Observational Study

Medicine®

OPEN

Association between volume of surgery for acute hemorrhagic stroke and mortality

Bo Yeon Lee, MPH[a], Shin Ha, MPH, PhD[b], Yo Han Lee, MD, PhD[c,d,*]

Abstract

This study aimed to investigate the association between volume of surgery and mortality in relation to interventions for acute hemorrhagic stroke, namely craniotomy and trephination.

We obtained data on acute hemorrhagic stroke patients for a 5-year period (2009–2013) from the Health Insurance Review and Assessment Service. Hospitals were classified into 3 categories according to volume of surgery (low, medium, high). To avoid intentionally setting a cutoff, we placed the hospitals in order from those with high volume of surgery to those with low volume of surgery and divided them into 3 groups (tertile) according to the number of patients. The covariates were age, sex, hemorrhagic stroke site, type of health insurance, intensive care unit admission, history of hypertension, and Charlson comorbidity index. Multiple logistic regression analysis was performed with statistical significance set at 5%.

A total of 41,917 patients who underwent craniotomy (n=20,982) or trephination (n=20,935) for acute hemorrhagic stroke were analyzed according to hemorrhage site (subarachnoid and others). The results showed that mortality from acute hemorrhagic stroke decreased with increasing volume of surgery. For subarachnoid hemorrhage, the odds ratios of the medium- and high-volume surgery groups were significantly lower (0.74 and 0.59, respectively) for mortality within 7 days of admission, and were also significantly lower (0.78 and 0.68) for mortality within 30 days of admission than that of the low-volume surgery group. The results for other hemorrhage sites were similar. The association between mortality and volume of surgery was more evident in the craniotomy group. Although this study was limited to a single country (South Korea), it partially addressed the shortcomings of previous studies by analyzing a nationwide database and examining all types of hemorrhagic strokes.

Abbreviations: CCI = Charlson comorbidity index, HIRA = Health Insurance Review and Assessment Service, ICD-10 = International Classification of Disease, 10th version, ICU = intensive care unit.

Keywords: acute hemorrhagic stroke, craniotomy, hospital volume, outcomes, trephination

1. Introduction

Stroke is the second leading cause of death worldwide and one of the major causes of disability.[1] Globally, ischemic stroke is the most common type of stroke,[2] but hemorrhagic stroke remains a clinical challenge. In particular, intracerebral hemorrhage accounts for about 10% to 20% of all strokes.[3]

The relationship between volume of surgery and health outcomes is an interesting topic that has been used as an index for the assessment of the quality of medical care in various fields of clinical medicine, including surgery for hemorrhagic stroke.[4] Recently, several studies have been performed to investigate the relationships between volume of surgery and various outcome indices, including mortality, in relation to a number of neurosurgery topics, including aneurysm and subarachnoid hemorrhage.[5] These studies found that a large volume of surgery is positively associated with shortening of hospital stay, reduction of mortality, and reduction of medical costs.[6–13]

However, previous studies have tended to concentrate on patients with subarachnoid hemorrhage who require highly sophisticated techniques, namely craniotomy.[10,14] Therefore, there is a fundamental limitation explaining cases of hemorrhagic stroke, including acute stroke, solely based on the existing literature.[15] Patients with subarachnoid hemorrhage cannot represent the entire pool of patients with a hemorrhagic stroke because the prevalence of intracerebral hemorrhage is higher than that of subarachnoid hemorrhage. Thus, there is a need for studies that investigate all types of stroke surgeries, including intracerebral hemorrhage.

This study aimed to investigate the association between volume of surgery and mortality in relation to interventions for acute hemorrhagic stroke, namely craniotomy and trephination.

2. Methods

2.1. Study population

Korea's health insurance system comprises social health insurance and government medical aid, and registration is mandatory for all Korean nationals.[16] All healthcare institutions in Korea that provide healthcare are required to submit the details of the

Editor: Danny Chu.

BYL and SH have contributed equally to this study.

YHL is an epidemiologist.

Authors declare no competing interests.

Supplemental Digital Content is available for this article.

