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Investigating the association between inpatient stroke therapy and disability, destination on discharge, length of stay and mortality: a prospective cohort study using the Sentinel Stroke National Audit Programme

Matthew Gittins ,[1] David Gibran Lugo-Palacios,[2] Andy Vail,[1] Audrey Bowen ,[3] Lizz Paley,[4] Benjamin Bray,[5] Brenda Gannon,[6] Sarah Tyson[7]

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For numbered affiliations see end of article.

Correspondence to
Dr Matthew Gittins; Matthew.Gittins@manchester.ac.uk

ABSTRACT

Objective 'More is better' is a recognised mantra within stroke therapy, however, this has been developed in patients receiving long term rehabilitation. We investigated the relationship between amount of therapy received (from therapists and psychologists) and key patient outcomes during inpatient care.

Design A secondary analysis of data from a prospective cohort study was performed. Multilevel mixed models adjusting for measured confounders (eg, severity), explored the relationship between therapy dose (average minutes per day of stay) and outcomes (disability, length of stay, home at discharge and mortality). Therapy was explored using simple linear terms and flexible natural cubic splines to allow for more complex relationships.

Setting Data from the Sentinel Stroke National Audit Programme, covering England, Wales and Northern Ireland between July 2013 and July 2015 contained 94 905 adults with a stroke and still an inpatient after 72 hours. These patients received 92% (physiotherapy), 88% (occupational therapy), 57% (speech and language therapy) and 5% (clinical psychology), respectively.

Results The average amount of therapy, for individual and 'any' therapy combined per day of stay was low. Overall, 41% were discharged with an 'independent' modified Rankin Scale (≤2), 14% died, 44% were discharged home, and the median length of stay was 16 days. We observed complex relationships between amount of therapy received and outcomes. An additional minute of 'any' therapy, occupational therapy, speech and language therapy and clinical psychology was associated with improved outcomes. Conversely, more physiotherapy was also associated with lower mortality and shorter length of stay, but also lower independence and discharge home.

Conclusions Our findings suggest for stroke inpatients requiring therapy, 'More is better' may be overly simplistic. Strong limitations associated with analysis of routine data restrict further robust investigation of the therapy–response relationship. Robust prospective work is urgently needed to further investigate the relationships observed here.

Strengths and limitations of this study

- The Sentinel Stroke National Audit Programme is a large dataset representing real-world events within a stroke patients experience of hospital care.
- Patients are representative of those admitted to hospital with acute stroke in England, Wales and Northern Ireland, with approximately 95% of patients who had a stroke included in the data.
- Study employs flexible modelling techniques to explores the commonly assumed linear association between the amount of therapy received by stroke inpatients and key outcomes (disability, length of stay, home destination at discharge and inpatient mortality).
- Limitations are present in that the data is focused on recording care process information and not patient care in detail.
- Only limited organisational level data were available, including resources such as staffing levels.

INTRODUCTION

Stroke is estimated to be the second leading cause of death and the third leading cause of disability worldwide.[1 2] Factors including, improvements in healthcare, increased incidence rates due to lifestyle factors and changes in population make up, mean the incidence of stroke and prevalence of patients with stroke disability are rising despite relative rates decreasing.[3] A fundamental element of any stroke care is therapy (eg, physiotherapy (PT), occupational therapy (OT), speech and language therapy (SLT) and clinical psychology). There is substantial evidence that stroke therapy is effective but it is thought that it needs to be provided intensively.[4–7] However, most studies investigating the relationship between the amount of therapy and outcomes have involved subacute or long-term community-based rehabilitation and small sample sizes.[8]

The National Clinical Guideline for Stroke in England, Wales and Northern Ireland provides recommendations for stroke care throughout the patients pathway including acute and postacute care. The guidelines recommend 'People with stroke should accumulate at least 45 min of each appropriate therapy every day, at a frequency that enables them to meet their rehabilitation goals, and for as long as they are willing and capable of participating and showing measurable benefit from therapy.' [9] The belief that 'more is better' has long been accepted in stroke care, particularly for PT.[7,10] However, most studies investigating the relationship between therapy intensity and outcomes have involved the subacute or chronic stages of stroke, often within the community and involving small sample sizes. Moreover, these recommendations have been proposed for individual therapy types, with little research currently confirming the individual therapy–outcome relationship in patients who had a acute care stroke. An improved understanding of patient outcomes in those identified as requiring each therapy, should help to improve stroke care. The Stroke Sentinel National Audit Programme (SSNAP)[9,11,12] collects data on approximately 80 000 patients who had a stroke per year in England, Wales, and Northern Ireland. Patient information is recorded at hospital admission, during in patient care and outcomes at discharge. It also records the available facilities, staffing levels and protocols in biennial audits of organisations providing acute and postacute care carried out every 2 years.[13,14]

The aim of this study was to use national stroke audit data to explore the association and shape of association between the amount of therapy during inpatient stroke care and key reported patient outcomes of disability, destination on discharge, length of inpatient stay and inpatient mortality.

