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Stroke resource utilisation and all-cause mortality in Thailand 2017–2020: A retrospective, cross-sectional study

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ABSTRACT

Objective To determine resource utilisation, costs and all-cause mortality related to stroke in Thailand.

Design Retrospective, cross-sectional study.

Setting and participants Patients with first-ever stroke in the Thai national claims database between 2017 and 2020 were included for analysis. No individuals were involved.

Methods We estimated annual treatment costs using two-part models. Survival analysis for all-cause mortality was performed.

Results We identified 386 484 patients with incident stroke of which 56% were men. Mean age was 65 years and ischaemic stroke was the most common subtype. Mean annual cost per patient was 37 179 Thai Baht (95% CI: 36 988 to 37 370). Haemorrhagic stroke was predominantly observed in the youngest age groups with the highest estimated mean annual cost. Patients with haemorrhagic stroke also had a longer length of stay (LOS) in hospital and an increased risk of mortality. Key cost drivers were identified to be age, LOS, comorbidity and thrombolysis. Costs were lower in patients who received rehabilitation; however, only 32% of patients received rehabilitation services. The 4-year survival rate of all stroke types was 66.5% (95% CI: 64.3% to 66.7%). Older age, high comorbidity score, long LOS and being treated outside the Bangkok area were factors associated with significantly increased mortality risk, while receiving thrombolysis or rehabilitation was associated with a decreased risk of death.

Conclusion The highest mean cost per patient was found in patients with haemorrhagic stroke. Receiving rehabilitation was associated with lower cost and mortality risk. Rehabilitation and disability outcomes should be improved to ensure an enhancement of health outcomes and efficient use of resources.

STRENGTHS AND LIMITATIONS OF THIS STUDY

⇒ This study assessed the mean annual costs and all-cause mortality of patients with stroke with the most up-to-date nationally representative stroke cohort.
⇒ The two-part models and parametric survival analysis were performed.
⇒ The analysis was based on hospitalised stroke events; however, a small proportion of patients with less severe symptoms who were not admitted to hospital could have been missed in this study.
⇒ By using nationwide claim data, we included neither loss of productivity costs of patients nor unpaid care costs by their caregivers.

INTRODUCTION

Stroke represents the second leading cause of death in Thailand. Stroke mortality rates have been reported to be 38.7 to 47.1 (per 100 000) between 2014 and 2018[1] and subsequently accounted for 27 361 deaths in men and 23 669 in women in 2019.[2 3] Although efforts to reduce the burden of stroke have been made, challenges of implementing stroke services still remain. Despite an increasing trend in thrombolysis provision, the absolute rate remains low,[4] and is further exacerbated by a shortage of neurology specialists and a low referral rate to rehabilitation services.[5 6]

The Thai Ministry of Public Health (MOPH) has established the emergency medical service in 2008 and introduced the stroke fast track system for stroke care.[7] The 'ship-and-drip' or 'drip-and-ship' and mother-ship models can be performed in Thailand[8 9] but depend on hospital capacity and context. Thrombolysis treatment can be prescribed by a well-trained general practitioner under the supervision of a neurologist at a hub. Following this, patients are transferred to the hub for further treatment or moved to stroke unit (SU) - a comprehensive specialised service with multidisciplinary team and care specifically tailored to stroke patients - or stroke corner (SC) - a specialised area in an intensive unit or general wards - in the same hospital, if a spoke hospital has adequate capacity. In addition, the proportion of SUs in advanced-level and standard-level hospitals was 97% and 65%, respectively.[10] Further details on stroke care are provided in online supplemental table 1.

In 2016, the Thai MOPH[11] published their service plan strategy and a set of national stroke key performance indicators (KPIs) for 2018–2022, to increase service capacities and improve health outcomes, according to hospital levels in all 12 health regions across Thailand. Following which, in 2018, a report[10] from the MOPH revealed that the quality of stroke care has improved and the number of hospitals providing a dedicated stroke unit has increased by 18% and 15% at advanced-level and standard-level hospitals, respectively. In addition, some mid-level hospitals can set-up SU/SC if hospitals have capacity and some community hospitals can set-up a rehabilitation ward. National stroke mortality rates have gradually declined from 8.2% in 2018 to 7.9% in 2020.[10 12] However, long-term outcomes, such as health-related quality of life (HRQoL) post-stroke or long-term survival, are rarely monitored. Although it is well known that most stroke survivors are being discharged from hospital with disability as a consequence of their stroke,[13] there is a lack of national-level information on service utilisation and health outcomes, so that a full assessment of the service plan strategy is difficult. This study aims to provide this national-level assessment by (1) estimating the resource utilisation of patients with stroke across stroke subtypes, and (2) estimating all-cause mortality of patients with incident stroke across stroke subtypes in Thailand.

METHODS

Design

The national stroke data set (January 2017 to November 2020) was obtained from the National Health Security Office which is a health insurance organisation managing the universal coverage scheme (UCS) covering 75% of the Thai population. This data contained both outpatient and inpatient data, and covered contracted public and private hospitals throughout Thailand. Details on hospital level are provided in supplementary materials (online supplemental table 2).

All patients aged 18 years and over with either a principal diagnosis or secondary diagnosis of stroke were included in the study cohort. The cohort was identified using the International Classification of Diseases, 10th revision using code I60–I62 for haemorrhagic, I63 for ischaemic and I64–I69 for unspecified stroke. A 2-year look-back period (2015–2016) was used to identify incident strokes and to avoid double-counting of incident stroke events. All patients were identified from the first recorded hospital episode of stroke diagnosis and followed-up until death or end of their records. The data recorded for each hospital record include patient demographics, medical treatment information, hospital charges, out-of-pocket payments by patients and hospital reimbursement with adjusted relative weight per admission.

Cost estimation

An average cost for outpatient visit and inpatient day were obtained from a recent cost study in Thailand.[14] For cost per inpatient admission, the unit cost from the cost study was multiplied by each inpatient admission from our data set. The estimation of annual hospitalisation costs per patient was carried out using a two-part model, with the first part estimating the probability of incurring any healthcare costs using a logistic regression model.

The second part estimated costs conditional on having incurred costs using a generalised linear model with a log link and a gamma distribution. Adjustments were made for age, sex, length of stay (LOS), comorbidities (Charlson Comorbidity Index (CCI)), type of stroke, rehabilitation, thrombolytic therapy with intravenous recombinant tissue plasminogen activator (rt-PA), type of hospital, health region and year of admission. Interaction terms between age and CCI were included in the model based on clinical evidence that most comorbid diseases become more common as people age (online supplemental table 3). These covariates were selected based on a review of the literature and clinically relevance. For the first modelling part, variables that were expected to impact on resource utilisation were included. The second part (cost estimation) included all variables used in the first part and in addition variables that were expected to affect costs (online supplemental table 4).

All-cause mortality

A Cox proportional hazards model was estimated initially, but showed violation of the proportional hazards assumption. Therefore, the Kaplan-Meier survival analysis and parametric survival analysis using the Gompertz distribution was employed.[15 16] Survival time was measured in days from incident stroke until date of death or censoring date (latest recorded discharge date). Adjustment for covariates were similar to those used in the cost estimation, except for year of admission. A variable indicating recurrence of stroke was also added to the model. The interaction term between age group and CCI was included based on clinical evidence that most comorbid diseases become more common as people age (online supplemental tables 3 and 5).

All analyses were carried out using R software V.3.2 with the exception of the two-part models which were estimated using Stata V.14.

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.

Ethics approval

The ethics approval was not required for this study. Patient consent was not required because it is a retrospective study of an anonymised dataset.

