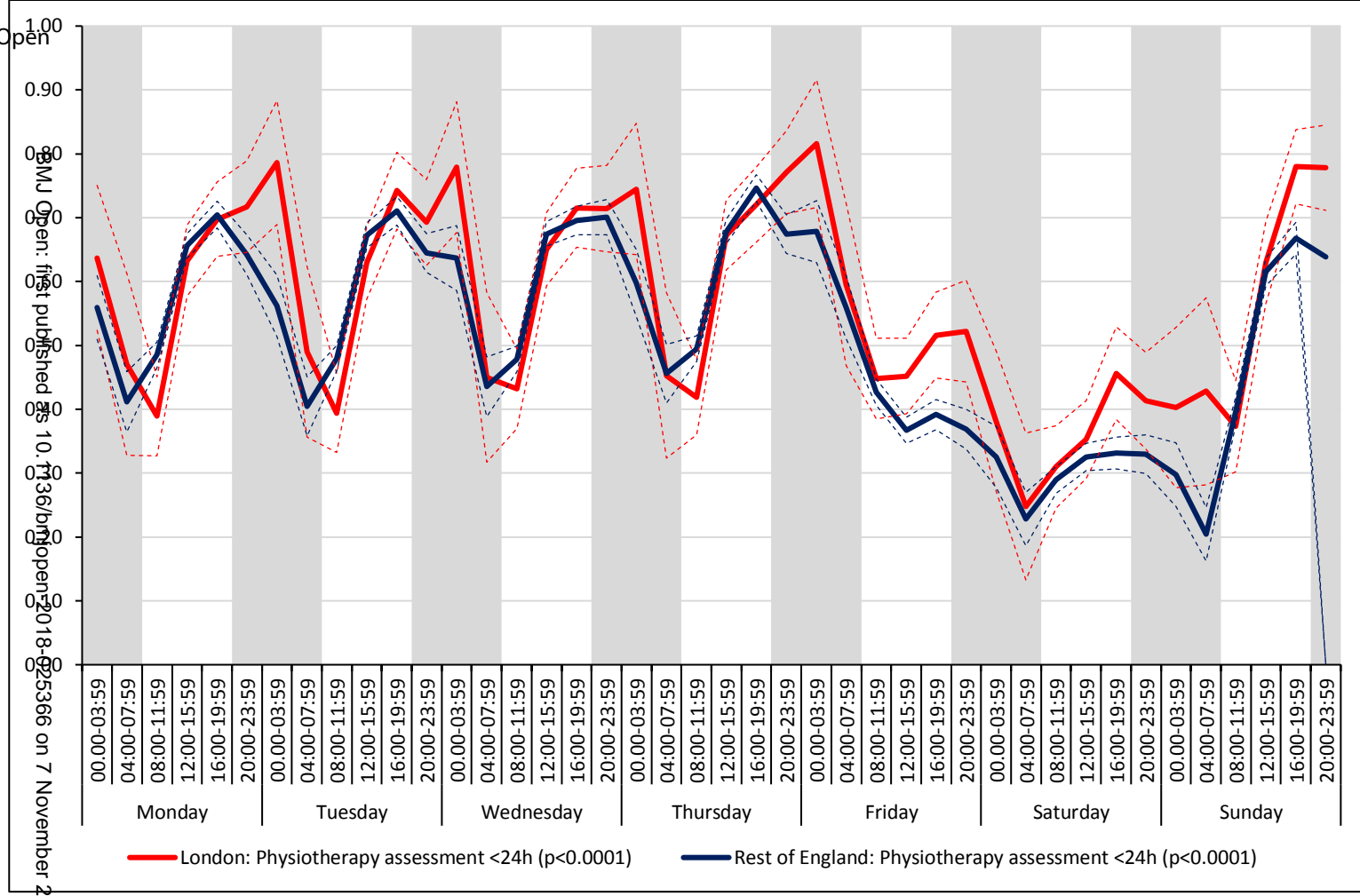


Figure S4(b). Physiotherapist assessment within 24 hours