METHODS

Anonymised patient data were obtained from the Sentinel Stroke National Audit Programme (SSNAP); with the approval of the Healthcare Quality Improvement Partnership (www.hqip.org.uk). Access to the raw data source was not possible, however the SSNAP analysis team were available to provide further interpretation and guidance to any data queries. The data request included all adults (>18 years) admitted to hospital with stroke between July 2013 and July 2015. To focus on the stroke population most likely to need and receive therapy, we excluded patients with a length of stay of less than 72 hours post admission to hospital. This removed those patients who did not receive inpatient therapy due to a very mild stroke or Transient Ischaemic Attack (TIA), or due to very severe strokes that required palliative care. Data from the 2014 acute organisational level audit containing trust level information (eg, staffing availability) were also matched to the patient data based on a codebook provided by SSNAP.[13,14] Further details on data collection, inclusion/exclusion criteria, formatting and analysis can be found in the main report.[15]

During inpatient care patients may move between two or more stroke units. This may result in multiple entries per patient where a patient may have moved from a hyper-acute or acute unit to a rehabilitation focused unit. The primary outcome of interest was 'disability on discharge' from each inpatient stroke care team measured using the modified Rankin Scale (mRS).[16] Secondary outcomes included length of inpatient stay (days), destination at discharge (home or residential care vs other), and inpatient mortality. In each case, the appropriate regression model (logistic, ordinal or negative binomial) was adopted for each outcome. SSNAP data on therapy received by patients included 'total number of days with therapy', and 'total number of minutes of therapy received' during each stroke unit stay for four stroke therapies (PT, OT, SLT and clinical psychology). We repeated each model for each therapy type individually. For each type, therapy was represented as the average amount of therapy per day of inpatient stay (total minutes of therapy/length of inpatient stay). This was deemed to be the most suitable representation of the amount of therapy experienced during the entire care period and less subject to reporter bias than the reported average duration of therapy session (total minutes of therapy/total days of treatment). The average therapy per day of stay was initially included as a linear therapy dose–response term to represent a simple 1 min increase in average therapy per day of stay relationship with outcome. To explore the potential for the influence of selection bias when modelling individual therapies, and the potential for more complex associations than a simple linear term (eg, a non-linear relationship). An exploratory analysis first including total of any therapy, that is, time associated with all four therapies combined adjusted for therapy received, and second using natural cubic splines to more flexibly represent the therapy dose–response relationship than a straight line.[17] Here the range of average therapy per day of stay was split into multiple regions, within which individual cubic polynomial functions were fitted that flexibly represent the change in outcome as therapy increased within the region. These cubic polynomials are further constrained to smoothly connect at the predefined locations or knot points connecting the regions and constrained to fit linear functions in the two extreme regions. To allow an adequate amount of flexibility 5 knot points were chosen and positioned at equally spaced percentiles as recommended by Harrell in 2001 (5%, 27.5%, 50%, 72.5% and 95%).[18] This corresponded to knot point positions consistent for each therapy at approximately 2.1, 7.7, 13.2, 20 and 36 min per day of stay. The point estimates and corresponding 95% CIs across the average therapy/day of stay were extracted and plotted.

To account for the hierarchical structure of the data with patients clustered within stroke teams, a multilevel mixed effects models with robust SEs accounted for the lack of independence between patients entries.[19] To account for as much measured confounding as possible a set of covariates was identified a priori by the study team. The full list of covariates and their individual structure are reported in online supplemental tables 1–4. These included available factors relating to patient demographics (age, gender, sociodeprivation, etc), admission characteristics (day of week, time of day, received thrombolysis, etc), clinical characteristics (premorbid mRS), stroke characteristics (including, stroke type, stroke severity and stroke impairment type on admission derived from the National Institute of Health Stroke Scale (NIHSS),[20 21] and organisational characteristics (eg, some staffing level information). Effect estimates (Odds/Rate Ratios) and associated 95% CIs were reported for a unit increase (ie, per minute) in average amount of therapy per day of stay when modelled as a linear term. Analysis was performed using Stata V.15.[22]

Patient and public involvement

The development and design of this project was supported by members of the patient and public involvement (PPI) panel of the University of Manchester's Stroke Research Centre. The panel consists of 30 plus stroke survivors (of all ages, types, and severity) and their families/carers who provide a PPI perspective for stroke research in Manchester. It was founded by the NW Stroke Research Network and further lead by the University of Manchester Stroke Research Group.