RESULTS

A total of 386 484 patients with stroke (first stroke) were identified from the database (table 1). Ischaemic stroke accounted for 50% (n=192 414) and haemorrhagic stroke accounted for 20% of all strokes; with the remaining 30% being recorded as unspecified stroke. Overall, 56% of the

Table 1 Baseline characteristics of patients at incident stroke

	Haemorrhage (N=78 081)	Ischaemic (N=192 414)	Unspecified (N=115 989)	Total (N=386 484)
Age (mean, SD)	61 (15)	66 (13)	67 (14)	65 (14)
Men	59 (14)	64 (13)	66 (14)	63 (14)
Women	64 (15)	67 (14)	69 (14)	67 (14)
Men (N, %)	47 334 (61)	103 261 (54)	64 113 (55)	214 708 (56)
Charlson Comorbidity Index (N, %)				
Score 0	47 528 (61)	126 531 (66)	32 920 (28)	206 979 (54)
Score 1–2	30 058 (38)	64 024 (33)	79 041 (68)	173 123 (45)
Score ≥3	495 (1)	1859 (1)	4028 (3)	6382 (2)

N, number of patients.;

cohort were men. The mean age at incident stroke was 65 years, and was consistent across all stroke subtypes. More than 60% of patients with haemorrhagic stroke and ischaemic stroke had no comorbidities (CCI score 0) while 68% of patients with unspecified stroke had a CCI score of 1–2 which might imply that these patients could be more severely ill than patients with other subtypes.

Resource utilisation

The mean LOS for incident stroke admission was greater among those with haemorrhagic stroke (9.9 days) compared with ischaemic stroke (6.1 days). Advanced-level hospitals recorded most of the incident strokes (50% of all haemorrhagic and 37% of all ischaemic strokes). The percentage of ischaemic patients receiving rt-PA was recorded at 7%. Only one-third of patients with stroke received rehabilitation during their incident stroke and ischaemic patients were more likely to receive rehabilitation compared with others. Computerised Tomographic (CT) scans, rt-PA prescription and rehabilitation services were mostly provided at advanced-level hospitals. Additionally, patients had four outpatient visits and two inpatient admissions on average. This was consistent across stroke subtypes. Average frequency of recurrent stroke, after excluding patients who died during their incident stroke, was approximately one (online supplemental table 6).

Cost estimation

Mean annual cost per patient was estimated to be 37 179 Baht (95% CI: 36 988 to 37 371). Haemorrhagic patients incurred higher costs compared to other subtypes (table 2).

Key variables that significantly contributed to an increase in costs were found to be higher age, longer LOS, higher CCI score, receiving rt-PA at incident admission and being admitted to a hospital outside of the Bangkok area. Patients who received rehabilitation were estimated to incur lower costs than those who did not receive rehabilitation during their incident stay. Mean annual costs increased with increasing age from the age of 50 years and these figures showed a similar trend in all stroke subtypes. Patients who had a CCI score of ≥3 incurred costs twice as high as comparable patients who had 0 CCI score. Having longer LOS, especially >7 days, was associated with a statistically significant increase in costs compared with having shorter hospital stays of LOS <3 days (reference). Being admitted to non-MOPH facilities was associated with higher costs than being admitted to MOPH hospitals. Lastly, patients who received rt-PA at their incident admission incurred higher costs compared with patients who did not receive rt-PA.

Mean annual costs incurred by patients receiving rehabilitation at their incident admission were estimated to be lower (by 3806 Baht) compared with patients who did not receive rehabilitation. There were three health regions, where patients incurred higher costs compared with the Bangkok area (reference); however, mean costs were almost identical in all health regions (figure 1). Full results can be found in supplementary materials (online supplemental table 7).

All-cause mortality

The Kaplan-Meier curves show the 4-year survival probability of all stroke subtypes (figure 2A, black line) was 66.5% (95% CI: 64.3% to 66.7%). There is a clear trend of decreasing survival probability during the 4 years following an incident stroke, with the ischaemic group having the highest probability of survival (70.5%; 95% CI: 70.2% to 70.7%) compared with other subtypes (figure 2A; unspecified: 60.6%; 95% CI: 60.2% to 61.0%; haemorrhagic: 64.9%; 95% CI: 64.4% to 65.5%). However, patients with haemorrhagic stroke had the lowest probability of survival at 1 year (76.5%; 95% CI: 76% to 77%) compared with other stroke subtypes (figure 2B).

After covariate adjustment (table 3, see online supplemental table 8 for full model results) the risk of mortality increased remarkably with age, and there was a noticeable upward trend in the risk of mortality especially in patients aged >70 years. This ranged from 2.5 to 15.6 times compared with those aged <40 years (reference), with patients with ischaemic stroke having a higher risk of mortality than patients with other stroke subtypes.

Table 2 Mean annual cost per patient by stroke subtypes

Variable	All subtypes mean (95% CI)	Haemorrhagic mean (95% CI)	Ischaemic mean (95% CI)	Unspecified mean (95% CI)
Stroke subtype				
Haemorrhagic	48 599 (48 099 to 49 099)	–	–	–
Ischaemic	34 125 (33 879 to 34 371)	–	–	–
Unspecified	34 629 (34 284 to 34 974)	–	–	–
Age group				
<40	34 752 (33 903 to 35 601)	45 335 (44 187 to 46 482)	31 833 (31 030 to 32 636)	32 303 (31 451 to 33 155)
40–49	32 458 (31 916 to 33 001)	42 340 (41 567 to 43 114)	29 730 (29 201 to 30 259)	30 170 (29 592 to 30 748)
50–59	34 375 (33 970 to 34 779)	44 873 (44 228 to 45 517)	31 508 (31 099 to 31 918)	31 974 (31 501 to 32 447)
60–69	37 562 (37 208 to 37 917)	49 017 (48 375 to 49 660)	34 419 (34 052 to 34 785)	34 927 (34 484 to 35 370)
70–79	40 111 (39 722 to 40 499)	52 315 (51 602 to 53 028)	36 734 (36 341 to 37 128)	37 277 (36 802 to 37 752)
80–89	41 497 (41 008 to 41 986)	54 113 (53 286 to 54 940)	37 997 (37 518 to 38 475)	38 558 (38 006 to 39 111)
≥90	41 187 (39 987 to 42 387)	53 710 (52 057 to 55 362)	37 714 (36 603 to 38 824)	38 271 (37 112 to 39 430)
Sex				
Women	36 959 (36 690 to 37 229)	48 313 (47 749 to 48 877)	33 924 (33 626 to 34 222)	34 425 (34 040 to 34 810)
Men	37 366 (37 116 to 37 616)	48 845 (48 307 to 49 382)	34 297 (34 008 to 34 587)	34 804 (34 426 to 35 183)
Charlson Comorbidity Index				
Score 0	30 086 (29 860 to 30 312)	39 232 (38 806 to 39 659)	27 548 (27 319 to 27 777)	27 955 (27 597 to 28 314)
Score 1–2	44 448 (44 127 to 44 768)	57 923 (57 228 to 58 617)	40 672 (40 300 to 41 044)	41 273 (40 853 to 41 693)
Score ≥3	70 242 (67 842 to 72 641)	91 482 (88 226 to 94 738)	64 236 (62 031 to 66 441)	65 185 (62 975 to 67 396)
Length of stay (LOS)				
LOS <3 days	29 087 (28,837 to 29,336)	38 525 (38 012 to 39 038)	27 051 (26 794 to 27 309)	27 451 (27 123 to 27 780)
LOS 3–7 days	29 782 (29 545 to 30 019)	39 448 (38 961 to 39 935)	27 699 (27 446 to 27 953)	28 109 (27 780 to 28 437)
LOS 8–15 days	44 395 (43 916 to 44 875)	58 793 (57 999 to 59 587)	41 283 (40 777 to 41 789)	41 893 (41 318 to 42 468)
LOS >16 days	93 221 (92 040 to 94 403)	123 421 (121 689 to 125 153)	86 663 (85 434 to 87 891)	87 944 (86 574 to 89 313)
Rehabilitation				
Not rehabilitation	38 490 (38 258 to 38 722)	50 322 (49 794 to 50 850)	35 335 (35 038 to 35 632)	35 857 (35 497 to 36 217)
Received rehabilitation	34 685 (34 381 to 34 988)	45 347 (44 761 to 45 933)	31 841 (31 551 to 32 131)	32 312 (31 892 to 32 731)
Thrombolysis				
No thrombolysis	37 021 (36 828 to 37 213)	48 375 (47 880 to 48 870)	33 967 (33 718 to 34 217)	34 469 (34 126 to 34 813)
Thrombolysis	41 986 (40 992 to 42 980)	54 863* (53 429 to 56 297)	38 523 (37 618 to 39 429)	39 093 (38 098 to 40 087)

*From 178 (0.05%) out of 386 484 patients.
95%CI, 95% confidence interval.