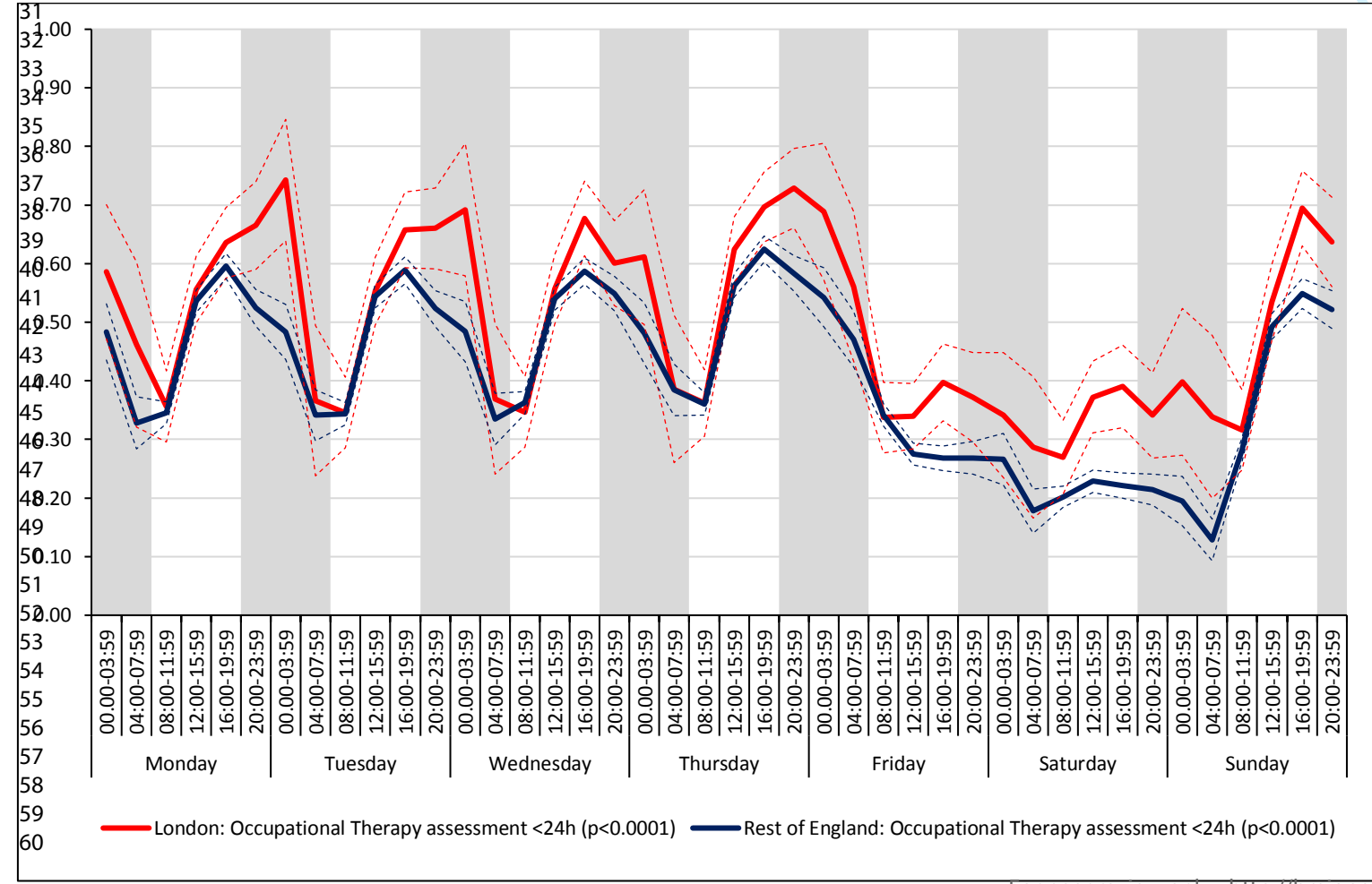


Figure S4(c). Occupational Therapist assessment