RESULTS

Between July 2013 and July 2015, 149 560 patients who were admitted to hospital with a stroke were recorded in the SSNAP clinical audit. Of the initial sample 41 706 were excluded due to length of stay less than 3 days. Investigation of the data found 12 949 patients had NIHSS Level of Consciousness on admission recorded as zero (ie, 'alert') but all other NIHSS items were incomplete. These patients were excluded as they were thought to be a distinct subgroup atypical to those in stroke care. Full details of the 94 905 patients who met the inclusion criteria can be found in table 1 and previous work.[15 23]

Nearly all patients required PT or OT (92% and 88%, respectively), whereas SLT was required by 57%, and only 4.7% were considered to need clinical psychology (table 2). The median duration of an individual therapy session was 34.5 (PT), 40 (OT), 31.3 (SLT) and 42 (clinical psychology) minutes, however, the average minutes of therapy per day of inpatient stay was much lower; 13.8, 12.9, 6.7 and 1.9 min for physical, occupational and speech therapy, and psychology, respectively (table 2) indicating that patients received therapy infrequently. During inpatient care, 14% of patients died after surviving the initial 72 hours after admission (table 1), 44% were discharged home and 13.4% to residential care (table 1). The median length of inpatient stay was 16.1 days and at discharge from hospital, 41% were considered independent (mRS ≤2).

Table 3 reports effect estimates (and 95% CIs) associated with each outcome where therapy per day of stay was modelled as a simple linear term. With respect to each therapy, an additional minute per day of inpatient stay was associated with lower odds of dying, and a shorter length of stay. PT was associated with 3% lower odds of dying per minute, 12% for OT, 6% for SLT and 16% for psychology. Correspondingly length of stay was also associated with 1%, 2%, 3% and 7% shorter lengths of stay for each therapy type, respectively.

For disability and destination on discharge, each additional average minute of OT, SLT and psychology per day of inpatient stay was associated with 2%–5% lower odds of increased disability at discharge and 0.4%–3% higher odds of being discharged home. However, an additional average minute of PT per day of stay was associated with 1% increased odds of increased disability at discharge (OR (95% CI)=1.009 (1.008 to 1.010)) and 1% decreased odds of being discharged home. Additional analysis, exploring total of any therapy per day of stay (ie, all four therapies combined), indicated an association with improved disability at discharge, a reduced length of stay, and reduced odds of mortality. The complete multilevel models for all four health outcomes, the main predictor and the a priori identified covariates can be found in online supplemental tables 1–5.

Modelling therapy per day of inpatient stay using natural cubic splines indicated similar patterns of association between outcomes and OT, SLT and psychology, with more therapy associated with improved outcome. The change in OR associated with ordinal mRS and increased minutes of therapy per day of inpatient stay can be found in figure 1 for PT, OT, SLT and clinical psychology. OT and SLT represented a steep slope up to approximately 10 min per day of stay before a gradual incline implying more gradual improvements. A similar result was observed for psychology, however, wide CIs due to limited sample size highlight the potential variability in the true effect. PT was represented with a similarly steep slope for each additional minute up to 8–10 min, before the odds of increased disability begins to decline. At approximately 35 min, the estimated effect crosses the axis, implying higher odds of increased disability than receiving no PT. Patterns of association for each therapy with the other outcomes are presented in online supplemental figure 1–3. The association between PT and home discharge shows a similar pattern to disability. Additional amounts of PT however, showed a consistent but gradual reduction in length of stay and the odds of dying. Figure 2 represents the change in disability, mortality, discharge home and length of inpatient stay as 'any' therapy (ie, all four combined) increases per min per day of stay. As noted, with the simple linear term, 'any' therapy increases were also associated with reduced disability, reduced mortality and reduced length of stay within the first 15 min before a more gradual improvement. Whereas home on discharge

Table 1 Patient characteristics at admission and outcomes at discharge, split by need for each therapy