The risk of mortality of patients who had a CCI score of 1–2 and a CCI score ≥3 were twice (95% CI: 1.9 to 2.3) and more than five times (95% CI: 4.2 to 7.9) the risk than in patients with no comorbidities. However, patients with stroke with a higher CCI score had a higher risk of mortality. There was also a higher risk of mortality for patients with longer LOS as compared with patients who had shorter hospital stays of <3 days. Patients with ischaemic stroke, whose LOS was ≥16 days, had 3.5 times the mortality risk (95% CI: 3.4 to 3.7) of patients who had LOS <3 days (reference). Further, patients who had a recurrent stroke had a 28% increase in the mortality risk compared with patients who had no recurrent stroke (95% CI: 1.26 to 1.31). Lastly, almost all geographical areas were associated with a higher risk of mortality compared with the Bangkok area.

Three additional measures were associated with a reduction in mortality risk. First, patients receiving rehabilitation during the incident episode showed a lower risk of mortality (0.85; 95% CI: 0.84 to 0.86) than patients who had no rehabilitation. Second, receiving rt-PA seemed to be associated with better health outcomes as it showed around 7% reduction in mortality (95% CI: 0.89 to 0.96). Third, among the types of hospitals, only patients admitted to non-MOPH hospitals showed a lower risk of mortality in all stroke subtypes when compared

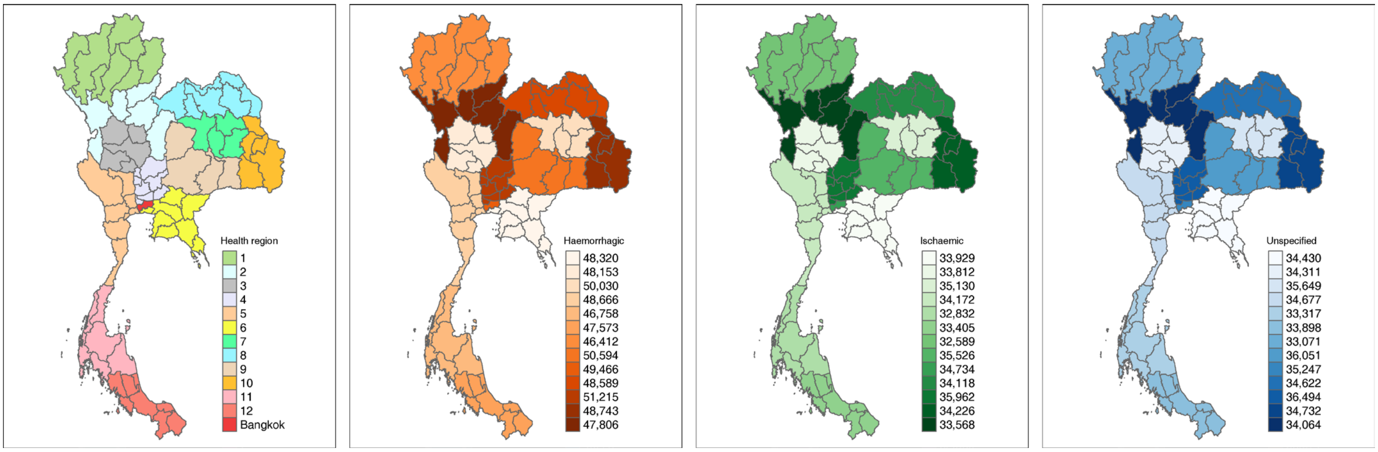

Figure 1 The mean annual cost per patient classified by stroke subtypes and health regions. Health region 13: Bangkok

with those being admitted to primary/community hospitals (reference). When comparing between all subtypes, only patients with unspecified strokes had a reduced risk of mortality when being admitted, across hospital types, namely middle-level, standard-level, advanced-level and non-MOPH hospitals, with the only exception being private hospitals/clinics.

DISCUSSION

This study is the first comprehensive analysis of recent Thai national stroke data to investigate costs and all-cause mortality of a nationally representative stroke cohort. Our results show that, presence of haemorrhagic stroke was associated with higher mean annual costs and 1-year risk of death compared with other stroke subtypes. Only

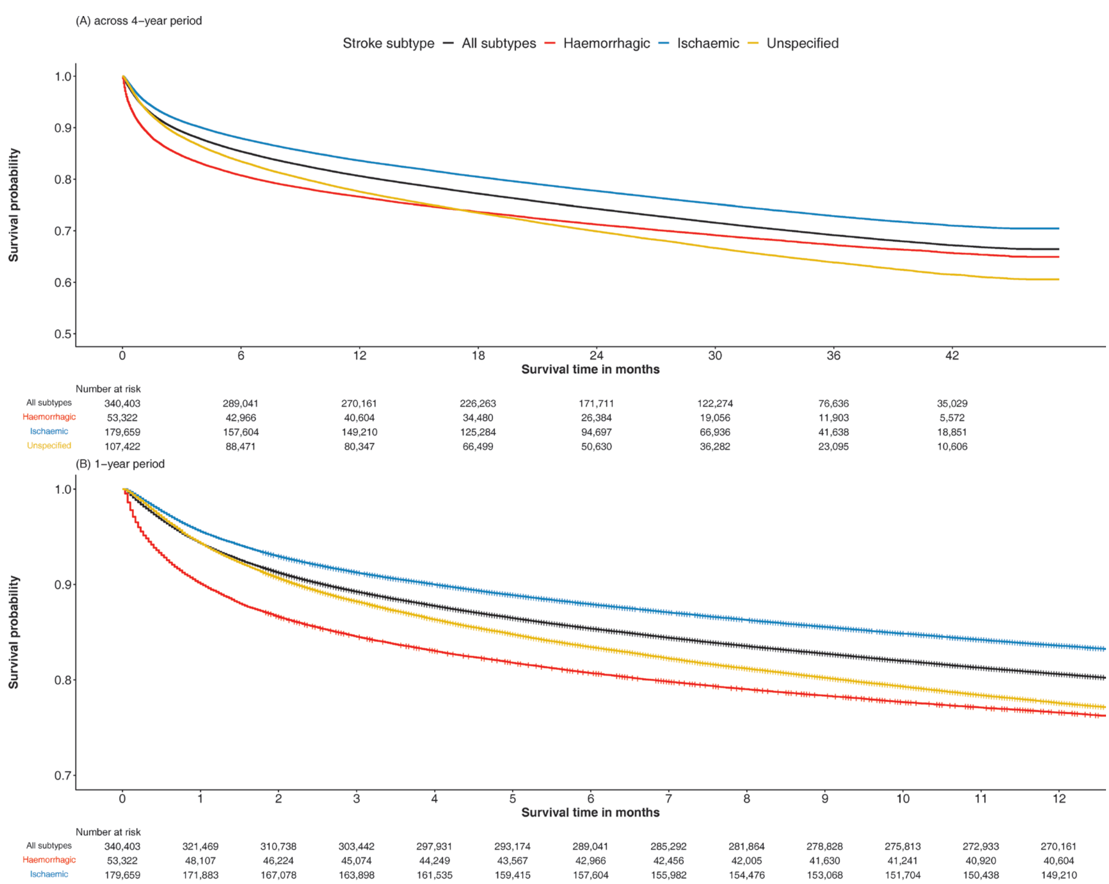

Figure 2 Kaplan-Meier curves for all-cause mortality. (A) 4-year survival probability, (B) 1-year survival probability