within 24 hours

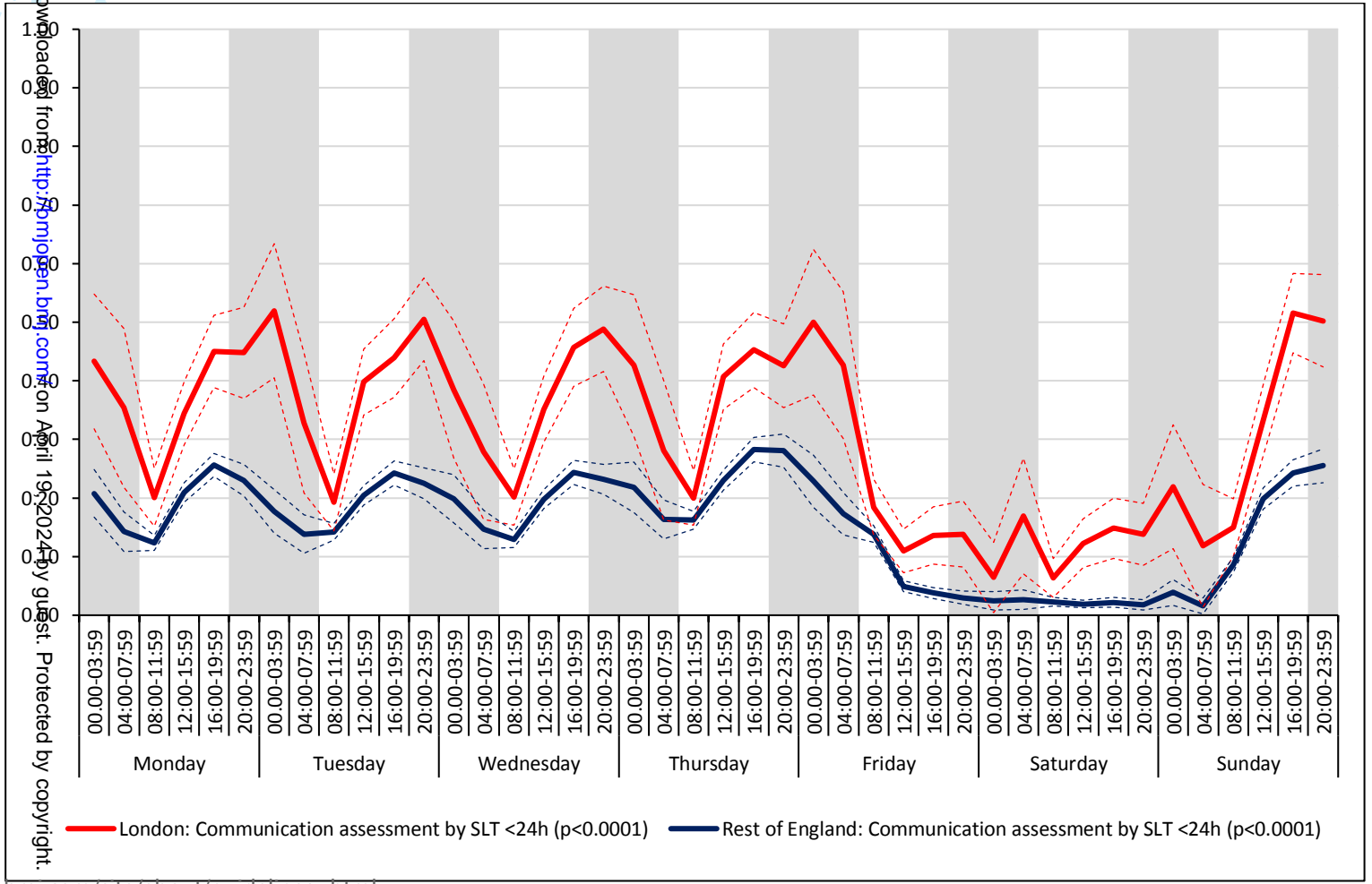


Figure S4(d). Communication assessment