Original Article

Mechanical thrombectomy reduces the gap in treatment outcomes of ischemic stroke between hospital levels of care: analysis of a Korean nationwide data

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Background: Mechanical thrombectomy (MT) of ischemic stroke was demonstrated to be effective in clinical trials and was reported to have favorable outcomes in real clinical settings since 2015. We aimed to determine the national trends of MT and compare the outcomes between the different levels of treating hospital.

Methods: We obtained data from the nationwide database from 2008 to 2017. Patients with ischemic stroke who received MT were identified using the International Classification of Disease Codes. Good outcome was defined as discharge to home, and a poor outcome was defined as cerebral hemorrhage, physical disability, or death. The study period was divided into three (off-label MT, transitional, MT period). Hospital groups where MT was performed were divided into tertiary and non-tertiary hospitals.

Results: In MT period, 47.0% of the MT procedures were performed in non-tertiary hospitals compared with 36.1% in off-label MT period. Comparison of the 3-month mortality between patients who were treated in tertiary *vs.* non-tertiary hospitals revealed significant lower mortality in tertiary hospital through all period. The incidence of cerebral hemorrhage and physical disability did not differ between hospital groups. However, the percentage of patients discharged home was 41.4% for tertiary hospitals and 42.4% for non-tertiary hospitals, which was not statistically different in MT period (P=0.4671).

Conclusions: Analysis of the nationwide data confirmed that the extent of increase in MT was higher in non-tertiary hospitals than tertiary hospitals. In addition, no significant difference was revealed in the number of favorable clinical outcome between the hospital groups during MT period.

Keywords: Thrombectomy; mortality; disability; population health; tertiary hospitals

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Introduction

Mechanical thrombectomy (MT) has become the standard procedure in 2015 (1), and previous studies showed that indications for MT have been increasing (2,3). Currently, MT is recommended for patients who develop neurologic deficit less than 24 hours after the occlusion of the anterior circulation (4). MT was first performed in 2005, and the number of cases has dramatically increased after 2015. The number of hospitals that provide MT has also increased (5). Performing MT at the earliest time possible increases the chance of a good prognosis for patients with acute ischemic stroke (6). Therefore, an increase in the number of hospitals performing this procedure will likely result in an increased number of patients with a favorable prognosis. Indeed, previous studies reported improved prognoses in real-world clinical settings after the recent guideline changes (7,8).

The prognosis will likely improve if a patient with acute ischemic stroke receives the procedure as early as possible. Previously, multiple studies categorized hospitals into comprehensive stroke centers (CSC) and primary stroke centers (PSC) based on the treatments available (9) and what system of treatments were effective (10). In South Korea, there are 11 designated Regional Cardiocerebrovascular Centers under the Ministry of Health and Welfare. All these hospitals are CSC (11), and none are a PSC. Because these centers are insufficient for treating all patients with acute ischemic stroke, currently, patients undergo treatment in other hospitals. Korean hospitals are categorized as tertiary hospitals and non-tertiary hospitals based on the number of beds, medical departments, and the ratio of severely ill patients. Out of the 11 CSC, 9 are tertiary hospitals; the tertiary hospitals that are not CSC are referral hospitals, so many patients with acute ischemic stroke are seen at referral hospitals, and the frequency of MT is higher than in non-tertiary hospitals. The Joint Commission, in conjunction with the Association/American Stroke Association, added that at least 15 cases of MT are performed annually as a qualification for a CSC (12). A previous study reported that the prognosis might be improved by receiving treatment at a tertiary hospital because the mortality rate was lower for patients treated in hospitals that performed many MT procedures (13).

The present study aimed to verify whether the number of MT procedures performed in tertiary and non-tertiary hospitals changed over time because there is still no apparent difference between CSC and PSC in South Korea. We also investigated whether there was a difference in patient prognosis after MT for different hospital types. We present the following article in accordance with the STROBE reporting checklist (available at https://dx.doi.org/10.21037/atm-21-2342).