Table 3 Hazard ratios (HR) from the Gompertz model

	Overall	Haemorrhage	Ischaemic	Unspecified
Covariates	HR (95% CI)	HR (95% CI)	HR (95% CI)	HR (95% CI)
Haemorrhage	Reference			
Ischaemic	0.76 (0.75 to 0.78)			
Unspecified	0.77 (0.76 to 0.79)			
Women	Reference			
Men	1.07 (1.06 to 1.09)	1.01 (0.97 to 1.04)	1.06 (1.04 to 1.08)	1.12 (1.10 to 1.15)
Age <40	Reference			
Age 40–49	1.17 (1.07 to 1.28)	1.19 (1.04 to 1.37)	1.25 (1.08 to 1.44)	1.15 (0.94 to 1.41)
Age 50–59	1.57 (1.45 to 1.71)	1.53 (1.35 to 1.74)	1.77 (1.54 to 2.02)	1.45 (1.21 to 1.74)
Age 60–69	2.47 (2.28 to 2.68)	2.46 (2.18 to 2.79)	2.76 (2.42 to 3.15)	2.29 (1.92 to 2.73)
Age 70–79	4.58 (4.23 to 4.96)	4.45 (3.93 to 5.03)	5.11 (4.47 to 5.83)	4.26 (3.58 to 5.07)
Age 80–89	8.48 (7.83 to 9.19)	8.01 (7.07 to 9.08)	9.62 (8.43 to 10.99)	7.3 (6.12 to 8.71)
Age ≥90	15.59 (14.24 to 17.06)	13.23 (11.26 to 15.55)	18.00 (15.60 to 20.75)	13.53 (11.04 to 16.59)
Charlson Comorbidity Index (CCI): score 0	Reference			
CCI: score 1–2	2.12 (1.92 to 2.34)	1.71 (1.45 to 2.00)	2.72 (2.29 to 3.22)	1.85 (1.51 to 2.25)
CCI: score ≥3	5.77 (4.18 to 7.97)	5.8 (2.58 to 13.02)	4.90 (2.85 to 8.42)	5.66 (3.50 to 9.16)
No rehabilitation	Reference			
Received rehabilitation	0.85 (0.84 to 0.86)	0.75 (0.73 to 0.78)	0.87 (0.85 to 0.88)	0.92 (0.89 to 0.95)
No thrombolysis	Reference			
Received thrombolysis	0.93 (0.89 to 0.96)	1.02 (0.74 to 1.40)	0.86 (0.82 to 0.89)	0.90 (0.73 to 1.10)
No recurrent stroke	Reference			
Recurrent stroke	1.28 (1.26 to 1.31)	1.14 (1.09 to 1.20)	1.36 (1.33 to 1.40)	1.23 (1.19 to 1.28)
Length of stay (LOS) <3 days	Reference			
LOS 3–7 days	1.16 (1.14 to 1.18)	0.63 (0.61 to 0.66)	1.32 (1.29 to 1.35)	1.21 (1.18 to 1.24)
LOS 7–15 days	1.82 (1.78 to 1.85)	0.76 (0.72 to 0.79)	2.56 (2.49 to 2.63)	1.81 (1.75 to 1.86)
LOS ≥16 days	2.45 (2.39 to 2.51)	1.13 (1.08 to 1.18)	3.54 (3.41 to 3.66)	2.40 (2.30 to 2.50)
Hospital type: primary and community hospital	Reference			
Mid-level	0.93 (0.91 to 0.96)	1.05 (0.96 to 1.14)	1.00 (0.96 to 1.04)	0.87 (0.83 to 0.90)
Standard-level	1.00 (0.98 to 1.02)	1.10 (1.03 to 1.17)	1.08 (1.05 to 1.12)	0.94 (0.91 to 0.97)
Advanced-level	0.91 (0.89 to 0.92)	0.99 (0.94 to 1.06)	1.01 (0.98 to 1.04)	0.86 (0.83 to 0.88)
Non-Ministry of Public Health	0.73 (0.70 to 0.75)	0.83 (0.75 to 0.91)	0.76 (0.71 to 0.81)	0.66 (0.62 to 0.70)
Private hospitals/clinics	0.99 (0.94 to 1.04)	1.02 (0.91 to 1.16)	1.05 (0.97 to 1.13)	0.95 (0.88 to 1.03)

one-third of patients with stroke received rehabilitation during their incident stroke and the percentage of thrombolysis was 7% for patients with ischaemic strokes. Possible explanations for a low rate of thrombolytic therapy[10–12] could relate to (a) the onset of symptoms had been more than 4.5 hours[7 17] which might be affected by health literacy of patients and families,[18] or (b) patients may have had contraindications or poor prognosis, which could affect the rate of thrombolysis initiation. Additionally, costs of thrombolytic therapy may have played a role in the mean annual costs as patients who received thrombolytic therapy had higher mean annual costs[18 19] compared with patients who did not receive thrombolytic therapy; however, it also played a vital role in improvement of mortality outcomes.

Our results support previous findings that although haemorrhagic is less common than ischaemic stroke, the cost that these patients incur tends to be higher.[18 20 21] This could be because haemorrhagic strokes are associated with a poorer prognosis,[22 23] higher risk of mortality,[18 24] and requiring more resources, such as longer hospitalisations,[18] to treat patients. Costs tended to be higher in older age groups in all stroke subtypes and costs incurred by patients with haemorrhagic stroke was highest in all age groups. We also found that patients with haemorrhagic stroke were younger than patients with ischaemic stroke. Furthermore, mean LOS in our study was shorter than other studies, ranging from 10 to 40 days[21 25 26] but our finding is consistent with another Thai study.[18] The shorter LOS is likely to be related to the diagnostic-related groups (DRGs) concepts to achieve cost containment, while the differences between other countries could be due to the variation of periods that counted after their hospitalisation.

We observed a low proportion of patients accessing rehabilitation services. This could be due to loss to follow-up while patients were being transferred to other healthcare settings, or lack of awareness of patients towards the importance of rehabilitation.[5] Moreover, this finding also showed that patients with stroke did not receive inpatient rehabilitation properly in current practices but the new policy recommends inpatient rehabilitation services.[27] These should focus further on cost-effectiveness and HRQoL such as the Barthel index scores, which has been suggested in the new rehabilitation guideline. However, patients receiving rehabilitation incurred lower costs than those who did not receive any rehabilitation. This could be partly explained by a less costly DRG value when discharged, with the reimbursement rate being lower than in the non-rehabilitation group. Another possible explanation is that there could be selection of faster recovering patients (with fewer comorbidities), who have the potential to gain more benefit from rehabilitation in real-life practices.[27]

Patients with ischaemic and unspecified stroke had a reduced mortality risk compared with patients with haemorrhagic stroke. Our findings related to an increased risk of mortality for older patients with stroke is consistent with a recent Thai study which indicates that stroke in the elderly is associated with higher mortality.[28] Longer LOS was also associated with an increased mortality risk. These results may be explained by the fact that shorter LOS might be associated with lower risk of mortality or less severe strokes.[22 29] Also, patients in regions other than Bangkok had a higher risk of death. This is comparable with previous Thai studies.[28] As quality of care may have an effect on stroke survival, this inequality between health regions could be attributed to the differences in stroke management systems. Moreover, a scarcity of specialists in some health regions as well as the differences in advanced medical technologies could be attributed to differences in the quality of stroke care.[28 29] Receiving rehabilitation was associated with a 15% decrease in the risk of death. Previous research reported that early rehabilitation is beneficial after stroke in the short-term and long-term.[30–32]

These results provide important insights into the different associations of our included covariates when mortality risk is modelled separately by stroke subtype and reveals findings that were masked when considering all stroke subtypes together. This information will be useful for policymakers for stroke management of specific subtypes in Thailand. Special attention for the service plan strategy should be given to the following activities: (1) follow-up on national KPI assessments in terms of health outcomes of stroke survivors to decrease costs and long-term risk of mortality, (2) improvement of rehabilitation post-hospital discharge as well as a daily functioning measurement (eg, recording of the Barthel Index scores in the national level database), (3) improvement of the health information system, linkage for interhospital transfer and continuum of care and (4) ensuring equitable access to care in all geographical areas.