by a SaLT within 24 hours

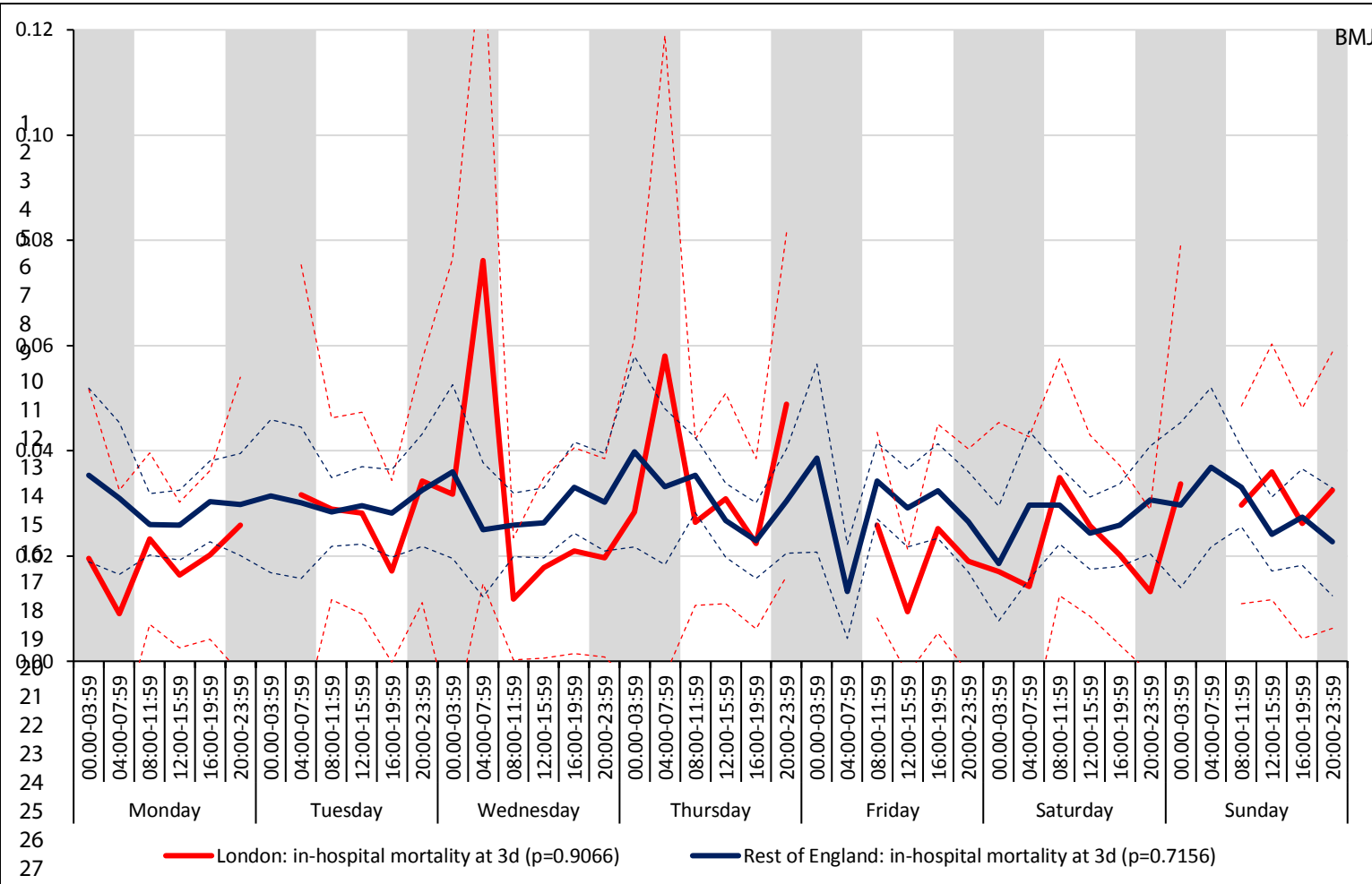


Figure S5(a). Mortality at three days