[a] Department of Public Health, Health Insurance Review and Assessment Service, Graduate School of Korea University, [b] Health Insurance Review and Assessment Service, Korea University Medical Center, Seoul, [c] Department of Preventive Medicine, Konyang University College of Medicine, [d] Myunggok Medical Research Center, Daejeon, Republic of Korea.

[*] Correspondence: Yo Han Lee, Konyang University College of Medicine, Daejeon, Republic of Korea (e-mail: vionic@hanmail.net).

Medicine (2018) 97:35(e12105)

Received: 31 December 2017 / Accepted: 3 August 2018

http://dx.doi.org/10.1097/MD.0000000000012105

healthcare services provided to the Health Insurance Review and Assessment Service (HIRA) to claim the costs for the services rendered.[17] Therefore, this study obtained data on acute hemorrhagic stroke patients for a 5-year period (2009–2013) from the HIRA for analysis.[18,19] Acute hemorrhagic stroke patients were defined as those with a hemorrhagic stroke as the primary disease (International Classification of Disease, 10th version [ICD-10]: I60, I61, and I62) who were admitted to the hospital via the emergency department within 7 days of the onset of symptoms. Patients <18 years were excluded, as stroke is very rare in this age group. Patients who also had a traumatic injury were not included in the study to exclude trauma-induced hemorrhagic stroke. We limited our sample to first-time hemorrhagic stroke patients who have not been hospitalized for a primary or secondary disease related to hemorrhagic stroke over the past year in order to enhance the homogeneity of the sample and minimize confusion resulting from mixed cases. The type of surgery was limited to craniotomy and trephination, which are the major surgical techniques used to treat hemorrhagic stroke.[20] The process of selecting participants from the obtained data is shown in the Fig. 1.

2.2. Categorizations for hospital volume and mortality

Hospitals were classified into 3 categories according to volume of surgery (low, medium, high). To avoid intentionally setting a cutoff, we placed the hospitals in order from those with high volume of surgery to those with low volume of surgery and divided them into 3 groups (tertile) according to the number of patients.[21]

We used post-hospital mortality instead of postoperative mortality because HIRA data did not show the date of surgery and patients who underwent surgery for cerebral hemorrhage could be regarded as having surgery at the time of admission. Since most of the deaths among the subjects occurred within 30 days of admission, the mortality rate after admission was divided into within 7 days and within 30 days (Supplementary Table 1, http://links.lww.com/MD/C434).

2.3. Covariates

The covariates were age, sex, hemorrhagic stroke site, type of health insurance, intensive care unit admission, history of hypertension, and Charlson comorbidity index (CCI). Ages were classified into <65 years, 65 to 75 years, 75 to 84 years, and >85 years. Older age itself is a risk factor for stroke, as evidenced by the highest prevalence of stroke in those in their 60s and 70s in Korea.[22] Hemorrhagic site was determined using the ICD-10 codes, and the specific hemorrhagic sites observed in this study were subarachnoid hemorrhage (I60), intracerebral hemorrhage (I61), and other non-traumatic intracranial hemorrhage (I62). Subarachnoid hemorrhage and other hemorrhage (I61–I62) were analyzed separately since their pathophysiologies and outcomes were different form each other. Data were classified into 2 types of health insurance (i.e., social health insurance and medical aid) for analysis. Medical aid is a system for providing public assistance for financially vulnerable individuals. We included intensive care unit (ICU) admission as an independent variable because providing treatment would be easier if the patient was admitted to the ICU, thereby lowering

