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Drivers of healthcare costs in patients with ischaemic stroke: a hospital-based retrospective cohort study

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ABSTRACT

Objectives To evaluate how costs of healthcare can be reduced, there is an increasing need to gain insight into the main drivers of such costs. We evaluated drivers of costs of predefined subgroups of patients who had a stroke by linking cost registration with clinical data.

Methods We retrospectively selected 555 consecutive patients with ischaemic stroke participating between June 2011 and December 2016 in the Dutch Parelsnoer Initiative. Patient characteristics and costs of healthcare activities during hospital admission and the first 3 months after discharge were linked. Patients were divided in subgroups based on age, severity of stroke, stroke subtype, discharge destination and functional outcome. Unit cost per healthcare activity was based on 2018 rates for mutual service in euros. Mean total costs per subgroup were calculated. Multivariate analysis was performed to identify factors associated with costs.

Results Number of admitted days was the main driver of total hospital costs (range 82%–93%) in all predefined subgroups of patients. Second driver was radiological diagnostic investigations (range 2%–9%). Highest costs were observed in patients with a younger age at the time of admission, a higher modified Rankin Scale at the time of discharge and a nursing home as discharge destination. The distribution of costs over the different healthcare activities was associated with stroke subtype; for example, in patients with a cardiac embolism most costs were spent on cardiology-related healthcare activities.

Conclusion The number of admitted days was the most important driver of costs in all subgroups of patients with ischaemic stroke. This implicates that to reduce healthcare costs for patients who had a stroke, focus should be on reducing length of hospital stay.

STRENGTHS AND LIMITATIONS OF THIS STUDY

⇒ Uniform collection of data for clinical and for research purposes.
⇒ Selection bias may have been introduced by including only patients with ischaemic stroke who gave informed consent to participate in the Dutch Parelsnoer Initiative Cerebrovascular Disease Study.
⇒ By focusing on the hospital setting, we did not include costs of post-hospital care, costs of loss of productivity of patients who had a stroke or costs of unpaid care for patients who had a stroke by their relatives.
⇒ Absolute cost prices and the healthcare system may differ between countries.

INTRODUCTION

In developed countries healthcare costs have been rising for decades and are expected to continue to increase.[1 2] Ischaemic stroke is the second most common cause of mortality and long-term disability,[3 4] while around 10% of the total costs of brain disorders are attributable to stroke.[5] The incidence of stroke is predicted to increase further and expensive treatments for stroke such as intra-arterial thrombectomy are expected to be more frequently used in the future. Therefore, costs of stroke care are expected to increase in the near future and will continue to consume a substantial part of the available healthcare budgets. To support innovation development and improved decision-making aimed at making stroke care more efficient, insight into the costs that are associated with the hospital care of patients who had a stroke is needed.

In The Netherlands, all residents are entitled to a basic health insurance offered by private insurance companies and regulated by the government.[6] The healthcare payment model is the same for all Dutch hospitals, including university hospitals. The Dutch Parelsnoer Initiative (PSI) is a collaboration between eight University Medical Centres in The Netherlands, and was established in 2007 by The Netherlands Federation of University Medical Centres. Currently, PSI consists of 17 large clinical cohorts covering a variety of diseases with prospective, standardised collections of comprehensive clinical data and biomaterials.[7–9] As a participant of the PSI Cerebrovascular Disease Study Group, the University Medical Centre Utrecht (UMCU) has integrated the registration of data for clinical and for research purposes in the electronic health records of patients with ischaemic stroke. These data are

Table 1 Baseline characteristics at the time of ischaemic stroke

	Patients with ischaemic stroke n=555
Mean age, years (SD)	65.1 (14.7)
Age range, years	18–97
Women, n (%)	226 (40.7)
Smoking	
Yes, n (%)	140 (25.2)*
Former, n (%)	228 (41.1)*
Alcohol, n (%)	337 (60.7)†
Drugs	
Yes, n (%)	9 (1.6)*
Former, n (%)	8 (1.4)*
Cardiovascular history	
Hypertension, n (%)	306 (55.1)†
Hypercholesterolaemia, n (%)	225 (40.5)†
Diabetes, n (%)	84 (15.1)*
Ischaemic stroke (including TIA), n (%)	137 (24.7)†
Intracerebral haemorrhage, n (%)	13 (2.3)*
Subarachnoid haemorrhage, n (%)	10 (1.8)*
Cerebral venous sinus thrombosis, n (%)	0 (0)*
Coronary artery disease, n (%)	81 (14.6)†
Atrial fibrillation, n (%)	79 (14.2)†
Peripheral artery disease, n (%)	43 (7.7)*
Other history	
Malignancy, n (%)	95 (17.1)*
NIHSS	
Median (range)	4 (0–25)*

*<1% missings.
†1–2.5% missings.
CABG, coronary artery bypass graft; n, number; NIHSS, National Institute of Health Stroke Scale; TIA, transient ischaemic attack.

therefore suitable to gain insight into the healthcare costs of patients with ischaemic stroke.