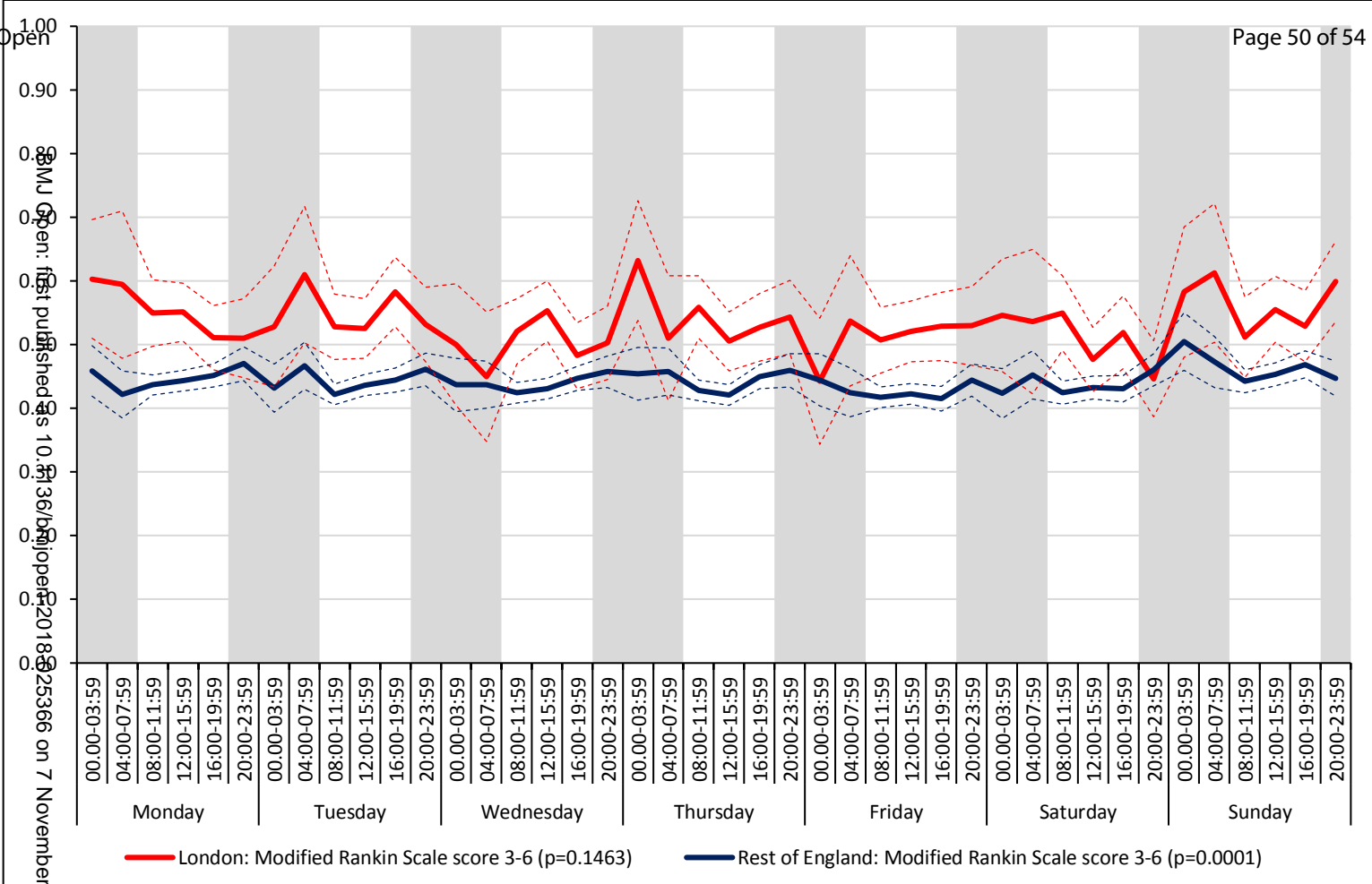


Figure S5(b). Modified Rankin Scale score 3-6