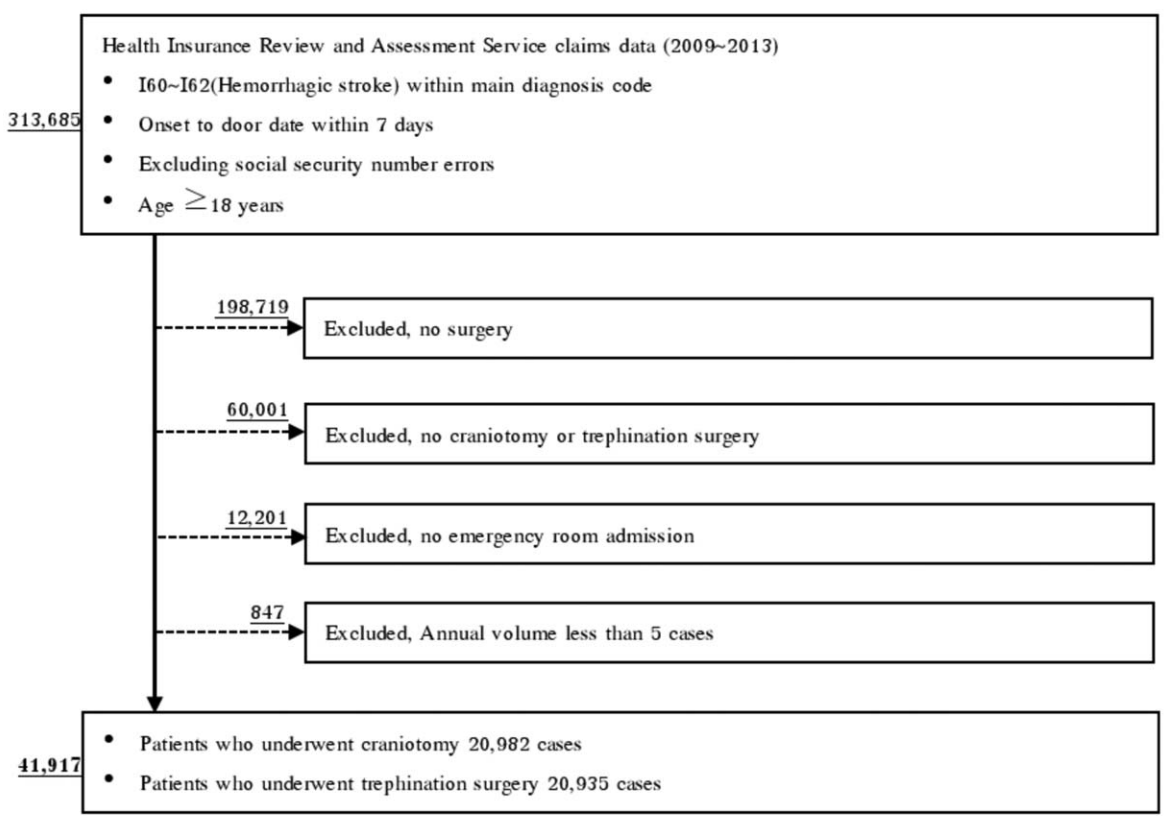

Figure 1. Enrollment flowchart for the study population. For patients with acute hemorrhagic stroke, the ICD-10 codes are I60 (subarachnoid hemorrhage), I61 (intracerebral hemorrhage), and I62 (other nontraumatic intracranial hemorrhage). We used the Health Insurance Review and Assessment Service's medical procedure code to exclude patients without craniotomy or trephination surgery. ICD-10 = International Classification of Disease, 10th version.

Table 1

Patient characteristics by surgery volume.