AIMS

Our first aim was to evaluate the main drivers of costs spent on the care of patients with ischaemic stroke by linking cost registration with clinical data. Next, we hypothesised that several characteristics such as age, clinical severity of stroke, stroke subtype and discharge destination may influence these costs. Therefore, our second aim was to determine if costs differed between predefined subgroups of patients with ischaemic stroke.

METHODS

Data collection

We retrospectively selected all consecutive patients with clinical features of cerebral ischaemia who were admitted between June 2011 and December 2016 and who gave informed consent to participate in the Dutch PSI Cerebrovascular Disease Study at the UMCU. If patients were not able to give informed consent because of aphasia or decreased consciousness, informed consent was obtained from their legal representative. Patients were divided in predefined subgroups based on age, National Institute of Health Stroke Scale (NIHSS) score at the time of hospital admission, the subtype of ischaemic stroke as classified by the Trial of Org 10172 in Acute Stroke Treatment classification,[10] discharge destination and modified Rankin Scale (mRS) score at the time of discharge. For age, we defined three subgroups, using a cut-off at 55 years (with patients with age <55 years being considered as 'young stroke patients') and at 75 years (with patients >75 years being more likely to have comorbidities and to need help from others in daily life). Data of patients who died either during hospital admission or within 3 months after discharge were included until the point of death. Data on healthcare activities during hospital admission and during the first 3 months after discharge were collected and grouped in the following categories: number of admitted days (admitted days on the intensive care unit (ICU) and general ward were recorded separately), ancillary investigations concerning laboratory tests, ancillary radiological and cardiological consultations and investigations, consultation of other specialists, consultation of paramedics, treatment with intravenous thrombolysis, intra-arterial thrombectomy or carotid endarterectomy and visits at the outpatient clinic. Unit cost per healthcare activity was based on 2018 rates for mutual service in euros as derived from the financial administration of the UMCU. An example of mutual service is the service of the radiology department to performa MRI scan. Using rates for mutual service allowed for more detailed costing than the use of cost prices from the Dutch Healthcare Authority (DHA). In case of missing values prices from DHA were used (2018 prices in euros, for all healthcare activities and corresponding unit costs see online supplemental table 1.[11] Unit costs were adjusted to 2021 euros using the general price index from the Dutch Central Bureau of Statistics.[12]

Patient and public involvement

Patients or public were not involved in the design or conduct of this study.

Statistical analysis

Per healthcare activity, the use was multiplied by the corresponding unit cost. Mean total costs of all used healthcare activities were calculated for the total group of patients and per patient subgroup. We compared baseline characteristics, healthcare activities used and costs between the predefined subgroups with a χ^2 test for categorical