Study characteristics at admission		Physiotherapy	Occupational therapy	Speech and language therapy	Clinical psychology	Total
Age mean (SD)		76.2 (13.0)	76 (13.1)	77.2 (12.8)	73.1 (13.7)	76 (13.2)
		Freq (row%)				Freq (col%)
Gender	Women	45524 (92.5)	43188 (87.8)	28665 (58.3)	2245 (4.6)	49199 (51.8)
Ethnicity	Asian (inc Chinese)	2435 (91.2)	2354 (88.2)	1482 (55.5)	96 (3.6)	2669 (2.8)
	Black	1220 (89.4)	1213 (88.9)	835 (61.2)	72 (5.3)	1365 (1.4)
	Mixed	263 (89.5)	256 (87.1)	144 (49.0)	20 (6.8)	294 (0.3)
	Unknown	4194 (90.8)	4026 (87.1)	2582 (55.9)	252 (5.5)	4620 (4.8)
	Other	1027 (90.0)	996 (87.3)	654 (57.3)	47 (4.1)	1141 (1.2)
	White	78422 (92.5)	74730 (88.1)	48371 (57.0)	3979 (4.7)	84816 (89.0)
Stroke severity (NIHSS on admission)	Mild (<5)	33099 (91.0)	32582 (89.6)	14240 (39.1)	1476 (4.1)	36376 (38.3)
	Moderate (5–14)	35578 (94.8)	34190 (91.1)	24190 (64.5)	2045 (5.4)	37527 (40.0)
	Severe (15–20)	9668 (92.0)	8794 (83.7)	8048 (76.6)	544 (5.2)	10505 (11.1)
	Very Severe (>20)	9221 (87.8)	8009 (76.3)	7590 (72.3)	401 (3.8)	10497 (11.1)
Co-morbidities	Previous stroke/TIA	24583 (92.8)	23164 (87.4)	15558 (58.7)	1189 (4.5%)	26496 (27.9%)
	Diabetes	18018 (92.8)	17193 (88.6)	10834 (55.8)	896 (4.6)	19414 (20.5)
	Atrial fibrillation	19750 (92.5)	18538 (86.8)	13430 (62.9)	879 (4.1)	21352 (22.5)
	Hypertension	48635 (92.8)	46476 (88.7)	30233 (57.7)	2392 (4.6)	52400 (55.2)
	Congestive heart failure	5350 (94.0)	4883 (85.8)	3391 (59.6)	246 (4.3)	5690 (6.0)
Stroke type	Infarction	77662 (91.6)	74972 (88.5)	48199 (56.9)	3848 (4.5)	84747 (89.3)
	Intracerebral haemorrhage	9200 (90.6)	8603 (84.7)	5869 (57.8)	618 (6.1)	10158 (10.7)
Sociodeprivation (IMD home postcode ranking)	1 (least)	20327 (92.7)	19380 (88.4)	12414 (56.6)	972 (4.4)	21922 (21.1)
	2	20586 (92.0)	19733 (88.2)	12767 (57.1)	958 (4.3)	22377 (23.6)
	3	20864 (92.6)	19927 (88.4)	13148 (58.3)	1021 (4.5)	22535 (23.7)
	4 (most)	18859 (92.0)	18094 (88.3)	11769 (57.4)	1155 (5.6)	20494 (21.6)
	Missing	6925 (91.4)	6441 (85.0)	3970 (52.4)	360 (4.8)	7577 (7.9)
Health outcomes at inpatient discharge		Freq (row%)				Freq (col%)
Disability status	Indep (mRS ≤2)	35356 (90.5)	35037 (89.7)	16687 (42.7)	1361 (3.5)	39 050 (41.1)
	Depen (mRS >2)	52205 (93.5)	48538 (86.9)	37381 (66.9)	3105 (5.6)	55855 (58.9)
Mortality		11002 (83.6)	8926 (67.8)	8344 (63.4)	225 (1.7)	13156 (13.9)
Discharge to residential car		12123 (95.5)	11227 (88.5)	9412 (74.2)	832 (6.6)	12690 (13.4)
Discharge home		37902 (91.6)	37302 (90.1)	19989 (48.3)	1939 (4.7)	41383 (43.6)
Length of inpatient stay (Med (IQR) days)		14.5 (7,36)	14.6 (7,36)	20.5 (9,45)	35.8 (15,64)	16.1 (9,40)
Total		87561	83575	54068	4466	94905

IMD, Index of Multiple Deprivation; mRS, modified Rankin Scale; NIHSS, National Institute of Health Stroke Scale; TIA, Transient Ischaemic Attack.

also improved, it was more gradual over 20–25 min before little to no improvement was observed.