	Surgery volume									
	Craniotomy					Trephination surgery				
	Subtotal (n=20,982)	Low (n=6849)	Medium (n=6994)	High (n=7139)	*P*	Subtotal (n=20,935)	Low (n=6806)	Medium (n=7152)	High (n=6977)	*P*
Age	56.1±13.1	56.9±3.1	55.9±13.4	55.6±12.8	<.001	61.3±14.1	61.9±14.1	61.2±14.2	60.9±14.0	<.001
<65 y	15,026 (71.6)	4767 (69.6)	5020 (71.8)	5239 (73.4)	<.001	11,532 (55.1)	3657 (53.7)	3978 (55.6)	3897 (55.9)	<.001
65–74 y	4058 (19.3)	1387 (20.3)	1321 (18.9)	1350 (18.9)		5197 (24.8)	1678 (24.7)	1747 (24.4)	1772 (25.4)	
75–84 y	1737 (8.3)	622 (9.1)	588 (8.4)	527 (7.4)		3605 (17.2)	1224 (18.0)	1219 (17.0)	1162 (16.7)	
≥85 y	161 (0.8)	73 (1.1)	65 (0.9)	23 (0.3)		601 (2.9)	247 (3.6)	208 (2.9)	146 (2.1)	
Sex					<.001					.002
Male	9530 (45.4)	3317 (48.4)	3156 (45.1)	3057 (42.8)		11,562 (55.2)	3796 (55.8)	4029 (56.3)	3737 (53.6)	
Female	11,452 (54.6)	3532 (51.6)	3838 (54.9)	4082 (57.2)		9373 (44.8)	3010 (44.2)	3123 (43.7)	3240 (46.4)	
Hemorrhage site					<.001					<.001
Subarachnoid	14,039 (66.9)	3888 (56.8)	4657 (66.6)	5494 (77.0)		4905 (23.4)	1495 (22.0)	1670 (23.4)	1740 (24.9)	
Intracerebral	5771 (27.5)	2466 (36.0)	1904 (27.2)	1401 (19.6)		11,695 (55.9)	3847 (56.5)	3805 (53.2)	4043 (58.0)	
Other	1172 (5.6)	495 (7.2)	433 (6.2)	244 (3.4)		4335 (20.7)	1464 (21.5)	1677 (23.5)	1194 (17.1)	
Social security system					<.001					<.001
National health insurance	19,880 (94.8)	6372 (93.0)	6686 (95.6)	6822 (95.5)		19,325 (92.3)	6172 (90.7)	6691 (93.5)	6462 (92.6)	
National medical aid	1102 (5.2)	477 (7.0)	308 (4.4)	317 (4.5)		1610 (7.7)	634 (9.3)	461 (6.5)	515 (7.4)	
ICU admission					<.001					<.001
No	321 (1.5)	191 (2.8)	130 (1.9)	0 (0.0)		480 (2.3)	351 (5.2)	128 (1.8)	1 (0.1)	
Yes	20,661 (98.5)	6658 (97.2)	6864 (98.1)	7139 (100.0)		20,455 (97.7)	6455 (94.8)	7024 (98.2)	6976 (99.9)	
Hypertension					.005					.001
No	1987 (9.5)	624 (9.1)	622 (8.9)	741 (10.4)		1899 (9.1)	572 (8.4)	622 (8.7)	705 (10.1)	
Yes	18,995 (90.5)	6225 (90.9)	6372 (91.1)	6398 (89.6)		19,036 (90.9)	6234 (91.6)	6530 (91.3)	6272 (89.9)	
CCI group score					<.001					<.001
0	9258 (44.1)	2301 (33.6)	3409 (48.7)	3548 (49.7)		7912 (37.8)	2068 (30.4)	2969 (41.5)	2875 (41.2)	
1	3136 (15.0)	1072 (15.7)	1041 (14.9)	1023 (14.3)		2840 (13.6)	975 (14.3)	978 (13.7)	887 (12.7)	
2	8517 (40.6)	3452 (50.4)	2528 (36.2)	2537 (35.5)		10,100 (48.2)	3729 (54.8)	3183 (44.5)	3188 (45.7)	
≥3	71 (0.3)	24 (0.4)	16 (0.2)	31 (0.4)		83 (0.4)	34 (0.5)	22 (0.3)	27 (0.4)	

Values are presented as mean±SD or n (%).

CCI=Charlson's comorbidity index, ICU=intensive care unit, SD=standard deviation.

the mortality associated with acute hemorrhagic stroke.[23] History of hypertension was included because it is one of the major causes of stroke. It was determined by investigating whether patients had a diagnosis of hypertension within a year from the date of hospital admission. CCI was used to reflect the severity of disease and comorbidity. One strength of CCI is that it is appropriate for ICD-10 codes and has great predictability for mortality.[23,24] From 19 comorbid conditions, the cerebrovascular disease group (G45.x, G46.x, I60.x–I69.x) was excluded because there was a possibility that they may overlap with the primary disease or the symptoms may have been caused by other types of stroke. Weighted values were set to 0, 1, 2, and 3 or greater.

2.4. Statistical analysis

The association between volume of surgery and mortality was analyzed with multiple logistic regression. SAS statistical software version 9.4 (Cary, NC) was used for the analyses. A *P* value <.5 indicated statistical significance.