Strengths and limitations

Our study provides results of mean annual cost and all-cause mortality of all stroke subtypes with the most up-to-date nationally representative stroke cohort. Although there are several published studies assessing the national stroke data, these mostly focused on costs or mortality only in specific subtypes and used out-of-date data.[19 28 33] Our study has some limitations. The current data covered only UCS patients and did not include patients who seek treatment at non-contracted hospitals. Data on endovascular thrombectomy were also not available for the covered population. The analysis was based on hospitalised stroke events; however, we could have missed a small proportion of patients with less severe symptoms who were not admitted to hospital. Cause of death and clinical outcome measures, for example, functional scores, could not be obtained. We were therefore unable to evaluate functional disability or conduct competing event analysis. Mortality was analysed based on in-hospital mortality only, patients dying at home were not included. Finally, this study made an assumption on the history of previous strokes to determine incident stroke based on a 2-year lookback period, rather than clinical history of patients.

CONCLUSION

This study shows that crucial variables that were significantly associated with increasing costs or risk of mortality included being admitted to non-MOPH hospitals and being treated at health regions outside Bangkok. Importantly, rehabilitation might help save costs as well as contribute to a reduction in the risk of mortality. The measurement and recording of proven health outcomes measures of rehabilitation in the national level database, such as the Barthel scores, should be emphasised. The findings also revealed key differences between stroke subtypes which could help determine measurements for stroke management towards mitigation of costs and to ensure that the quality of stroke services is adequate to preserve or improve health outcomes of patients with stroke.

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Supplementary Table 1. Current stroke care

The service plan strategy 2018 – 2022 [1] has been endorsed by the Thai ministry of public health (MOPH) aiming to improve service delivery of stroke care and the national KPIs have been set according to hospital level. There are 12 health regions under the MOPH, comprising of serves 3-5 million people in 4-8 provinces, which have an authority to design their systems for improvement of service provision under the concept of a seamless health service network, self-contain and referral hospital cascade.

In terms of stroke care, Thai MOPH has introduced the stroke fast track system which includes emergency medical services (EMS) since 2008 [2]. The 'ship-and-drip' or 'drip-and-ship' and mothership models are performed in Thailand [3, 4]. The selection of model is depended on a hospital capacity and the most suitable for the context of each health region[3]. However, the ship-and-drip' model seems to be the most frequently used model to receive thrombolytic treatment, from spoke to hub hospital [3]. A thrombolysis treatment can be prescribed by non-neurologist, e.g. well-trained general practice, under supervision of a neurologist at a hub. Furthermore, stroke units (SUs) can be set up and provisioned in advanced-level and standard-level hospitals; however, SUs can also be set up in big or node mid-level hospitals. In addition, stroke corners (SCs) might be set up in mid-level hospitals. SC denotes a specialised area in the general inpatient ward to provide specifically for stroke care. The service plan strategy 2018 - 2022 stipulates that SU should be set up and deliver stroke service in all advanced-level, and in 80% of standard-level hospitals within each health region. rehabilitation units should be established at all mid-level hospitals to reduce the over-crowding of stroke care in advanced-level and standard-level hospitals and to increase capacity and accessibility of rehabilitation in rural areas. In 2019, all provinces have the stroke fast track system while the percentage of SUs in advanced-level and standard-level hospitals were 97% and 65%, respectively [5].

Supplementary Table 2. Classification of hospitals in Thailand [1, 6-8]

Types of hospitals	Level of care	Hospital level	Number of hospitals [9]	Details
hospital under the ministry of public health (MOPH)	Tertiary	Advanced-level referral hospitals (A-level)	34	- A regional/provincial hospital and mostly located in big provincial cities throughout Thailand. some hospitals can have a function as the medical school. - more than 500 hospital beds per hospital. - having all major medical specialists, all minor specialties and all sub-specialties. - being able to deliver advance and sophisticate health technology.
		Standard-level referral hospitals (S-level)	49	- A provincial general hospital and designated as the hospital node of the province. - 300 to 500 hospital beds per hospital. - having all major medical specialists, all minor specialties and sub - specialties in some fields (as needed).
		Mid-level referral hospitals (M1-level)	36	- A district general hospital. - 120 to 30 hospital beds per hospital. - having medical specialists in all 6 major specialties (physician, surgeon, obstetrician, paediatrician, orthopaedist and anaesthesiologist) and some minor specialties that are required.
	Secondary	Mid-level referral hospitals (M2-level)	84	- A big/node community hospitals. - 120 to 30 hospital beds per hospital. - having medical specialists in all 6 major specialties (physician, surgeon, obstetrician, paediatrician, orthopaedist and anaesthesiologist).
		First-level referral hospital (F-level)	694	- A district hospital or community hospital. - 10 to more than 120 hospital beds per hospital. - providing the services that cover basic primary health care and secondary cares from medical specialties in all or some fields.

Types of hospitals	**Level of care**	**Hospital level**	**Number of hospitals [9]**	**Details**
	Primary	Primary health care	N/A	- offering basic primary care services including health prevention and promotion, but not for admission services. - closed to the community, village or patient's home.
non-MOPH hospitals	wide variations in levels of care	N/A	N/A	- hospitals under other governmental ministries and organisations. - included university hospitals, military and police hospitals, other specialised hospitals (e.g. heart, cancer), and hospitals in the Bangkok area.
Private health care sectors	wide variations in levels of care	N/A	N/A	- contracted private hospitals and private clinics partnering with the National Health Security Office (NHSO) – the purchasing agencies which manages the Universal Coverage Scheme (UCS). - delivering free health services to the UCS beneficiaries.

Kumluang S, *et al. BMJ Open* 2023; 13:e072259. doi: 10.1136/bmjopen-2023-072259

Supplementary Table 3. Lists of covariates

Covariates	Category
Age	Categorised into 10-year age bands starting from 40-49 years until ≥90 years where the youngest (age <40 years) served as the reference group.
Sex	Sex in 2 categories: women and men. The reference group was women.
Comorbidity Index	Comorbidities were based on secondary diagnoses using the Charlson comorbidity index (CCI). The scales were categorised into three categories: a score of zero (no comorbidity), score 1-2 and score ≥3. No comorbidities served as the reference group.
Type of stroke	Stroke subtypes were divided into three groups: ischemic, unspecified and haemorrhagic stroke (reference).
Length of stay (LOS)	LOS was converted to a categorical variable which was dichotomised to LOS <3 days (reference group), LOS 3 to 7 days, LOS 8 to 15 days and LOS >15 days.
Rehabilitation	Stroke patients who received rehabilitation during the incident in-patient admission or out-patient visit were compared to patients who did not receive rehabilitation (reference group).
Thrombolytic therapy	Stroke patients who received thrombolysis during the incident in-patient admission or out-patient visit were compared to patients who did not receive this treatment (reference).
Health region	Health regions in Thailand were classified into 12 health region and the Bangkok area. As Bangkok outperforms other regions in terms of technology advancements, it is used as the reference group.
Type of hospital	Hospital types were divided into six groups, comprising (1) primary and community hospitals (reference group), (2) mid-level, (3) standard-level, (4) advanced-level, (5) non-MOPH hospitals which included university hospitals, military hospitals, other specialised hospitals, hospitals in the Bangkok area, and (6) private hospitals/clinics.
Year of admission	Year of admission ranged from year of the first admission until the last visit in the data. The first year of admission served as the reference group.
Recurrent event	Stroke patients experiencing a recurrent stroke event were compared to patients who did not experience a recurrent stroke (reference group). This covariate was used only in survival analysis.

Kumluang S, *et al. BMJ Open* 2023; 13:e072259. doi: 10.1136/bmjopen-2023-072259

Supplementary Table 4. Two-part models (TPM)

The TPM consists of two parts: the first part estimates the probability of incurring any healthcare costs (Pr(Y>0 | X)) using a logistic regression model. The second part estimates costs conditional on having incurred positive costs using Generalised Linear Model (GLM) with a gamma distribution and log link. Mean estimated costs per individual patient can be calculated by multiplying the first and second part.