DISCUSSION

This observational study of routinely collected consecutive stroke admissions described the amount of therapy typically received during inpatient stroke care in England, Wales and Northern Ireland. As reported elsewhere[12] we found that the amount of each therapy, and total combined 'any' therapy, provided per day of stay was lower than that recommended in national clinical guidelines.[24 25] Focusing on those in the acute care period, treatment sessions were recorded as being both shorter than recommended but also less frequent. For each individual therapy, and for 'any' therapy, increasing the average amount per day of stay was associated with reduced odds of mortality and shorter length of inpatient stay. When the amount of 'any' therapy, or separately the individual therapies OT, SLT, and psychology were increased an association was observed indicating a lower odds of increased disability at discharge and increased odds of being discharged home. However, each relationship observed was more complex

Table 2 Description of therapy provided during inpatient stay

	Physiotherapy	Occupational therapy	Speech and language therapy	Clinical psychology	Total 'any' therapy
No patients who required each therapy (total 94 05)*	87 561 (92%)	83 575 (88%)	54 068 (57%)	4466 (4.7%)	90 435 (95%)
No admission entries with therapy (total 115 247)†	106 294 (92%)	102 001 (89%)	67 314 (58%)	7697 (6.7%)	109 889 (95%)
	Median (IQR)				
No of days patients received therapy	5 (2–11)	4 (2–8)	3 (1–7)	1 (1–2)	‡
Percent days of stay which patients received therapy	40 (24–57)	31 (17–50)	12 (21–33)	5 (2–10)	‡
Average therapy received (min/ day of stay)	13.8 (7.5–21.7)	12.9 (6.8–21.1)	6.7 (3.3–12.3)	1.9 (0.6–4.5)	30(17–46)
Average duration of therapy session (min/session)	34.5 (26.6–45.0)	40 (30–49.8)	31.3 (23.3–44.4)	42 (30–53.6)	37(30–45)

*Number of patients who are identified to require each therapy at admission.
†Number of stroke unit admissions where therapy are reported (note multiple stroke unit admission per individual patients who had a stroke).
‡Not available, due to data collected for each therapy individually determining total no days and percentage days of stay, without overlap (ie, pt and ot on same day) not possible,.

than a simple linear 'more is better' relationship. This was particularly evident in the association between inpatient PT and both patient follow-up disability level, and home destination at discharge. The complex association found here between PT and both disability on discharge and whether they were discharged home was unexpected and difficult to explain. Data available in SSNAP were a simple aggregated measure of minutes of therapy received and number of days at each stroke team, therefore, we were unable to comment on which days within the inpatient period patients received therapy, the content or structure of the therapy provided, or any indirect patient contact (such as arranging discharge or home visits).

Interpretation of the associations presented here between therapy and inpatient outcomes needs to be performed with caution. These results do not indicate that therapists only need provide 5–10 min of PT/day of stay for maximum benefit, nor will providing more than 35 min be harmful. They do, however, suggest that 'the more therapy, the better' may be an oversimplification. A similar conclusion was drawn from the AVERT study, a randomised clinical trial which found early mobilisation of patients within the first 24 hours of their stroke could be detrimental.[26] We should be cautious to comparing these studies. However, the majority of research looking into therapy effects have been done in the subacute and chronic stages of poststroke care, whereas AVERT and this study were performed in patients acute stages of poststroke care. A greater proportion of patients who had a stroke receive PT for a greater proportion of their hospital stay. Physiotherapists may be more likely to treat the subgroup of patients for whom large doses of therapy are not beneficial, or have a floor or ceiling effect on the mRS. This may be supported by the indication that an increase in the amount of psychology per day of stay is associated with implausibly large improvements in outcome. Patients receiving psychology could be considered to be a casemix which is the 'opposite end of the scale' to PT. Very few stroke survivors receive psychology and those who do, often receive small amounts and usually relatively late in their rehabilitation. The unexpected findings associated with PT dose may, therefore, be an artefact, connected to a different casemix. The analyses performed here were adjusted for all known and measured confounders, the proportion of patients receiving PT was large, and results robust to different methods of analysis including linear and cubic splines. The same analytical methods applied to the other individual therapies, including 'any' therapy, resulted in associations thought to be reliable.