2.5. Ethics statement

The study was exempted from ethical approval of the Institutional Research Board at Konyang University College of Medicine, as it is a secondary data analysis of an anonymous sample with no personal identifier (2017–087).

3. Results

3.1. Patient characteristics by surgery volume

A total of 41,917 patients who underwent craniotomy (n=20,982) or trephination (n=20,935) for acute hemorrhagic stroke were analyzed. Patient characteristics are described in Table 1. The mean age of the patients who underwent craniotomy was 56.1 years and for those who underwent trephination was 61.3 years. Two-thirds of the former group had a subarachnoid hemorrhage and 56% of the latter group had intracerebral hemorrhage. All of the participant characteristics were significantly associated with the volume of surgery.

3.2. Multivariable logistic regression analysis for association between surgery volume and mortality

For subarachnoid hemorrhage, the odds ratios of the medium- and high-volume surgery groups were significantly lower (0.74 and 0.59, respectively) for mortality within 7 days of admission than that of the low-volume surgery group (Table 2). The odds ratios for mortality within 30 days of admission were also significantly lower for the medium- and high-volume surgery groups than that of the lower-volume surgery group at 0.78 and 0.68, respectively. The association between mortality and volume of surgery was more evident in the craniotomy group; the odds ratios for mortality within 7 days of admission and mortality within 30 days of admission for the medium-volume (0.65 and

Table 2

Association between surgery volume and mortality for subarachnoid hemorrhage (I60).

	Mortality											
	Total (n=18,944)				Craniotomy (n=14,039)				Trephination surgery (n=4905)			
	Within 7 days after admission		Within 30 days after admission		Within 7 days after admission		Within 30 days after admission		Within 7 days after admission		Within 30 days after admission	
	n=1196		n=2446		n=493		n=1140		n=730		n=1306	
Volume group	N (%)	OR (CI)	N (%)	OR (CI)	N (%)	OR (CI)	N (%)	OR (CI)	N (%)	OR (CI)	N (%)	OR (CI)
Low	428 (35.8)	1.00	840 (34.3)	1.00	179 (36.3)	1.00	390 (34.2)	1.00	249 (35.4)	1.00	450 (34.5)	1.00
Medium	400 (33.4)	0.74 (0.64–0.86)	800 (32.7)	0.78 (0.70–0.87)	171 (34.7)	0.65 (0.52–0.81)	388 (34.0)	0.75 (0.65–0.87)	229 (32.6)	0.83 (0.67–1.01)	412 (31.6)	0.75 (0.64–0.88)
High	368 (30.8)	0.59 (0.51–0.69)	806 (33.0)	0.68 (0.61–0.76)	143 (29.0)	0.54 (0.43–0.67)	362 (31.8)	0.54 (0.47–0.63)	225 (32.0)	0.83 (0.68–1.01)	444 (34.0)	0.88 (0.76–1.04)

Adjusted for age, sex, hemorrhage site, social security system, intensive care unit admission, hypertension, charlson's comorbidity index group score.
CI=95% confidence intervals, OR=odds ratio.

0.75, respectively) and high-volume surgery groups (0.54 and 0.54, respectively) showed a dose-dependent response. In the trephination group, the higher volume surgery groups were associated with lower mortality rates compared with the low-volume surgery group, but the trend was not obvious.

The results for other hemorrhage sites (I61–I62) were similar. The odds ratios of the medium- and high-volume surgery groups were significantly lower (0.80 and 0.66, respectively) for mortality within 7 days of admission than that of the low-volume surgery group (Table 3). The odds ratios for mortality within 30 days of admission were also significantly lower for the medium- and high-volume surgery groups than that of the lower-volume surgery group at 0.82 and 0.79, respectively.

4. Discussion

This study investigated the association between volume of surgery and mortality in the entire pool of patients with acute hemorrhagic stroke, including intracerebral hemorrhage and other non-traumatic hemorrhage, which have been relatively neglected in the literature. The results showed that mortality from acute hemorrhagic stroke decreased with increasing volume of surgery for all types of hemorrhages. This is in line with previous findings that a higher volume of surgery leads to better surgery outcomes.