(1) Probability of incurring any healthcare costs

The dependent binary variable (Y) can be estimated in the form of log odds ratio

$$\Pr(Y>0 \mid X) = \frac{exp(\beta^{j} X_{it}^{j})}{(1+exp(\beta^{j} X_{it}^{j})}$$ Equation (1)

Where:
- X_{it}^{j} is the variables at that could incur costs (j = 1, ... J). These Variables comprised age group, sex, CCI group, LOS group and interaction terms between age group and CCI group.
- i is the patient i at time t.
- β^{j} is the estimated coefficient for variable at the j^{th}.

(2) Cost estimation conditional on having incurred positive cost values

$$\mathbf{E(Y|Y>0, X) = exp(\boldsymbol{\beta}^{j} X_{i}^{j})}$$ Equation (2)

Where:
- X_{it}^{j} is the variables at that could influence costs (j = 1, ... J). These Variables comprised the same variables that were used in the first part, but in addition variables that would affect costs were also included: stroke subtype, type of hospital, health region, receiving rehabilitation at admission, receiving thrombolytic therapy at admission, year of admission and interaction between age group and CCI group.
- β^{j} is the coefficient on the j^{th} variable in the GLM equation

(3) Multiplying first and second part for mean estimated costs per individuals

$$E(Y|X) = \Pr(Y>0 \mid X) * E(Y|Y>0, X)$$ Equation (3)

Supplementary Table 5. Survival analysis

Survival analyses were performed in three parts as follows.
(1) a non-parametric method using the Kaplan-Meier survival analysis which estimated the survival probability from observed survival times. The survival function is denoted in Equation (4).

Survival function

$$S(t_k) = S(t_{k-1}) * \left(1 - \frac{d_k}{n_k}\right) \quad \text{Equation (4)}$$

Where:
- d_k is the number of events at time t_k
- n_k is the size of risk sets at time t_k

(2) a semi-parametric analysis was carried out using Cox proportional hazards regression which was used to investigate the effect of covariates on all-cause mortally (Equation (5)).

Hazard function

$$h(t, X) = h_0(t)e^{\sum_{i=0}^{p} \beta_i X_i} \quad \text{Equation (5)}$$

Where:
- X_i is covariate variables. These Variables comprised age group, sex, CCI group, LOS group, stroke subtype, receiving rehabilitation at admission, receiving thrombolytic therapy at admission, recurrence status, type of hospital, health region, and interaction between age group and CCI group.
- $h_0(t)$ is baseline hazard function
- β_i is the regression coefficients indicating the effect of each covariate X_i

(3) a parametric model using the Gompertz distribution. Generally, the hazard is assumed to be constant in the exponential model while the Gompertz models have a monotonically increasing or decreasing hazard as it contains the distributional parameters that determine the shape of hazard models.

Gompertz distribution

$$\text{Hazard function} = h(t) = \exp(\exp(\lambda) + \gamma t) \quad \text{Equation (6)}$$

$$\text{Survival function} = S(t) = \exp\left[\frac{-\exp(\lambda)(\exp(\gamma t) - 1}{\gamma}\right] \quad \text{Equation (7)}$$

Where:
λ = scale parameter and $\lambda > 0$, for $0 \leq t < \infty$
γ = shape parameter
$\gamma > 0$ = increasing hazard
$\gamma < 0$ = decreasing hazard

Supplementary Table 6. Resource Utilisation by all subtypes and by stroke subtypes

	Haemorrhage N=78,081	Ischaemic N=192,414	Unspecified N=115,989	Total N=386,484
Length of stay (mean, SD)	9.9 (16)	6.1 (10)	6.7 (11)	7.1 (12)
Imaging (CT scan) (N, %)	60,929 (78)	167,860 (87)	30,194 (26)	258,983 (67)
- Primary and community	5,649 (7)	12,381 (6)	3,540 (3)	21,570 (6)
- Mid-level	3,463 (4)	18,498 (10)	3,220 (3)	25,181 (6)
- Standard-level	16,183 (21)	48,336 (25)	7,504 (6)	72,023 (19)
- Advanced-level	31,691 (41)	65,886 (34)	9,791 (8)	107,368 (28)
- Non-MOPH*	2,302 (3)	17,664 (9)	5,158 (4)	25,124 (6)
- Private hospitals/clinics	1,641 (2)	5,095 (3)	981 (1)	7,717 (2)
Thrombolysis (N, %)	178 (0.2)	12,951 (6.7)	459 (0.4)	13,588 (3.5)
- Primary and community	8 (0.02)	404 (0.2)	55 (0.05)	467 (0.1)
- Mid-level	29 (0.04)	1,105 (0.6)	37 (0.03)	1,171 (0.3)
- Standard-level	53 (0.07)	3,885 (2)	153 (0.13)	4,091 (1.1)
- Advanced-level	69 (0.09)	5,775 (3)	144 (0.12)	5,988 (1.5)
- Non-MOPH	18 (0.02)	1,686 (0.9)	70 (0.06)	1,774 (0.5)
- Private hospitals/clinics	1 (0)	96 (0.05)	0 (0)	97 (0.03)
CT scan & Thrombolysis (N, %)	155 (0.2)	12,884 (6.7)	326 (0.3)	13,365 (3.5)
- Primary and community	4 (0.01)	399 (0.2)	13 (0.01)	416 (0.1)
- Mid-level	26 (0.03)	1,103 (1)	26 (0.02)	1,155 (0.03)
- Standard-level	49 (0.06)	3,877 (2)	121 (0.1)	4,047 (1)
- Advanced-level	61 (0.08)	5,760 (3)	113 (0.1)	5,934 (1.5)
- Non-MOPH	14 (0.02)	1,652 (1)	53 (0.05)	1,719 (0.4)
- Private hospitals/clinics	1 (0)	93 (0.05)	0 (0)	94 (0.02)
Rehabilitation (N, %)	18,641 (24)	89,716 (47)	17,204 (15)	125,561 (32)
- Primary and community	886 (1)	8,306 (4)	7,335 (6)	16,527 (4)
- Mid-level	1,064 (1)	9,996 (5)	1,604 (1)	12,664 (3)
- Standard-level	4,784 (6)	29,313 (15)	3,157 (3)	37,254 (10)
- Advanced-level	10,030 (13)	34,988 (18)	3,388 (3)	48,406 (13)
- Non-MOPH	1,525 (2)	5,610 (3)	1,368 (1)	8,503 (2)
- Private hospitals/clinics	352 (0.5)	1,503 (0.8)	0,352 (0.3)	2,207 (0.6)
Type of hospital (N, %)				
- Primary and community	5,434 (7)	27,896 (14)	51,737 (45)	85,067 (22)
- Mid-level	4,230 (5)	20,158 (10)	8,675 (7)	33,063 (8)
- Standard-level	19,024 (24)	51,962 (27)	16,635 (14)	87,621 (23)

Kumluang S, *et al. BMJ Open* 2023; 13:e072259. doi: 10.1136/bmjopen-2023-072259

	Haemorrhage N=78,081	**Ischaemic** N=192,414	**Unspecified** N=115,989	**Total** N=386,484
- Advanced-level	39,348 (50)	70,960 (37)	24,260 (21)	134,568 (35)
- Non-MOPH	7,596 (10)	14,990 (8)	11,228 (10)	33,814 (9)
- Private hospitals/clinics	2,449 (3)	6,448 (3)	3,454 (3)	12,351 (3)
Modes of hospitalisation*				
Out-patient visits (mean, SD)	3.7 (7.4)	3.7 (6.9)	4.2 (8.0)	3.9 (7.4)
In-patient admissions (mean, SD)	2.0 (2.1)	2.4 (2.4)	2.8 (3.1)	2.5 (2.6)
Frequency of recurrence events[†] (mean, SD)	1.2 (0.7)	1.2 (0.6)	1.2 (0.8)	1.2 (0.7)

SD: standard deviation; *all cohort data; [†]Exclude patients who died during their incident stroke