Methods

Databases and study population

We selected subjects from the data of the Korean National Health Insurance, to which 97% of the Korean population is registered. We extracted all insurance claims data between 2007–2017 for patients who were >45 years old and claimed a history of hospitalization under cerebral infarction (ICD-10 code: I63) as the main diagnosis or the first sub-diagnosis. Considering the washout time, we excluded data from the year 2007. We sorted these data by procedure codes related to thrombectomy. Before June 30, 2017 in Korea, these codes were M6631 and M6633. Later, these codes were subdivided from M6631 to M6630 and M6635 and from M6633 to M6636 and M6637, depending on the location of occluded vessel. Then, we reviewed whether these patients used tissue plasminogen activator (tPA) at the time of thrombectomy. From these data, we checked for the product codes 223501BIJ or 223502BIJ.

Outcome variables

Good outcomes were defined as patients who were discharged home after 30 days without significant issues, such as death or re-hospitalization. To screen patients with good outcomes, we tracked the patients who were discharged home after hospitalization for stroke treatment with an insurance claim. To increase the reliability of good outcomes, we excluded those who had died within 30 days of discharge and those who had claimed re-hospitalization under either ICD-10 codes I63 or I61 within 30 days of discharge because their prognosis was expected to be poor even if they experienced recurrence or were hospitalized again for rehabilitation. Since readmission within 30 days was used as a criterion to evaluate the quality of medical care in the previous study (14), the same period was applied as the criterion in this study.

Poor outcomes were defined as cerebral hemorrhage following the procedure, significant disability, and death. To identify the incidence rate of a cerebral hemorrhage, we screened patients with insurance claims of ICD-10 code I61 as the principal diagnosis, the first sub-diagnosis, or with a procedure code related to cerebral hemorrhage within 30 days of MT. We defined the following cases as cerebral hemorrhage outcome variables: (I) when a new hospitalization claim was identified with I61 as the main or first sub-diagnosis within 30 days of the hospitalization episode in which the MT claimed, (II) when the first sub-diagnosis with I61 was identified with I63 as the principal diagnosis after MT.

The procedure codes used for screening were N0322 (burr Hole), N0333 (craniectomy), and S4756/S4622 (hematoma removal). We tracked deaths within three months and deaths within one year of treatment through mor tality data. In South Korea, disability can be registered when at least six months have passed from the time of the stroke event, permitting those patients who had registered for the cerebral injury disability.

Analysis

We divided patients into a tertiary hospital group or non-tertiary hospital group depending on the hospital level to investigate annual changes in treatment outcomes in each hospital group. In order to reveal the annual prognosis change, we analyzed 3-month mortality, cerebral hemorrhage, and home discharge rates by 2017, since we were unable to track the mortality or the state of disability registration for the cerebral injury within one year from the selected data.

Consequently, we analyzed subjects and outcome variables by period and group of hospitals. We classified the patients based on the period when MT was performed. The period when the stent-retriever was used off-label in South Korea was estimated to be October – December of 2010 (15). The stent-retriever was not reimbursed by the Korean National Health Insurance between May 2013 – July 2014, even though its usage was officially approved. Therefore, we categorized the periods as "off-label MT period (2008.01–2010.12)" when the stent-retriever was rarely used, "transitional period (2011.01–2014.07)" when we could not precisely identify stent-retriever usage, and "MT period (2014.08–2016.12)" when the insurance claims data verified the frequency of stent-retriever use. The 2017 data were excluded from the MT period because the information on disability registration was unavailable.

In the previous study based on the Korean National Health Insurance Data, hospitals that performed 18 or less annual MT were in the bottom quarter (16). The CSC's eligibility criteria is 15 or more MTs per year in hospitals (12). Therefore, in this study, the prognosis depending on the MT volume for each hospital was analyzed as a confounding variable whether or not hospitals that perform MT more than 18 per year. Also, we identified the comorbidities hypertension, diabetes mellitus, dyslipidemia, and atrial fibrillation that might increase the risk of stroke and thus affect the prognosis and the risk factors of patients from the insurance claims data before MT treatment and during hospitalization for MT. Therefore, we analyzed the Charlson Comorbidity Index (CCI) of subjects to verify the influence of comorbidities on death.