The practice-makes-perfect and selective-referral pattern theories, which are the general explanations for the differences of mortality in relation to volume of surgery, are continually discussed in the context of the causal relationship between volume of care and outcome.[25] The former theory states that treatment outcomes are improved as surgeons' and other assistants' skills are improved by performing numerous surgeries,[26] whereas the latter theory suggests that surgeons and hospitals with good treatment outcomes attract more patients.[25,27] The current study confirms the practice-makes-perfect theory in the context of a broader group of diseases. However, information showing patient visits to different healthcare institutions is lacking to substantiate the selective-referral pattern theory.

Existing studies only focused on the association between volume of craniotomy and mortality from subarachnoid hemorrhage. Therefore, the fact that this study confirmed an association between volume of surgery and mortality from a broader group of hemorrhagic strokes, including intracerebral hemorrhage, is highly meaningful for countries like Korea where intracerebral hemorrhage is the most prevalent type of stroke. Furthermore, most previous studies used a regional database or data from regional population provided by a few large hospitals, making it difficult to interpret the results at the national level.[5] However, the present study established the grounds for national-level interpretation of results using the national health insurance claims data, which comprise data from Korea's general public nationwide.[28]

This study investigated whether mortality rates from the same disease may vary according to the type of surgery. Surgical treatments for hemorrhagic stroke are generally divided into 2 types: craniotomy, where a bone flap from the skull is temporarily removed to ligate or remove the part of blood vessel in which hematoma has formed due to vascular malformations, such as aneurysm or arteriovenous malformation, and trephination, where a hole (perforation) is made in the skull to drain the blood through a catheter.[29,30] With regard to craniotomy, which is considered to have a high degree of difficulty, we were able to

Table 3

Association between surgery volume and mortality for other intracranial hemorrhage (I61–I62).

	Mortality											
	Total (n=22,973)				Craniotomy (n=6943)				Trephination surgery (n=16,030)			
	Within 7 days after admission		Within 30 days after admission		Within 7 days after admission		Within 30 days after admission		Within 7 days after admission		Within 30 days after admission	
	n=1533		n=3196		n=582		n=1158		n=951		n=2038	
Volume group	N (%)	OR (CI)	N (%)	OR (CI)	N (%)	OR (CI)	N (%)	OR (CI)	N (%)	OR (CI)	N (%)	OR (CI)
Low	668 (43.6)	1.00	1,325 (41.5)	1.00	291 (50.0)	1.00	552 (47.7)	1.00	377 (39.6)	1.00	773 (37.9)	1.00
Medium	503 (32.8)	0.80 (0.70–0.90)	1,021 (32.0)	0.82 (0.75–0.90)	188 (32.3)	0.68 (0.56–0.83)	365 (31.5)	0.72 (0.62–0.84)	315 (33.1)	0.78 (0.66–0.92)	656 (32.2)	0.78 (0.70–0.88)
High	362 (23.6)	0.66 (0.58–0.76)	850 (26.6)	0.79 (0.72–0.87)	103 (17.7)	0.60 (0.48–0.77)	241 (20.8)	0.64 (0.54–0.76)	259 (27.2)	0.82 (0.69–0.96)	609 (29.9)	0.92 (0.82–1.03)

Adjusted for age, sex, hemorrhage site, social security system, intensive care unit admission, hypertension, charlson's comorbidity index group score.
CI=95% confidence intervals, OR=odds ratio.

confirm that mortality decreased with increasing volume of surgery. However, with regard to the less difficult trephination, we were not able to observe a trend in which mortality decreases with increasing volume of surgery, though both the medium-volume and high-volume surgery groups had lower mortality rates than the lower-volume surgery group. Trephination has a poor prognosis because it is used as a primary aspiration technique for a wide hematoma and is used in cases with larger volumes of hemorrhage.[20]