Supplementary Table 7. Mean annual cost per patient by all subtypes and by stroke subtypes

Variable	All subtypes	**Haemorrhagic** mean (95%CI)	**Ischemic** mean (95%CI)	**Unspecified** mean (95%CI)
Stroke subtype				
Haemorrhagic	48,599 (48,099-49,099)	..	..	..
Ischemic	34,125 (33,879-34,371)	..	..	..
Unspecified	34,629 (34,284-34,974)	..	..	..
Age group				
<40	34,752 (33,903-35,601)	45,335 (44,187-46,482)	31,833 (31,030-32,636)	32,303 (31,451-33,155)
40-49	32,458 (31,916-33,001)	42,340 (41,567-43,114)	29,730 (29,201-30,259)	30,170 (29,592-30,748)
50-59	34,375 (33,970-34,779)	44,873 (44,228-45,517)	31,508 (31,099-31,918)	31,974 (31,501-32,447)
60-69	37,562 (37,208-37,917)	49,017 (48,375-49,660)	34,419 (34,052-34,785)	34,927 (34,484-35,370)
70-79	40,111 (39,722-40,499)	52,315 (51,602-53,028)	36,734 (36,341-37,128)	37,277 (36,802-37,752)
80-89	41,497 (41,008-41,986)	54,113 (53,286-54,940)	37,997 (37,518-38,475)	38,558 (38,006-39,111)
≥90	41,187 (39,987-42,387)	53,710 (52,057-55,362)	37,714 (36,603-38,824)	38,271 (37,112-39,430)
Sex				
Women	36,959 (36,690-37,229)	48,313 (47,749-48,877)	33,924 (33,626-34,222)	34,425 (34,040-34,810)
Men	37,366 (37,116-37,616)	48,845 (48,307-49,382)	34,297 (34,008-34,587)	34,804 (34,426-35,183)
Charlson Comorbidity Index				
No CCI	30,086 (29,860-30,312)	39,232 (38,806-39,659)	27,548 (27,319-27,777)	27,955 (27,597-28,314)
score 1-2	44,448 (44,127-44,768)	57,923 (57,228-58,617)	40,672 (40,300-41,044)	41,273 (40,853-41,693)
score ≥3	70,242 (67,842-72,641)	91,482 (88,226-94,738)	64,236 (62,031-66,441)	65,185 (62,975-67,396)
LOS				
LOS <3 days	29,087 (28,837-29,336)	38,525 (38,012-39,038)	27,051 (26,794-27,309)	27,451 (27,123-27,780)
LOS 3-7 days	29,782 (29,545-30,019)	39,448 (38,961-39,935)	27,699 (27,446-27,953)	28,109 (27,780-28,437)
LOS 8-15 days	44,395 (43,916-44,875)	58,793 (57,999-59,587)	41,283 (40,777-41,789)	41,893 (41,318-42,468)
LOS >16 days	93,221 (92,040-94,403)	123,421 (121,689-125,153)	86,663 (85,434-87,891)	87,944 (86,574-89,313)

Kumluang S, *et al. BMJ Open* 2023; 13:e072259. doi: 10.1136/bmjopen-2023-072259

Variable	All subtypes	Haemorrhagic mean (95%CI)	Ischemic mean (95%CI)	Unspecified mean (95%CI)
Rehabilitation				
Not rehabilitation	38,490 (38,258-38,722)	50,322 (49,794-50,850)	35,335 (35,038-35,632)	35,857 (35,497-36,217)
Received rehabilitation	34,685 (34,381-34,988)	45,347 (44,761-45,933)	31,841 (31,551-32,131)	32,312 (31,892-32,731)
Thrombolysis				
No thrombolysis	37,021 (36,828-37,213)	48,375 (47,880-48,870)	33,967 (33,718-34,217)	34,469 (34,126-34,813)
Thrombolysis	41,986 (40,992-42,980)	54,863* (53,429-56,297)	38,523 (37,618-39,429)	39,093 (38,098-40,087)
Hospital type				
Primary and community	32,001 (31,629-32,374)	41,863 (41,205-42,521)	29,395 (29,000-29,790)	29,829 (29,461-30,198)
Mid-level	37,402 (36,806-37,997)	48,927 (48,008-49,846)	34,355 (33,793-34,918)	34,863 (34,233-35,493)
Standard-level	35,798 (35,386-36,211)	46,829 (46,152-47,506)	32,882 (32,481-33,283)	33,368 (32,873-33,863)
Advanced-level	33,524 (33,224-33,824)	43,854 (43,334-44,374)	30,793 (30,486-31,100)	31,248 (30,831-31,666)
Non-MOPH	53,847 (52,728-54,966)	70,440 (68,846-72,034)	49,461 (48,385-50,537)	50,192 (49,086-51,298)
Private hospitals/clinics	56,440 (54,608-58,272)	73,833 (71,356-76,309)	51,843 (50,152-53,535)	52,609 (50,821-54,398)
Health region				
Bangkok	37,844 (36,943-38,745)	49,466 (48,202-50,731)	34,734 (33,900-35,567)	35,247 (34,342-36,153)
1	35,507 (35,030-35,984)	46,412 (45,661-47,163)	32,589 (32,114-33,065)	33,071 (32,555-33,587)
2	36,573 (36,019-37,128)	47,806 (46,976-48,636)	33,568 (33,031-34,105)	34,064 (33,468-34,660)
3	36,839 (36,004-37,673)	48,153 (46,980-49,325)	33,812 (33,026-34,597)	34,311 (33,482-35,140)
4	39,182 (38,287-40,077)	51,215 (49,961-52,470)	35,962 (35,125-36,799)	36,494 (35,599-37,388)
5	37,231 (36,538-37,925)	48,666 (47,662-49,670)	34,172 (33,513-34,831)	34,677 (33,967-35,387)
6	36,967 (36,301-37,633)	48,320 (47,340-49,300)	33,929 (33,287-34,571)	34,430 (33,758-35,103)
7	38,275 (37,629-38,921)	50,030 (49,078-50,983)	35,130 (34,503-35,757)	35,649 (34,986-36,312)
8	37,173 (36,658-37,687)	48,589 (47,792-49,387)	34,118 (33,609-34,627)	34,622 (34,066-35,178)

Variable	All subtypes	Haemorrhagic mean (95%CI)	Ischemic mean (95%CI)	Unspecified mean (95%CI)
9	38,706 (38,122-39,290)	50,594 (49,717-51,471)	35,526 (34,957-36,094)	36,051 (35,428-36,674)
10	37,291 (36,648-37,933)	48,743 (47,792-49,695)	34,226 (33,605-34,847)	34,732 (34,076-35,388)
11	35,772 (35,043-36,501)	46,758 (45,726-47,790)	32,832 (32,151-33,513)	33,317 (32,567-34,067)
12	36,395 (35,651-37,140)	47,573 (46,514-48,633)	33,405 (32,699-34,110)	33,898 (33,149-34,648)
Follow-up year				
1	39,646 (39,343-39,948)	51,855 (51,246-52,463)	36,411 (36,079-36,742)	36,949 (36,524-37,374)
2	39,991 (39,701-40,282)	52,307 (51,714-52,900)	36,728 (36,407-37,050)	37,271 (36,845-37,697)
3	39,845 (39,540-40,151)	52,116 (51,501-52,731)	36,594 (36,259-36,929)	37,135 (36,711-37,560)
4	29,496 (29,087-29,905)	38,579 (37,940-39,218)	27,089 (26,688-27,491)	27,490 (27,047-27,932)

CI: confidence interval; LOS: length of stay. [*]From 178 (0.05%) out of 386,484 patients; the proportion of individuals with missing follow-up data stratified by follow-up year were 47% in follow-up year 2, 43% in follow-up year 3 and 39% in follow-up year 4.