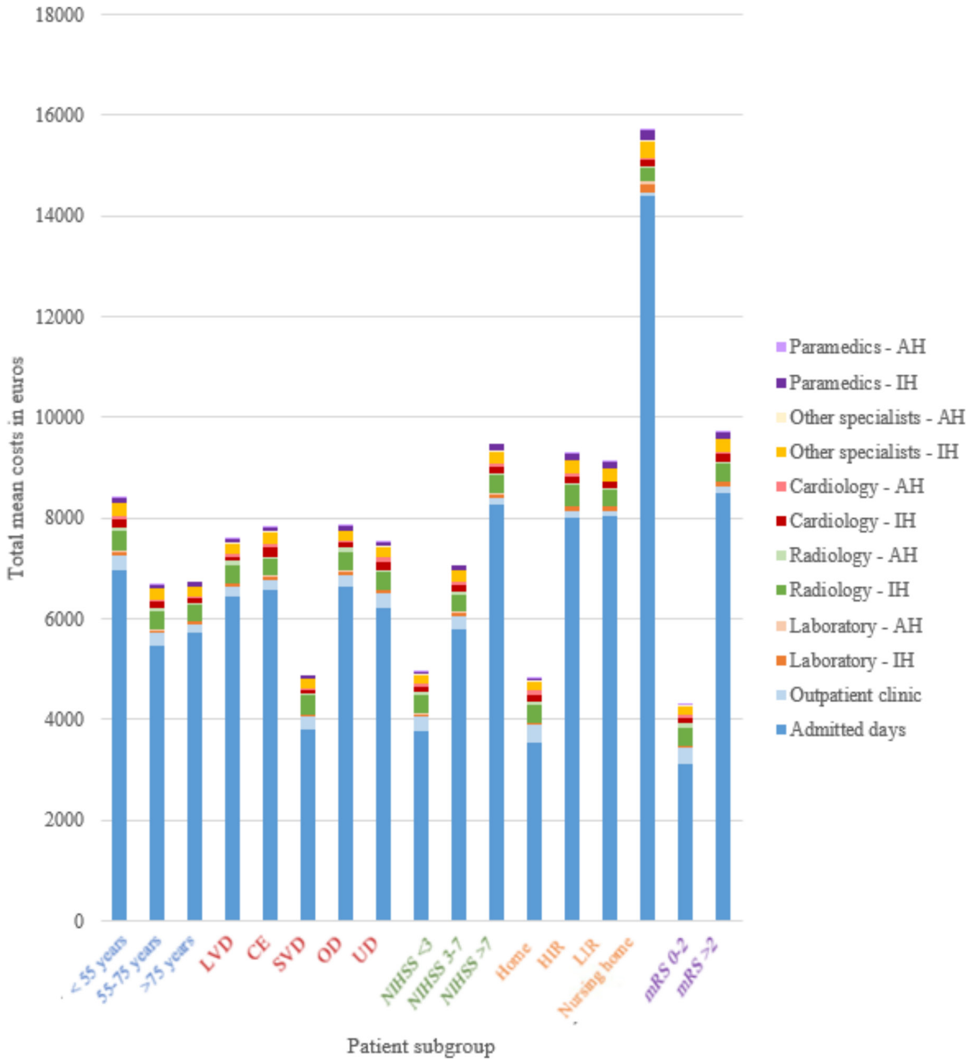

Figure 1 Mean costs in euros per patient subgroup. AH, after hospital; CE, cardiac embolism; HIR, high intensity rehabilitation; IH, in-hospital; LIR, low intensity rehabilitation; LVD, large vessel disease; mRS, modified Ranking Scale; NIHSS, National Institute of Health Stroke Scale; OD, other determined; SVD, small vessel disease; UD, undetermined.

variables and an independent samples t-test for continuous variables. Multivariate analysis of patient characteristics was performed to determine the main drivers of hospital costs for patients with ischaemic stroke. Statistical analyses were performed with R software (V.3.6.2 R Foundation).[13]

RESULTS

Five hundred and fifty-five patients were included, which corresponds to 34% of all patients admitted for ischaemic stroke in our hospital between June 2011 and December 2016. Mean age was 65.1 years (range 18–97 years) and 40.7% were women (table 1).

Mortality rate during hospital admission was 3.6% (20/553 patients) and within 3 months after discharge 5.2% (29/455 patients) (see online supplemental table 2). Median total hospital costs for patients with ischaemic stroke were €5249.25 (range €967.10–€76 530.35), which could be subdivided in €4790.08 during hospital admission and €217.55 during the first 3 months after discharge. The high upper range of in-hospital costs are attributable to patients who were admitted 10 days or more at the ICU. Main driver of the total hospital costs was the number of admitted days (€5909.20; 83% of the total hospital costs), followed by radiology diagnostics during hospital admission (€352.39; 5% of the total hospital costs).

Baseline characteristics and healthcare activities used per patient subgroup showed no relevant differences (see online supplemental tables 3–6). On analysing the predefined patient subgroups, the highest hospital costs of €15 742.59 were observed in patients who were discharged to a nursing home (figure 1). With respect to age, total costs were highest in the subgroup of patients younger than 55 years, both during hospital admission and after discharge (table 2).