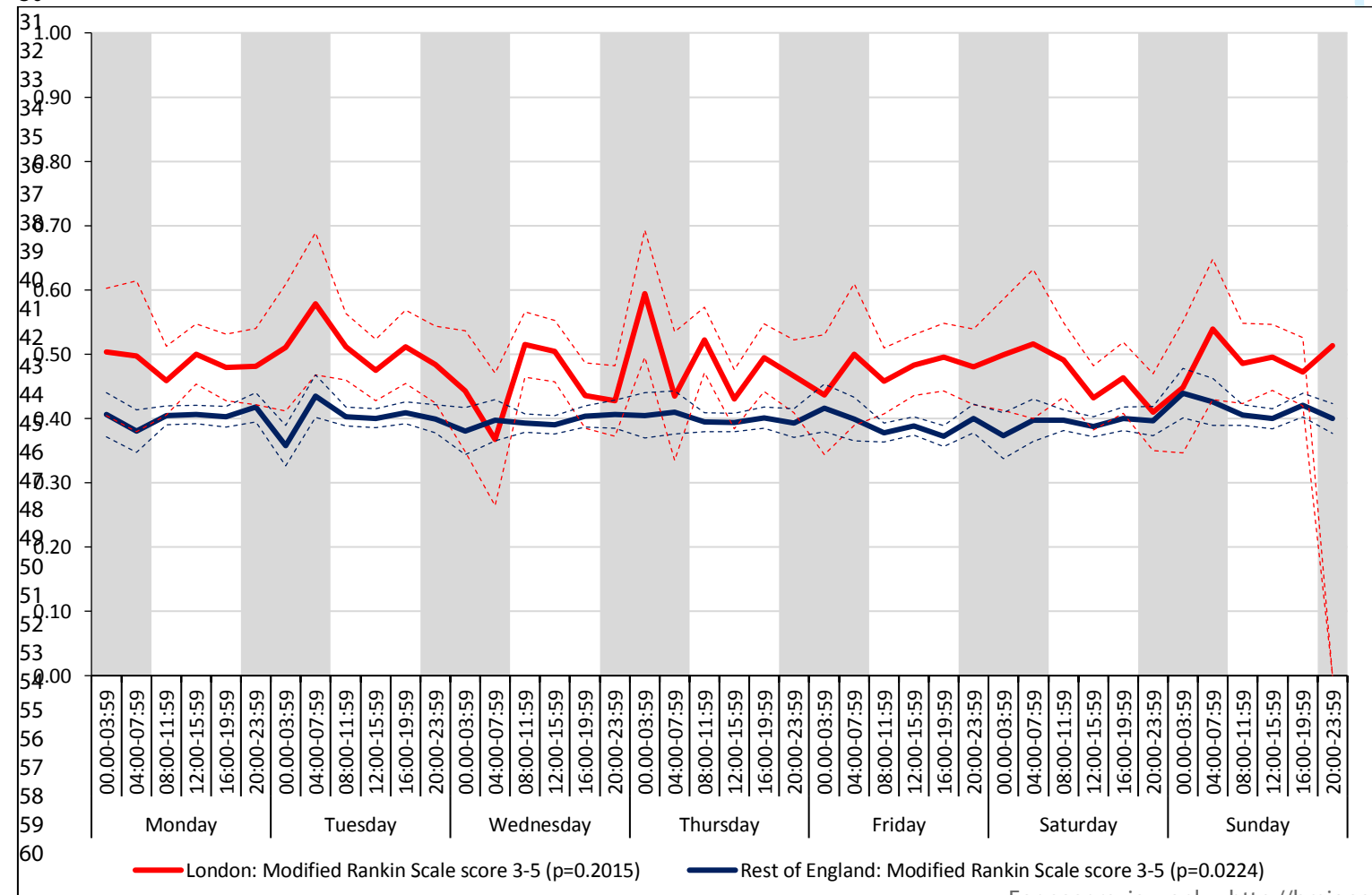


Figure S5(c). Modified Rankin Scale score 3-5