Despite our effort to overcome the limitations of previous studies by using nationwide data, this study has a few limitations. First, we could not link the clinical data needed to adjust for severity. However, we tried to address this issue by using CCI, which is generally used to adjust for severity in studies based on claims data.[23] Second, we could not develop or use new methods for classifying volume of surgery and hospital size. Although the hypothesis that high volume of surgery is related to better experience has long been a key concept in studies investigating the association between volume of surgery and outcome, clear definitions of classifying volume of surgery and hospital size are lacking. In the present study, we set the cutoff point before checking mortality to maintain objectivity when classifying hospitals.[21] Finally, we classify hemorrhagic stroke simply as subarachnoid hemorrhage and other hemorrhagic stroke, and did not provide information regarding genetic causes such as Anderson–Fabry disease.[31,32] In the future, it is necessary to examine the relationship between surgical volume and mortality based on classification of hemorrhagic stroke according to individual cause.

This study analyzed mortality within 7 days of admission and mortality within 30 days of admission in patients who underwent craniotomy or trephination for acute hemorrhagic stroke with regard to the volume of surgery handled by the treating hospital. Mortality was lower among patients who were operated in hospitals with high volumes of surgery. Although this study was limited to a single country (South Korea), it has significance in that it partially addressed the shortcomings of previous studies by analyzing a nationwide database and examining all types of hemorrhagic strokes.

Author contributions

Conceptualization: Bo Yeon Lee, Shin Ha, Yo Han Lee.
Data curation: Bo Yeon Lee, Shin Ha, Yo Han Lee.
Formal analysis: Bo Yeon Lee, Shin Ha, Yo Han Lee.
Investigation: Bo Yeon Lee, Shin Ha, Yo Han Lee.
Methodology: Bo Yeon Lee, Shin Ha, Yo Han Lee.
Project administration: Shin Ha, Yo Han Lee.
Resources: Bo Yeon Lee, Shin Ha, Yo Han Lee.
Software: Bo Yeon Lee, Shin Ha, Yo Han Lee.
Supervision: Bo Yeon Lee, Shin Ha, Yo Han Lee.
Validation: Bo Yeon Lee, Shin Ha, Yo Han Lee.
Visualization: Bo Yeon Lee, Shin Ha, Yo Han Lee.
Writing – original draft: Bo Yeon Lee, Shin Ha, Yo Han Lee.
Writing – review & editing: Bo Yeon Lee, Shin Ha, Yo Han Lee.

References

[1] Feigin VL. Stroke in developing countries: can the epidemic be stopped and outcomes improved? Lancet Neurol 2007;6:94–7.
[2] Słomka A, Świtońska M, Sinkiewicz W, et al. Haemostatic factors do not account for worse outcomes from ischaemic stroke in patients with higher C-reactive protein concentrations. Ann Clin Biochem 2017; 54:378–85.