Patients with small vessel disease had lower in-hospital costs compared with other stroke subtypes (table 2). Patients with a poor clinical condition, for example, patients with an NIHSS >7 at the time of hospital admission

Table 2 Relative mean costs per patient subgroup

Subgroup	Mean total costs %*	Mean total costs Costs	Mean total costs during admission %*	Mean total costs during admission Costs	Mean total costs after discharge %*	Mean total costs after discharge Costs
Age						
<55 years, n=137	**100**	**€8433.57†**	**100**	**€7920.61‡**	**100**	**€512.95†**
55–75 years, n=272	80	€6728.63§	80	€6315.26§	81	€413.91†
>75 years, n=146	80	€6768.42	82	€6515.90	49	€252.51§
TOAST classification						
LVD, n=148	97	€7679.61†	98	€7336.06†	74	€343.55§
CE, n=101	99	€7849.23†	**100**	**€7503.98†**	74	€345.25
SVD, n=92	62	€4893.69§	60	€4519,76§	80	€373.93
OD, n=56	**100**	**€7892.79†**	99	€7437.07 †	98	€455.73
UD, n=141	96	€7566.74†	95	€7101.87†	**100**	**€464.86†**
NIHSS at admission						
NIHSS <3, n=193	52	€4975.18§	48	€4478.84§	**100**	**€496.34†**
NIHSS 3–7, n=169	75	€7104.44†	72	€6647.12 †	92	€457.33a
NIHSS >7, n=188	**100**	**€9501.28†**	**100**	**€9269.43†**	47	€231.84§
Discharge destination						
Home, n=284	31	€4865.27§	28	€4270.55§	**100**	**€594.72†**
High intensity rehabilitation, n=93	59	€9322.91†	59	€9087.25†	40	€235.65
Low intensity rehabilitation, n=73	58	€9153.53†	58	€9002.62†	25	€150.91§
Nursing home, n=15	**100**	**€15 742.59†**	**100**	**€15 512.80†**	39	€229.78
mRS at discharge						
0–2, n=265	45	€4361.25§	40	€3809.25§	**100**	**€552.00 †**
>2, n=288	**100**	**€9742.24 †**	**100**	**€9489.96 †**	46	€252.29§

*% of subgroup with highest total costs, with highest set at 100 and marked in bold.
†P<0.01.
‡P<0.05.
§Reference group for statistical test, which is the subgroup with lowest costs per column.
CE, cardiac embolism; LVD, large vessel disease; mRS, modified Rankin Scale; n, number; NIHSS, National Institute of Health Stroke Scale; OD, other determined; SVD, small vessel disease; TOAST, Trial of Org 10172 in Acute Stroke Treatment; UD, undetermined.

or patients with an mRS >2 at the time of discharge, had highest costs during admission, while highest costs after discharge were seen in patients with a good clinical condition, for example, patients with an NIHSS <3 at the time of hospital admission or patients with an mRS 0–2 at the time of discharge (table 2).

Multivariate analysis showed that age at time of ischaemic stroke, mRS at time of discharge and discharge to a nursing home were significantly associated with total hospital costs (table 3).

In all predefined subgroups studied, the vast majority of costs (ranging from 82% to 93%) during hospital admission was determined by the number of admitted days, including both days of admission at the ICU and the general ward (online supplemental figure S1). In all subgroups studied, the hospital costs of admitted days were mainly driven by the number of admitted days at the general ward and not by the number of admitted days at the ICU (figure 2). By far, most admitted days were observed in patients discharged to a nursing home (figure 2). The second main driver of costs during hospital admission was radiological diagnostic investigations, ranging from 2% to 9% of total mean costs.

During the first 3 months after discharge, physical or telephone consultation at the outpatient clinic mainly determined the costs of healthcare use, ranging from 35% to 71% of total mean in-hospital costs after hospital discharge (online supplemental figure S2). Both during hospital admission and after discharge, the distribution of costs over the different healthcare activities was related to the aetiological cause of the ischaemic stroke, for example, in patients with a cardiac embolism most costs were spent on diagnostics as required by a cardiologists and in patients with small vessel disease most costs were spent during hospital admission on radiological

Table 3 Multivariate analysis of patient characteristics to determine potential drivers of total hospital costs for patients with ischaemic stroke

Factor	Coefficient	95% CI
Age	−132	−178 to −86
TOAST		
LVD	923	−805 to 2651
CE	774	−1128 to 2676
SVD		*Reference*
OD	−296	−2536 to 1943
UD	754	−947 to 2456
NIHSS at admission	15	−106 to 135
Discharge destination		
Home		*Reference*
High intensity rehabilitation	608	−1119 to 2334
Low intensity rehabilitation	1916	−85 to 3917
Nursing home	6146	2661 to 9632
mRS at discharge	1902	1298 to 2507
Female sex	−645	−1776 to 487
Current smoking	−1117	−2449 to 215
Current alcohol consumption	310	−876 to 1496
Current drug use	−3541	−8840 to 1758
Hypertension	241	−968 to 1449
Diabetes	−516	−2149 to 1116
History of cerebral ischaemia	546	−811 to 1904

CE, cardiac embolism; LVD, large vessel disease; mRS, modified Rankin Scale; NIHSS, National Institute of Health Stroke Scale; OD, other determined; TOAST, Trial of Org 10172 in Acute Stroke Treatment; UD, undetermined.

diagnostic investigations (online supplemental figures S1 and S2).