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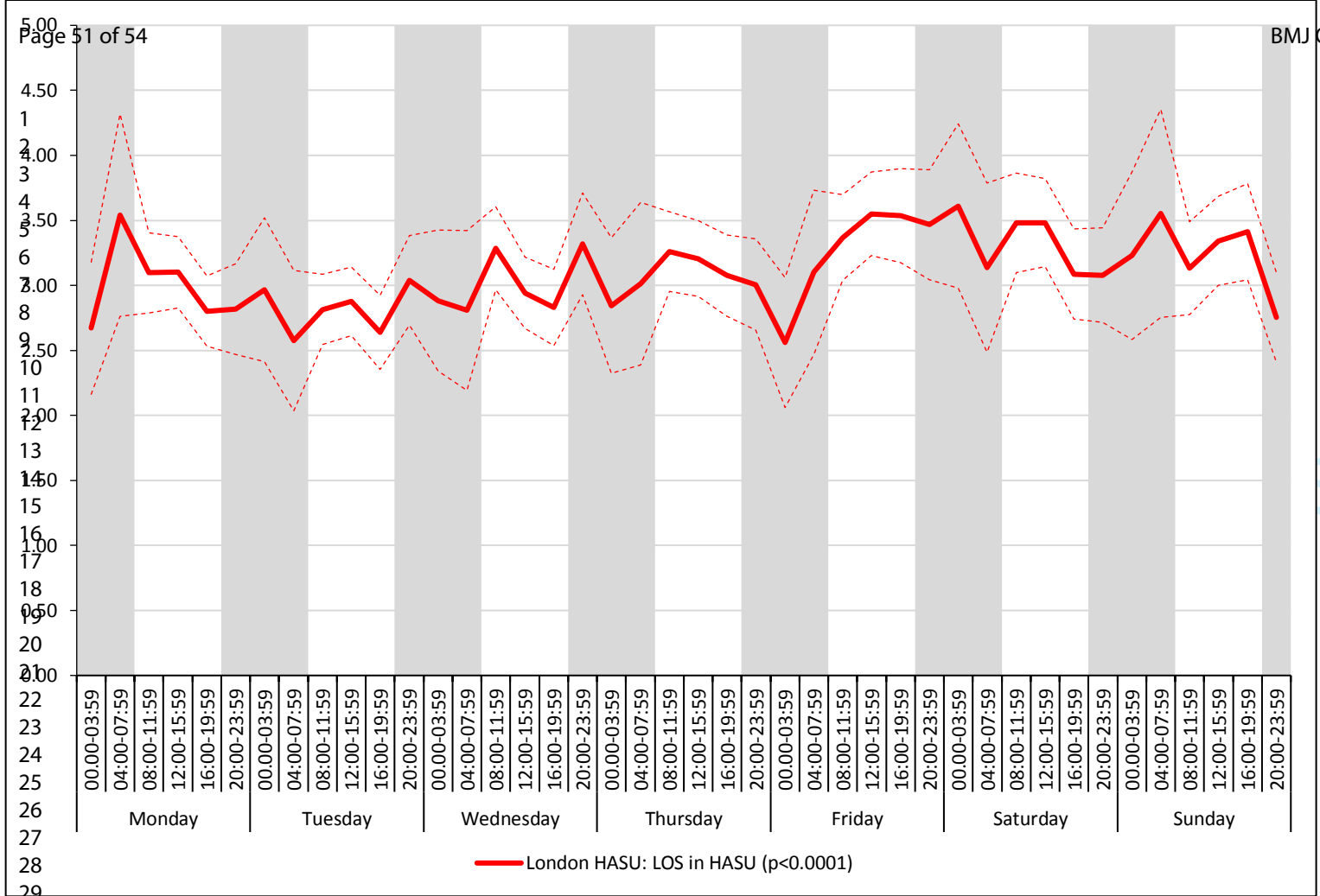