Limitations

Though we have employed a large, representative, real-world data set there are several limitations that should be acknowledged when interpreting these results. This is an observational records-based dataset with an exploratory analysis in addition to that preplanned. At no point should causality be inferred. The accuracy and reliability of the data, particularly the amount of therapy per day of stay, may be subject to reporter bias and has previously been thought to be overestimated.[26] We were limited to the information recorded in SSNAP and steps taken to protect patient confidentiality meant not all SSNAP data were available to us. We are unable to comment on the structure or content of the therapy provided; whether patients received more than one treatment session per day; when the therapy was received poststroke; or whether the number or order of therapies per day had any assoication with outcomes. Furthermore, the amount of therapy recorded is that provided by therapists, rather than that received by the patient. One concern raised is that a patient who received 1 hour of joint therapy from three different therapists working together may have

Table 3 The association between the average amount therapy/day of stay (minutes/day) and mortality, discharge destination and length of inpatient stay

Health outcome at discharge	Physiotherapy	Occ therapy	SLT	Clinical psyc	Total 'any' Therapy
Disability mRS (OR (95% CI))	1.009 (1.008 to 1.010)	0.979 (0.978 to 0.980)	0.975 (0.974 to 0.977)	0.945 (0.934 to 0.955)	0.995 (0.994 to 0.995)
Home destination on discharge (OR (95% CI))*	0.985 (0.984 to 0.986)	1.015 (1.013 to 1.017)	1.004 (1.002 to 1.007)	1.026 (1.011 to 1.041)	1.000 (0.999 to 1.001)
Mortality (OR (95% CI))*	0.975 (0.972 to 0.978)	0.883 (0.879 to 0.887)	0.945 (0.940 to 0.950)	0.843 (0.786 to 0.904)	0.966 (0.964 to 0.967)
Length of inpatient stay (RR (95% CI))*	0.994 (0.994 to 0.995)	0.981 (0.982 to 0.982)	0.971 (0.969 to 0.972)	0.932 (0.928 to 0.936)	0.990 (0.989 to 0.990)

Note, all models fully adjusted for all known and measured confounding factors in a multilevel mixed effects regression model, total 'any' therapy included further indicators for therapy received.
*OR as produced by ordinal and binary logisitic regression models, RR as produced from the negative binomial model.
mRS, modified Rankin Scale; OR, Odds Ratio; RR, rate ratio; SLT, speech and language therapy.

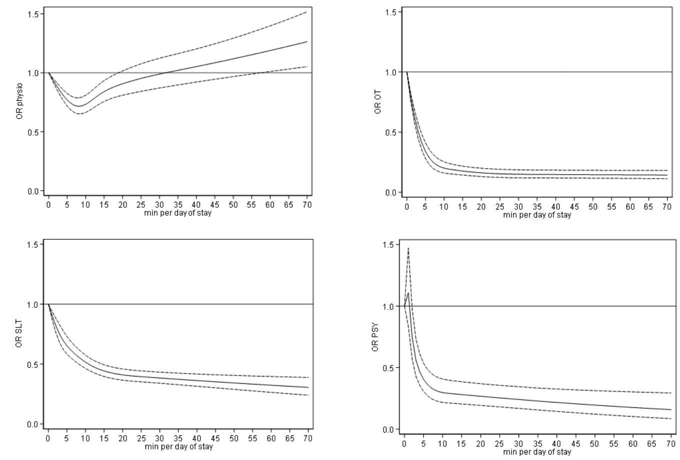

Figure 1 Cubic splines describing the Odds Ratio (95% CI) for disability on discharge per minute therapy/day of inpatient stay (referenced to zero). Top left to bottom right=physiotherapy; occupational therapy (OT); speech and language therapy (SLT); psychology (PSY).

been recorded as having 3 hours of therapy in SSNAP. We wonder whether this contributed to the unexpected findings for PT where more severely impaired patients might require multiple therapists to treat them.

The primary outcome (mRS) is a crude measure of disability for such a complex condition and is thought to contain strong interobserver variability.[26] Furthermore, the baseline measure of stroke severity (the NIHSS) was one of the few clinical measurements to contain missing data. We accounted for this by creating a categorical variable based on consciousness level and the other reported items which was clinically meaningful but crude and may have contributed to residual confounding. Further missing data techniques were considered however we were concerned that techniques such as a multiple imputation procedure would only increase bias in the results as we could not plausibly consider the missing