[3] Feigin VL, Lawes CM, Bennett DA, et al. Worldwide stroke incidence and early case fatality reported in 56 population-based studies: a systematic review. Lancet Neurol 2009;8:355–69.
[4] Dudley RA, Johansen KL, Brand R, et al. Selective referral to high-volume hospitals: estimating potentially avoidable deaths. JAMA 2000;283:1159–66.
[5] Davies JM, Ozpinar A, Lawton MT. Volume-outcome relationships in neurosurgery. Neurosurg Clin N Am 2015;26:207–18.
[6] Leake CB, Brinjikji W, Kallmes DF, et al. Increasing treatment of ruptured cerebral aneurysms at high-volume centers in the United States. J Neurosurg 2011;115:1179–83.
[7] Bardach NS, Zhao S, Gress DR, et al. Association between subarachnoid hemorrhage outcomes and number of cases treated at California hospitals. Stroke 2002;33:1851–6.
[8] Cross DTIII, Tirschwell DL, Clark MA, et al. Mortality rates after subarachnoid hemorrhage: variations according to hospital case volume in 18 states. J Neurosurg 2003;99:810–7.
[9] Boogaarts HD, Van Amerongen MJ, De Vries J, et al. Caseload as a factor for outcome in aneurysmal subarachnoid hemorrhage: a systematic review and meta-analysis. J Neurosurg 2014;120:605–11.
[10] Solomon RA, Mayer SA, Tarmey JJ. Relationship between the volume of craniotomies for cerebral aneurysm performed at New York state hospitals and in-hospital mortality. Stroke 1996;27:13–7.
[11] McNeill L, English SW, Borg N, et al. Effects of institutional caseload of subarachnoid hemorrhage on mortality. Stroke 2013;44:647–52.
[12] Pandey AS, Gemmete JJ, Wilson TJ, et al. High subarachnoid hemorrhage patient volume associated with lower mortality and better outcomes. Neurosurgery 2015;77:462–70.
[13] Berman MF, Solomon RA, Mayer SA, et al. Impact of hospital-related factors on outcome after treatment of cerebral aneurysms. Stroke 2003;34:2200–7.
[14] Lee S, Jwa Y. The study on volume relationships in several diseases. Korean J Prev Med 1994;27:793–806.
[15] Health at a glance 2015. OECD indicators, vol. 15. Paris. OECD, 2015. Available at: http://www.oecd-ilibrary.org/social-issues-migration-health/health-at-a-glance-2015_health_glance-2015-en. Accessed December 21, 2017.
[16] NHI Service. System of social security. Available at: https://www.nhis.or.kr/menu/retriveMenuSet.xx?menuId=B1200. Accessed December 21, 2017.
[17] HIRA Services. About us. Available at: http://www.hira.or.kr/eng/index.html. Accessed December 21, 2017.
[18] Choi JY, Yoon HK, Lee JH, et al. Current status of asthma care in South Korea: nationwide the Health Insurance Review and Assessment Service database. J Thorac Dis 2017;9:3208–18.
[19] Choi H, Yang SY, Cho HS, et al. Mortality differences by surgical volume among patients with stomach cancer: a threshold for a favorable volume-outcome relationship. World J Surg Oncol 2017;15:134.
[20] Winn HR. Youmans and Winn Neurological Surgery. Elsevier, Philadelpia: 2017.
[21] Birkmeyer JD, Siewers AE, Finlayson EV, et al. Hospital volume and surgical mortality in the United States. N Engl J Med 2002;346:1128–37.
[22] Lee M, Huang WY, Weng HH, et al. First-ever ischemic stroke in very old Asians: clinical features, stroke subtypes, risk factors and outcome. Eur Neurol 2007;58:44–8.
[23] Charlson ME, Pompei P, Ales KL, et al. A new method of classifying prognostic comorbidity in longitudinal studies: development and validation. J Chronic Dis 1987;40:373–83.
[24] Quan H, Sundararajan V, Halfon P, et al. Coding algorithms for defining comorbidities in ICD-9-CM and ICD-10 administrative data. Med Care 2005;43:1130–9.
[25] Luft HS, Hunt SS, Maerki SC. The volume-outcome relationship: practice-makes-perfect or selective-referral patterns? Health Services Res 1987;22:157–82.
[26] Flood AB, Scott WR, Ewy W. Does practice make perfect? Part I: The relation between hospital volume and outcomes for selected categories. Med Care 1984;22:98–114.
[27] Farley DE, Ozminkowski RJ. Volume-outcome relationships and inhospital mortality: the effect of changes in volume over time. Med Care 1992;30:77–94.
[28] Luft HS, Bunker JP, Enthoven AC. Should operations be regionalized? The empirical relation between surgical volume and mortality. N Engl J Med 1979;301:1364–9.
[29] Lindsay KW, Fuller I, Lindsay GW, et al. Neurology and Neurosurgery Illustrated. Elsevier Health Sciences, NewYork:2010.
[30] Hoh BL, Rabinov JD, Pryor JC, et al. In-hospital morbidity and mortality after endovascular treatment of unruptured intracranial aneurysms in the United States, 1996-2000: effect of hospital and physician volume. Am J Neuroradiol 2003;24:1409–20.
[31] Tuttolomondo A, Pecoraro R, Simonetta I, et al. Neurological complications of Anderson-Fabry disease. Curr Pharm Des 2013;19: 6014–30.
[32] Tuttolomondo A, Pecoraro R, Simonetta I, et al. Anderson-Fabry disease: a multiorgan disease. Curr Pharm Des 2013;19:5974–96.