Figure S6(a). Length of stay in HASU

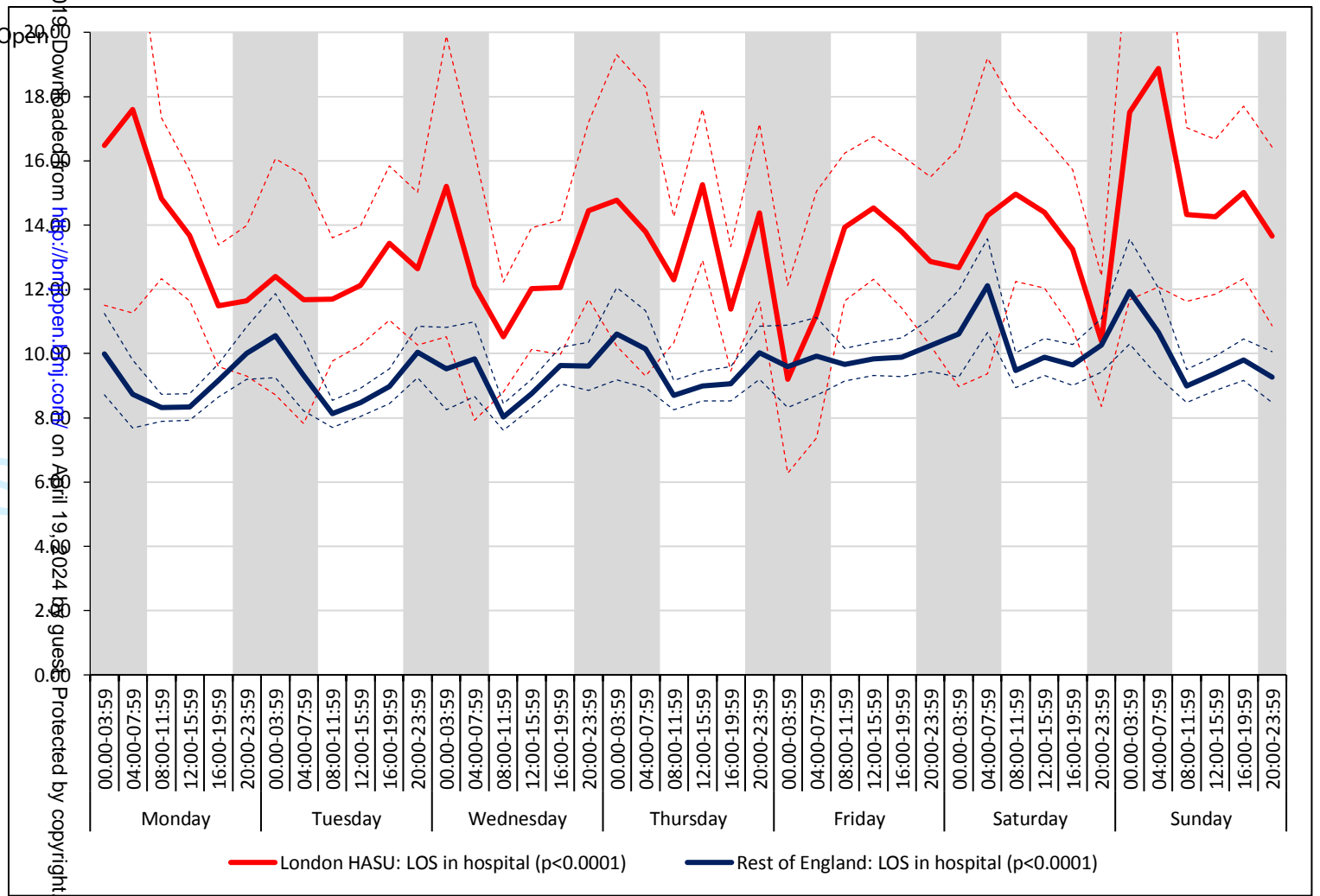


Figure S6(b). Length of stay in hospital

STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cohort studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(a) Indicate the study's design with a commonly used term in the title or the abstract	Title: P1; Abstract: P1-2
		(b) Provide in the abstract an informative and balanced summary of what was done and what was found	P1-2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	P3-4
Objectives	3	State specific objectives, including any prespecified hypotheses	P4, paragraph 3
Methods			
Study design	4	Present key elements of study design early in the paper	P4, paragraph 3; P5-6
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	P5, paragraph 1
Participants	6	(a) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up	P5, paragraph 1
		(b) For matched studies, give matching criteria and number of exposed and unexposed	Not applicable
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	P5, paragraph 2; P6, paragraphs 1-3; P7, paragraph 1
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	P5, paragraphs 1&2; P6, paragraphs 1&2
Bias	9	Describe any efforts to address potential sources of bias	P6, paragraph 3; P7, paragraph 1
Study size	10	Explain how the study size was arrived at	P5, paragraph 1; P6, paragraph 1
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	P5, paragraph 2 P6, paragraph 1-3; P7, paragraph 1

Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding	P6, paragraph 3; P7, paragraph 1
		(b) Describe any methods used to examine subgroups and interactions	Not applicable
		(c) Explain how missing data were addressed	Not applicable
		(d) If applicable, explain how loss to follow-up was addressed	Not applicable
		(e) Describe any sensitivity analyses	P7, paragraph 1; Supplementary Table 3
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	P8, paragraph 1; Supplementary Table 1
		(b) Give reasons for non-participation at each stage	Not applicable
		(c) Consider use of a flow diagram	Not applicable
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	P8, paragraph 1; Supplementary Table 1
		(b) Indicate number of participants with missing data for each variable of interest	Not applicable
		(c) Summarise follow-up time (eg, average and total amount)	Not applicable
Outcome data	15*	Report numbers of outcome events or summary measures over time	Supplementary Table 2
Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	Supplementary Table 2
		(b) Report category boundaries when continuous variables were categorized	Not applicable
		(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	Supplementary Table 2
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	Supplementary Table 3
Discussion			
Key results	18	Summarise key results with reference to study objectives	P11
Limitations			

Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	P12-13
Generalisability	21	Discuss the generalisability (external validity) of the study results	P13-15
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	P20, paragraph 1

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at <http://www.plosmedicine.org/>, Annals of Internal Medicine at <http://www.annals.org/>, and Epidemiology at <http://www.epidem.com/>). Information on the STROBE Initiative is available at www.strobe-statement.org.