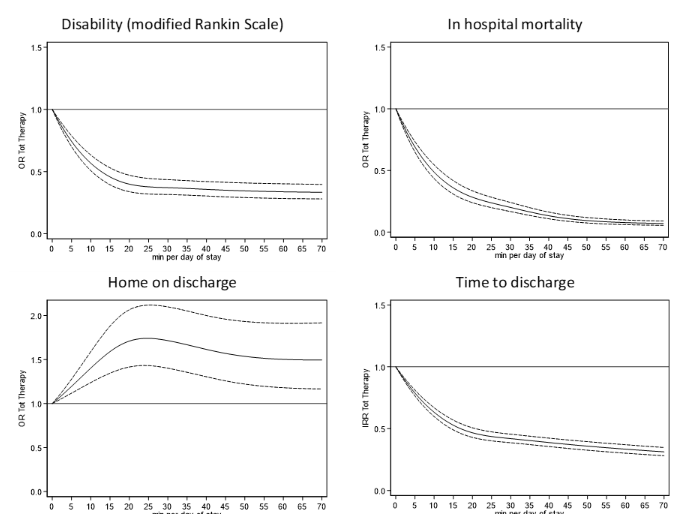

Figure 2 Cubic splines describing Odds Ratio (OR) assoicated with disability on discharge, in hospital mortality, and home on discharge, and Incidence Rate Ratio (IRR) assoicated with length of inpatient stay against per minute 'any' therapy/day of inpatient stay (referenced to zero).

data to be Missing at Random.[27] We were also unable to include day to day changes in stroke severity/disability in our analyses as these data are not collected by SSNAP. This is thought to be a particular problem in patients with 'mild' stroke who nonetheless stay in hospital for 3 days or more. These factors, plus the inconsistency between different methods of measuring severity, and the need to categorise the continuous NIHSS measure are all likely to contribute to the presence of residual confounding. It is also likely that other, unmeasured confounding factors were present, specifically (but not exclusively) at the organisational level where limited relevant information was available regarding the stroke team and patients. To some extent these unmeasured organisational characteristics were accounted for by the random effects portion of the mixed model, however, residual confounding may persist.

CONCLUSION

Carefully increasing the amount of therapy received per day of stay may improve inpatient outcomes, however, the magnitude of the benefit may be small. More complex relationships than might have been expected were observed between therapy and inpatient outcomes. The reason for these findings is unclear. Given the limitations of the data available, which was collected routinely and so not designed a priori to answer these questions, we strongly recommend caution when interpreting these results. Before any further action is taken, further investigation through well-designed prospective work will be required to in order to corroborate our findings and better understand the optimal dose and frequency of therapy, the most effective content of sessions, and optimal models of organising and providing services.

Author affiliations

[1]Centre for Biostatistics, School of Health Sciences, The University of Manchester, Faculty of Biology Medicine and Health, Manchester, UK
[2]Department of Health Services Research and Policy, London School of Hygiene and Tropical Medicine Faculty of Public Health and Policy, London, UK
[3]Division of Neuroscience & Experimental Psychology, School of Biological Sciences, FBMH, The University of Manchester, Manchester, UK
[4]National Disease Registration Service, NHS Digital, London, UK
[5]Health Analytics team, Lane Clark & Peacock, Durham, London, UK
[6]Centre for the Business and Economics of Health, The University of Queensland, Saint Lucia, Queensland, Australia
[7]Stroke & Vascular Research Centre, School of Nursing, Midwifery & Social Work, The University of Manchester, Manchester, UK

Twitter Audrey Bowen @audreybowenprof

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Contributors MG, is guarantor for the overall content. MG designed the study, conducted data management, data analysis, results interpretation, write up and dissemination of results. DGL-P contributed to the interpretation the results. AV, AB and ST developed the project; designed the study, interpreted the results, and contributed to the write up. BB contributed to development of the project; interpretation of results. LP contributed to data management and interpretation of the results. BG developed the study and interpreted the results.

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Patient consent for publication Not applicable.

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ORCID iDs

Matthew Gittins http://orcid.org/0000-0002-9888-1197
Audrey Bowen http://orcid.org/0000-0003-4075-1215