Supplementary Table 8. Hazard ratio from the Gompertz model

	Overall	Haemorrhage	Ischaemic	Unspecified
Covariates	**HR (95%CI)**	**HR (95%CI)**	**HR (95%CI)**	**HR (95%CI)**
Haemorrhage	Reference			
Ischaemic	0.76 (0.75-0.78)			
Unspecified	0.77 (0.76-0.79)			
Women	Reference			
Men	1.07 (1.06-1.09)	1.01 (0.97-1.04)	1.06 (1.04-1.08)	1.12 (1.10-1.15)
Age <40	Reference			
Age 40-49	1.17 (1.07-1.28)	1.19 (1.04-1.37)	1.25 (1.08-1.44)	1.15 (0.94-1.41)
Age 50-59	1.57 (1.45-1.71)	1.53 (1.35-1.74)	1.77 (1.54-2.02)	1.45 (1.21-1.74)
Age 60-69	2.47 (2.28-2.68)	2.46 (2.18-2.79)	2.76 (2.42-3.15)	2.29 (1.92-2.73)
Age 70-79	4.58 (4.23-4.96)	4.45 (3.93-5.03)	5.11 (4.47-5.83)	4.26 (3.58-5.07)
Age 80-89	8.48 (7.83-9.19)	8.01 (7.07-9.08)	9.62 (8.43-10.99)	7.3 (6.12-8.71)
Age ≥90	15.59 (14.24-17.06)	13.23 (11.26-15.55)	18.00 (15.60-20.75)	13.53 (11.04-16.59)
CCI: score 0	Reference			
CCI: score 1-2	2.12 (1.92-2.34)	1.71 (1.45-2.00)	2.72 (2.29-3.22)	1.85 (1.51-2.25)
CCI: score ≥3	5.77 (4.18-7.97)	5.8 (2.58-13.02)	4.90 (2.85-8.42)	5.66 (3.50-9.16)
No rehabilitation	Reference			
Received rehabilitation	0.85 (0.84-0.86)	0.75 (0.73-0.78)	0.87 (0.85-0.88)	0.92 (0.89-0.95)
No rt-PA	Reference			
Received rt-PA	0.93 (0.89-0.96)	1.02* (0.74-1.40)	0.86 (0.82-0.89)	0.90 (0.73-1.10)
No recurrent stroke	Reference			
Recurrent stroke	1.28 (1.26-1.31)	1.14 (1.09-1.20)	1.36 (1.33-1.40)	1.23 (1.19-1.28)
LOS <3 days	Reference			
LOS 3-7 days	1.16 (1.14-1.18)	0.63 (0.61-0.66)	1.32 (1.29-1.35)	1.21 (1.18-1.24)
LOS 7-15 days	1.82 (1.78-1.85)	0.76 (0.72-0.79)	2.56 (2.49-2.63)	1.81 (1.75-1.86)
LOS ≥16 days	2.45 (2.39-2.51)	1.13 (1.08-1.18)	3.54 (3.41-3.66)	2.40 (2.30-2.50)
hospital type: primary and community hospital	Reference			

Covariates	Overall HR (95%CI)	Haemorrhage HR (95%CI)	Ischaemic HR (95%CI)	Unspecified HR (95%CI)
mid-level	0.93 (0.91-0.96)	1.05 (0.96-1.14)	1.00 (0.96-1.04)	0.87 (0.83-0.90)
standard-level	1.00 (0.98-1.02)	1.10 (1.03-1.17)	1.08 (1.05-1.12)	0.94 (0.91-0.97)
advanced-level	0.91 (0.89-0.92)	0.99 (0.94-1.06)	1.01 (0.98-1.04)	0.86 (0.83-0.88)
non-MOPH	0.73 (0.70-0.75)	0.83 (0.75-0.91)	0.76 (0.71-0.81)	0.66 (0.62-0.70)
private hospitals/clinics	0.99 (0.94-1.04)	1.02 (0.91-1.16)	1.05 (0.97-1.13)	0.95 (0.88-1.03)
Bangkok	Reference			
Health Region1	1.13 (1.08-1.18)	1.19 (1.08-1.32)	1.21 (1.12-1.29)	1.01 (0.93-1.08)
Health Region2	1.11 (1.06-1.17)	1.18 (1.06-1.31)	1.18 (1.10-1.27)	0.99 (0.92-1.07)
Health Region3	1.22 (1.16-1.28)	1.46 (1.29-1.65)	1.32 (1.22-1.42)	1.01 (0.93-1.10)
Health Region4	1.26 (1.20-1.32)	1.54 (1.38-1.72)	1.42 (1.32-1.53)	1.02 (0.95-1.09)
Health Region5	1.04 (0.99-1.09)	1.02 (0.91-1.14)	1.14 (1.06-1.22)	0.90 (0.83-0.97)
Health Region6	1.14 (1.09-1.20)	1.25 (1.12-1.39)	1.22 (1.13-1.31)	0.99 (0.92-1.07)
Health Region7	1.29 (1.23-1.35)	1.31 (1.17-1.46)	1.39 (1.29-1.50)	1.14 (1.05-1.23)
Health Region8	1.25 (1.19-1.31)	1.40 (1.26-1.55)	1.34 (1.25-1.44)	1.05 (0.98-1.14)
Health Region9	1.09 (1.04-1.15)	1.07 (0.96-1.19)	1.21 (1.12-1.30)	0.94 (0.88-1.02)
Health Region10	1.25 (1.19-1.31)	1.35 (1.20-1.50)	1.34 (1.24-1.44)	1.04 (0.96-1.13)
Health Region11	1.09 (1.03-1.14)	1.24 (1.10-1.40)	1.20 (1.12-1.30)	0.89 (0.82-0.97)
Health Region12	1.19 (1.14-1.25)	1.39 (1.23-1.56)	1.31 (1.21-1.41)	0.99 (0.91-1.07)
Age <40#CCI score 0	Reference			
Age 40-49#score1-2	1.10 (0.98-1.23)	1.20 (0.99-1.45)	0.89 (0.73-1.09)	1.20 (0.95-1.52)
Age 50-59#score1-2	1.07 (0.97-1.19)	1.24 (1.04-1.48)	0.87 (0.73-1.04)	1.15 (0.93-1.43)
Age 60-69#score1-2	0.92 (0.83-1.02)	1.13 (0.95-1.34)	0.71 (0.59-0.84)	0.97 (0.78-1.19)
Age 70-79#score1-2	0.73 (0.66-0.81)	0.94 (0.79-1.12)	0.58 (0.49-0.69)	0.74 (0.60-0.91)
Age 80-89#score1-2	0.59 (0.53-0.65)	0.8 (0.67-0.95)	0.48 (0.41-0.57)	0.62 (0.50-0.76)

	Overall	Haemorrhage	Ischaemic	Unspecified
Covariates	**HR (95%CI)**	**HR (95%CI)**	**HR (95%CI)**	**HR (95%CI)**
Age ≥90#score1-2	0.46 (0.41-0.52)	0.62 (0.49-0.79)	0.38 (0.31-0.46)	0.49 (0.38-0.62)
Age 40-49#score ≥3	0.89 (0.60-1.31)	1.03 (0.37-2.86)	0.87 (0.45-1.71)	0.81 (0.46-1.43)
Age 50-59#score ≥3	1.07 (0.76-1.51)	1.02 (0.42-2.48)	1.27 (0.71-2.26)	0.98 (0.59-1.63)
Age 60-69#score ≥3	0.69 (0.49-0.96)	0.83 (0.35-1.94)	0.84 (0.48-1.46)	0.59 (0.36-0.96)
Age 70-79#score ≥3	0.42 (0.30-0.58)	0.43 (0.18-1.00)	0.48 (0.28-0.84)	0.37 (0.23-0.61)
Age 80-89#score ≥3	0.29 (0.21-0.40)	0.38 (0.16-0.89)	0.37 (0.21-0.65)	0.27 (0.16-0.44)
Age ≥90#score ≥3	0.19 (0.13-0.27)	0.20 (0.06-0.62)	0.21 (0.11-0.40)	0.19 (0.11-0.32)

CI: confidence interval; HR: hazard ratio. *From 178 (0.05%) out of 386,484 patients.

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