Neurologic defict severity assessed using NIH Stroke Scale (NIHSS) is known as the most important factor for predicting the prognosis of ischemic stroke patient (17). However, NIHSS cannot be identified in claim data for which no clinical information is available. In order to supplement the limitations of the claim data study, a stroke severity index (SSI) that can be substituted for the NIHSS was proposed (18). In other study using claim data such as our study, the SSI was calculated using the claims presented in the previous study and validated based on real clinical data (16). We also calculated the SSI using the same items and coefficients (16), analyzed whether there was a difference between hospital groups, and included it as a confounding variable in the prognosis analysis.

The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). This study was approved by the Institutional Review Board of the National Health Insurance Service Ilsan Hospital (NHIMC 2019-01-006). The need for written informed consent was waived as patient identification data were removed from the database used.

Statistical analysis

SAS 9.4 (SAS Institute Inc., Cary, NC, USA) was used for data analysis, and the one-way ANOVA and the chi-square test were used to compare descriptive statistics and the frequency of various factors. To confirm the difference in the trend of the outcome variables by year, we conducted Cochran-Armitage Trend test. To compare the distribution of baseline covariates between hospitals, we used the chi-square test. For the identification of the risk of death and cerebral injury disability, time-dependent Cox proportional hazard regression analysis was applied. For the identification of factors relating to discharge-to-home patients, multiple logistic regression analysis was used. P values <0.05 for two-

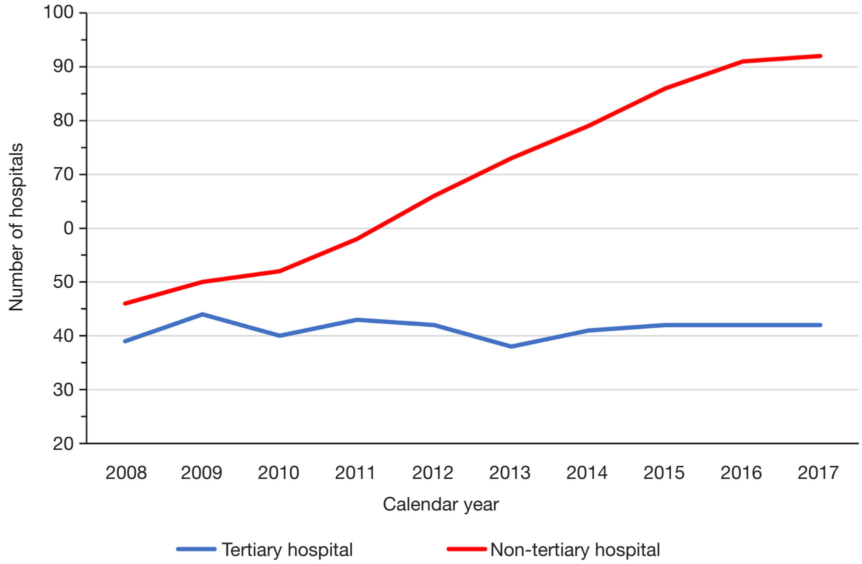

Figure 1 Annual change in the number of hospitals with endovascular therapy from 2008 to 2017.

sided tests were considered statistically significant.

Results

The number of tertiary hospitals that provided MT did not change significantly between 2008 and 2015 (39 in 2008 to 42 in 2017). In contrast, the number of non-tertiary hospitals that provided MT was 46 in 2008, which increased gradually to 92 in 2017 (*Figure 1*). In 2008, about 37% of MT was performed at non-tertiary hospitals, whereas, in 2017, almost half of MT was done at non-tertiary hospitals. In 2014, 565 patients underwent the MT procedure at non-tertiary hospitals, and in 2015, 959 underwent MT. The largest annual increase rate was 70% (*Figure 2*).

The annual trend showed an increased proportion of patients with good outcomes and a reduced proportion of patients with poor outcomes in both hospital groups (*Figure 3*). In the trend analysis, there was no statistical difference in the 3-month mortality rate and home discharge rate between hospital groups. The percentage of patients discharged home from tertiary versus non-tertiary hospitals was 36.9% versus 34.4% in 2008, and 43.1% versus 40.2% in 2017—the highest rate was in 2016. The 3-month mortality rate was 28.8% and 24.4% in 2008, and 17.0% and 18.1% in 2017, respectively. A gradual decrease of the ratio of patients receiving surgery for cerebral hemorrhage within 30 days between 2008 and 2017 was 7.2% to 1.3% and 6.3% to 3.0% for tertiary and non-tertiary hospitals, respectively.