DISCUSSION

This study shows that for patients with ischaemic stroke 83% of the costs during the hospital admission were determined by the number of admitted days. We found substantial differences in distribution of costs between patient subgroups based on age, severity of stroke at admission, stroke subtype, discharge destination and functional outcome at discharge. The highest costs were observed in patients with a younger age at the time of stroke, a worse mRS score at time of discharge and patients who were discharged to a nursing home.

In accordance with our study, previous studies performed in The Netherlands and Greece showed that length of hospital stay is the main driver for in-hospital costs for patients with ischaemic stroke.[14–16] This observation implicates that to reduce costs of healthcare for patients with ischaemic stroke, one should focus on the reduction of the length of hospital stay. A previous study demonstrated that the introduction of integrated stroke services, defined as regional networks of caregivers who together ensure treatment and care for patients who had a stroke in all phases, could reduce the length of hospital stay after ischaemic stroke.[14] Our study was performed in a hospital that participates in such an integrated stroke service, which implies that at least part of the effect of these integrated stroke services on length of hospital stay is included in our findings. We found mean length of hospital stay for patients with ischaemic stroke to be longer compared with other in-hospital patients or length of hospital stay for patients with ischaemic stroke in the USA,[17] and hypothesised that this is mainly caused by the waiting list for the discharge destination since patients who had a stroke frequently need to be discharged to specialised rehabilitation centres or nursing homes. We showed that costs during hospital admission were lower for patients with small vessel disease compared with other stroke subtypes, which was mainly caused by a lower number of admitted days, followed by less laboratory diagnostics and less consultation of other specialists. This is in accordance with a previous study demonstrating a shorter length of hospital stay for patients with small vessel disease compared with other stroke subtypes.[18]

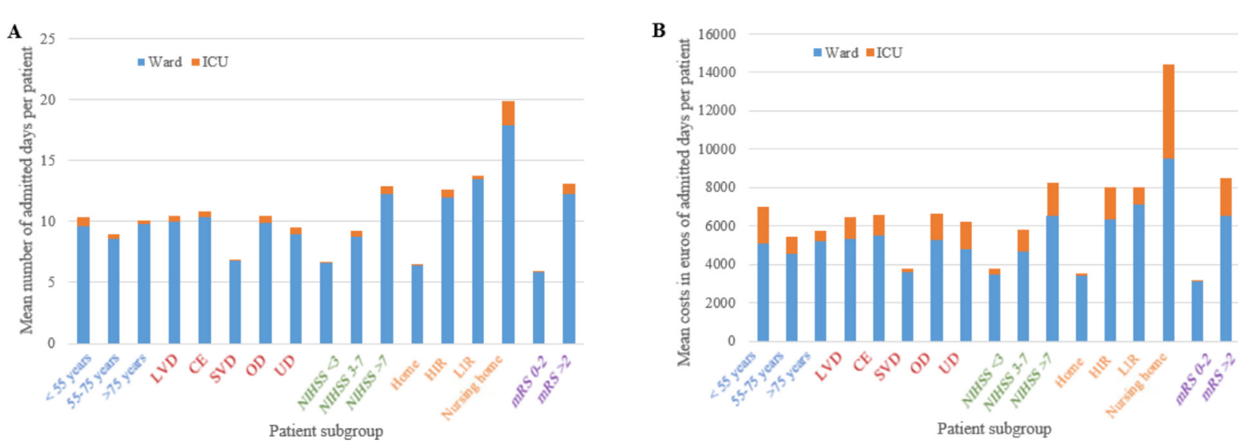

Figure 2 Mean number of admitted days (A) and mean costs in euros of admitted days (B) at general ward and ICU per patient per subgroup. CE, cardiac embolism; HIR, high-intensity rehabilitation; ICU, intensive care unit; LIR, low-intensity rehabilitation; LVD, large vessel disease; mRS, modified Ranking Scale; NIHSS, National Institute of Health Stroke Scale; OD, other determined; SVD, small vessel disease; TOAST, Trial of Org 10172 in Acute Stroke Treatment; UD, undetermined.