REFERENCES

1 WHO. *Geneva: global health estimates*, 2012..
2 National Audit Office. *Progress in improving stroke care*. London, UK, 2010.
3 Feigin VL, Norrving B, Mensah GA. Global burden of stroke. *Circ Res* 2017;120:439–48.
4 Langhorne P, Wagenaar R, Partridge C. Physiotherapy after stroke: more is better? *Physiother Res Int* 1996;1:75–88.
5 Kwakkel G, Wagenaar RC, Twisk JW, *et al*. Intensity of leg and arm training after primary middle-cerebral-artery stroke: a randomised trial. *Lancet* 1999;354:191–6.
6 Kwakkel G, Wagenaar RC, Koelman TW, *et al*. Effects of intensity of rehabilitation after stroke. A research synthesis. *Stroke* 1997;28:1550–6.
7 Kwakkel G, van Peppen R, Wagenaar RC, *et al*. Effects of augmented exercise therapy time after stroke: a meta-analysis. *Stroke* 2004;35:2529–39.
8 Winstein CJ, Stein J, Arena R, *et al*. Guidelines for adult stroke rehabilitation and recovery: a guideline for healthcare professionals from the American heart Association/American stroke association. *Stroke* 2016;47:e98–169.
9 RCo P. Sentinel stroke national audit programme (SSNAP) clinical audit July-Sept 2014 public report, 2015. Available: https://www.strokeaudit.org/Documents/National/Clinical/JulSep2014/JulSep2014-PublicReport.aspx [Accessed Oct 2018].
10 Veerbeek JM, van Wegen E, van Peppen R, *et al*. What is the evidence for physical therapy poststroke? A systematic review and meta-analysis. *PLoS One* 2014;9:e87987.
11 Scotland I. Scottish stroke care audit, Scottish stroke improvement programme Report-2016, 2016. Available: https://www.strokeaudit.scot.nhs.uk/Publications/Main.html [Accessed Jul 2018].
12 Physicians RCo. Sentinel stroke national audit programme (SSNAP), 2015. Available: https://www.rcplondon.ac.uk/projects/outputs/sentinel-stroke-national-audit-programme-ssnap
13 Physicians RCo. Sentinel stroke national audit programme (SSNAP) acute care organisational audit, 2014. Available: https://www.strokeaudit.org/results/Organisational.aspx [Accessed Mar 2018].

14 Physicians RCo. Sentinel stroke national audit programme (SSNAP) post –acute care organisational audit, 2015. Available: https://www.strokeaudit.org/results/PostAcute/National.aspx [Accessed Mar 2018].
15 Gittins M, Lugo-Palacios D, Vail A. *Delivery, dose, outcomes and resource use of stroke therapy: the SSNAPIEST observational study*. Southampton (UK), 2020.
16 Bonita R, Beaglehole R. Recovery of motor function after stroke. *Stroke* 1988;19:1497–500.
17 Desquilbet L, Mariotti F. Dose-Response analyses using restricted cubic spline functions in public health research. *Stat Med* 2010;29:n/a–57.
18 Harrell FE. *Regression modeling strategies: with applications to linear models, logistic and ordinal regression, and survival analysis*. 2 edn. Springer Ser Stat, 2015.
19 Gelman A, Hill J. *Data analysis using regression and multilevel/hierarchical models*. Cambridge: Cambridge University Press, 2007.
20 Adams HP, Davis PH, Leira EC, *et al*. Baseline NIH stroke scale score strongly predicts outcome after stroke: a report of the trial of ORG 10172 in acute stroke treatment (TOAST). *Neurology* 1999;53:126.
21 De Haan R, Horn J, Limburg M, *et al*. A comparison of five stroke scales with measures of disability, handicap, and quality of life. *Stroke* 1993;24:1178–81.
22 StataCorp LLC. *Stata Statistical Software: Release 15. [program]*. College Station, TX: StataCorp LLC, 2017.
23 Gittins ML-P, Paley D;, Bray L;. How do patients pass through stroke services? Identifying stroke care pathways using national audit data - Accepted for publication. *Clin Rehabil* 2019.
24 NICE. Stroke rehabilitation in adults: clinical guideline 2013, 2019. Available: https://www.nice.org.uk/guidance/CG162/chapter/1-Recommendations#planning-and-delivering-stroke-rehabilitation [Accessed Nov 2019].
25 London ISWPR. National clinical guideline for stroke, 4th ED, 2012. Available: https://www.strokeaudit.org/Guideline/Historical-Guideline/National-Clinical-Guidelines-for-Stroke-fourth-edi.aspx
26 Bernhardt J. A trial to Determine the Optimal early mobility Training after StrokE (AVERT DOSE) - Trial Regsiter Australian New Zealand Clinical Trials Registry (ANZCTR): ANZCTR, 2019. Available: https://www.anzctr.org.au/Trial/Registration/TrialReview.aspx?id=376646&isReview=true [Accessed 01 Dec 2019].
27 Sterne JAC, White IR, Carlin JB, *et al*. Multiple imputation for missing data in epidemiological and clinical research: potential and pitfalls. *BMJ* 2009;338:b2393.