In off-label MT period, 36.1% of MT was performed at non-tertiary hospitals, whereas, in MT period, 47.0% of MT was done at non-tertiary hospitals. Of note, patient age was significantly higher in tertiary hospitals during the transitional period, but there was no statiscally significant difference during other periods. The prevalence of atrial fibrillation, which is the most frequent comorbidity, was higher in tertiary hospitals regardless of the period. Dyslipidemia occurred more frequently in tertiary hospitals except during the off-label MT period. The mean value of SSI was statistically higher in non-tertiary hospitals than in tertiary hospitals during all period, but the median values differed only during the off-label period (*Table 1*). Mortality rates were higher in non-tertiary hospitals than in tertiary hospitals for all periods; the rate decreased in the order of off-label MT period, transitional period, and MT period. The percentage of surgery for cerebral hemorrhage or disability registration tended to decrease gradually, and there was no statistical difference between the hospital groups for all periods. The rate of home discharge for the MT period was not statistically different between the hospital groups.

In the MT period, 87.1% of the patients were treated at the tertiary hospital with an annual volume of MT greater than 18, and 48.2% of the patients were treated at the non-tertiary hospital with the same MT volume. The proportion of patients treated in hospitals with MT volume exceeding

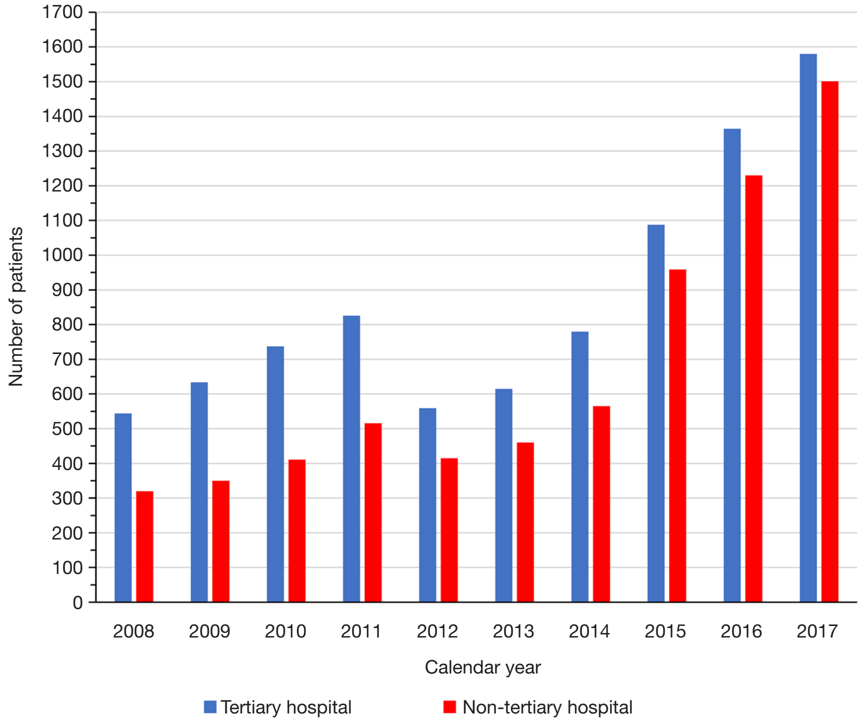

Figure 2 Annual trends of the number and proportion of patients treated for ischemic stroke with endovascular therapy by hospital group.