Strength of our study is the uniform collection of data for clinical and for research purposes. Also, the possibility to easily link cost registration with clinical data for other diseases in the future is a strength of our study. Linking cost registration with clinical data may serve as a starting point for improving efficiency of clinical care. An important limitation of our study is the possibility that the registration of healthcare activities is not complete, since we based our analysis on the number of healthcare activities registered per patient in the hospital setting. For example, the use of intravenous thrombolysis has to be registered manually. However, as most healthcare activities are registered automatically when requested through the electronic patient record, we think that the registration bias is limited. Second, selection bias may have been introduced by including only patients with ischaemic stroke who gave informed consent to participate in the Dutch PSI Cerebrovascular Disease Study (estimated to be 34% of the patients admitted for stroke in our hospital). We observed a lower mRS at hospital discharge in our study population compared with all patients admitted for stroke in our hospital during the study period, which may have resulted in a slight underestimation of the cost estimates presented in our study. Third, we did not exclude patients who died during hospital admission or within 3 months after discharge, but included their data until the point of death. Including this patient category may have resulted in higher costs during hospital admission and lower costs after discharge (See online supplemental table 2). Fourth, relatively few intra-arterial thrombectomies were performed in our patient group which could be explained by the introduction of this treatment as standard care in 2015, whereas most of the patients in our study were treated before 2015. Expensive therapies for acute ischaemic stroke, such as intra-arterial thrombectomy, have increased during the recent years and probably will increase even more in the near future. A recent Dutch economic evaluation study of intra-arterial thrombectomy added to usual care demonstrated it to be clinically effective and cost saving compared with usual care alone.[19] Fifth, by focusing on the hospital setting, we only included costs related to registered healthcare activities based on mutual service rates in the hospital and not included societal costs such as loss of productivity of patients who had a stroke or costs of unpaid care for patients who had a stroke by their relatives, or costs from primary care after discharge. This perspective will result in an underestimation of the total healthcare costs for patients with ischaemic stroke. This is especially true for the costs after hospital discharge since a substantial part of patients who had a stroke are discharged to a rehabilitation centre or nursing home which costs are not included in our study. Last, absolute cost prices and the healthcare system may differ between countries, which might influence the distribution of hospital costs per different healthcare activity.

Future studies including data from multiple hospitals should determine if the patient factors predicting length of hospital stay as found in our study are generalisable to other hospitals. Several possible ways to reduce length of hospital stay should be considered, for example, by further integrating clinical care for patients who had a stroke between hospitals and discharge destinations. This applies in particular to the integration between hospitals and nursing homes, since by far most admitted days were observed in patients discharged to a nursing home. However, also interventions for patients who are discharged home require further study, such as early supported discharge (ESD) with help from a local rehabilitation centre. Recent studies report different effects of ESD on length of hospital stay, ranging from a significant reduction of up to 5 days to an increase of 1 day in length of hospital stay.[20–22] Future studies should determine the effect of ESD in current clinical practice since length of hospital stay of patients who had a stroke in general might have been reduced by the introduction of intra-arterial thrombectomy and the stroke unit, also other outcomes such as well-being of caregivers, re-admission rate and long-term functional outcome should be studied. Other potential ways to reduce length of hospital stay concern the time needed to clinically stabilise patients who had a stroke by improving acute treatment and/or limiting the time to perform additional diagnostic tests by increasing the short-term availability of these diagnostics and/or by performing some of these tests during the outpatient phase. The effect on costs and healthcare outcomes of such changes in clinical care for patients with ischaemic stroke should be evaluated regularly, so that only effective measures are retained in clinical practice.

Contributors YMR, LJK and HK conceived the study. YMR, LJK, HK and LAM were involved in protocol development and searched literature. LAM and YMR were involved in gaining ethical approval. All authors were involved in data analysis. LAM wrote the first draft of the manuscript. All authors reviewed and edited the manuscript and approved the final version of the manuscript.YMR accepts as guarantor the full responsibility for the work and conduct of the study.

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Competing interests None declared.

Patient and public involvement Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

Patient consent for publication Not applicable.

Ethics approval The Medical Ethical Review Committee of the UMCU approved this study (approval number 16-500). Participants gave informed consent to participate in the study before taking part.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data are available upon reasonable request. Data set and statistical code are available from the authors on request.

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