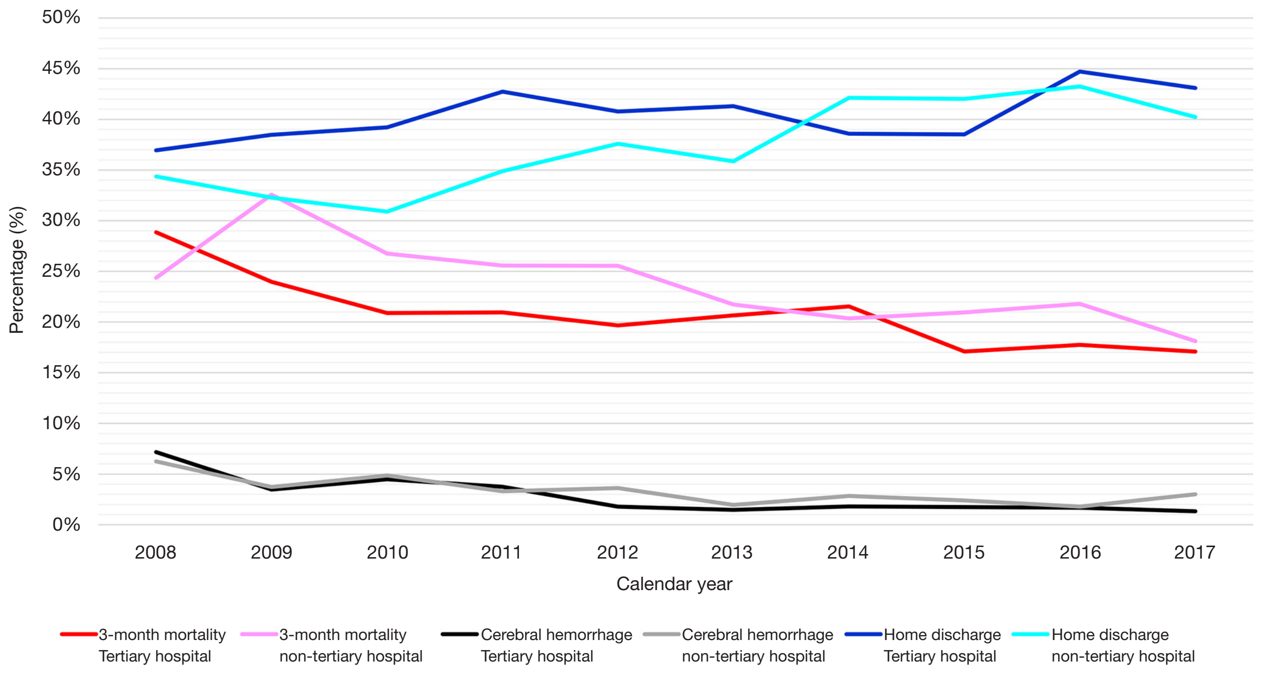

Figure 3 Annual trends of outcomes of endovascular therapy by hospital group from 2008 to 2017. The P value of the Cochran-Armitage Trend test of 3-month mortality was 0.4777, home discharge was 0.1163, cerebral hemorrhage was 0.0017.

Table 1 Characteristics of patients receiving endovascular treatment by hospital type

Period	2008.01–2010.12 (off-label MT)			2011.01–2014.07 (transitional)			2014.08–2016.12 (MT)		
	Tertiary hospital (n=1,915)	Non-tertiary hospital (n=1,081)	P value	Tertiary hospital (n=2,413)	Non-tertiary hospital (n=1,644)	P value	Tertiary hospital (n=2,819)	Non-tertiary hospital (n=2,501)	P value
Male	1,094 (57.1%)	582 (53.8%)	0.0816	1,312 (54.4%)	901 (54.8%)	0.7856	1,536 (54.5%)	1,410 (56.4%)	0.1663
Age	68.93±10.73	69.07±10.69	0.726	71.30±10.62	70.52±11.10	0.0235	71.24±10.96	70.90±11.09	0.2641
<60	405 (21.1%)	221 (20.4%)	0.9653	374 (15.5%)	321 (19.5%)	0.0028	462 (16.4%)	463 (18.5%)	0.1363
≥60, <70	493 (25.7%)	285 (26.4%)		580 (24.0%)	343 (20.9%)		678 (24.1%)	563 (22.5%)	
≥70, <80	709 (37.0%)	400 (37.0%)		888 (36.8%)	609 (37.0%)		966 (34.3%)	870 (34.8%)	
≥80	308 (16.1%)	175 (16.2%)		571 (23.7%)	371 (22.6%)		713 (25.3%)	605 (24.2%)	
Hypertension	1,346 (70.2%)	754 (69.8%)	0.7579	1,852 (76.8%)	1,299 (79.0%)	0.0892	2,143 (76.0%)	1,949 (77.9%)	0.0991
Diabetes mellitus	594 (31.0%)	371 (34.3%)	0.0633	1,073 (44.5%)	713 (43.4%)	0.4893	1,368 (48.5%)	1,184 (47.3%)	0.3872
Dyslipidemia	720 (37.6%)	415 (38.4%)	0.6676	1,458 (60.4%)	919 (55.9%)	0.0041	1,985 (70.4%)	1,635 (65.4%)	<0.0001
Atrial fibrillation	926 (48.4%)	467 (43.2%)	0.0066	1,325 (54.9%)	776 (47.2%)	<0.001	1,568 (55.6%)	1,276 (51.0%)	0.0008
Ischemic heart disease	509 (26.6%)	284 (26.3%)	0.8545	891 (36.9%)	559 (34.0%)	0.0565	1,058 (37.5%)	930 (37.2%)	0.7946
Chronic kidney disease	123 (6.4%)	77 (7.1%)	0.461	212 (8.8%)	159 (9.7%)	0.3366	216 (7.7%)	199 (8.0%)	0.6893
CCI >5	706 (36.9%)	531 (49.1%)	<0.0001	1,335 (55.3%)	1,033 (62.8%)	<0.0001	1,728 (61.3%)	1,672 (66.9%)	<0.0001
Stroke severity index, mean ± SD	11.3±4.01	11.82±4.17	0.0007	10.62±3.93	10.89±4.27	0.0414	10.37±3.89	11.01±4.14	<0.0001
Stroke severity index median (Q1–Q3)	10.92 (7.6–14.77)	12.12 (9.03–15.85)	<0.0001	10.34 (6.9–13.96)	10.34 (6.79–13.96)	0.2824	10.23 (6.79–13.96)	10.23 (7.48–13.96)	0.1245
Intravenous tPA	637 (33.3%)	379 (35.1%)	0.3185	764 (31.7%)	500 (30.4%)	0.3994	1,090 (38.7%)	935 (37.4%)	0.3368
3-month mortality	463 (24.2%)	302 (27.9%)	0.0234	499 (20.7%)	393 (23.9%)	0.0149	507 (18.0%)	529 (21.2%)	0.0036
Cerebral hemorrhage (I61)	125 (6.5%)	68 (6.3%)	0.7997	83 (3.4%)	64 (3.9%)	0.4482	57 (2.0%)	75 (3.0%)	0.0223
Cerebral hemorrhage (operation)	94 (4.9%)	53 (4.9%)	0.9944	55 (2.3%)	52 (3.2%)	0.0846	51 (1.8%)	50 (2.0%)	0.6122
Disability	641 (33.5%)	363 (33.6%)	0.9523	650 (26.9%)	433 (26.3%)	0.6719	632 (22.4%)	615 (24.6%)	0.0621
Home discharge without event	734 (38.3%)	351 (32.5%)	0.001	1,004 (41.6%)	616 (37.5%)	0.0082	1,167 (41.4%)	1,062 (42.5%)	0.4318
Home discharge and readmission within 30 days	37 (1.9%)	11 (1.0%)	0.0555	48 (2.0%)	22 (1.3%)	0.118	41 (1.5%)	26 (1.0%)	0.1757
Home discharge and death within 30 days	78 (4.1%)	35 (3.2%)	0.1255	67 (2.8%)	29 (1.8%)	0.3068	46 (1.6%)	62 (2.5%)	<0.0001
Number of patients treated in hospitals with annual volume >18	1,291 (67.4%)	204 (18.9%)	<0.0001	1,530 (63.4%)	289 (17.6%)	<0.0001	2,456 (87.1%)	1,206 (48.2%)	<0.0001

MT, mechanical thrombectomy; tPA, tissue plasminogen activator; CCI, Charlson Comorbidity comorbidity index; SD, standard deviation.

Table 2 Hazard ratio and odds ratio for death, disability, and home discharge in patients between tertiary versus non-tertiary hospital in three periods

	Death					Disability					Home discharge	
	Unadjusted HR (95% CI)	P	Adjusted HR (95% CI)	P	Unadjusted HR (95% CI)	P	Adjusted HR (95% CI)	P	Unadjusted OR (95% CI)	P	Adjusted OR (95% CI)	P
Non-MT period												
Tertiary hospital	1		1		1		1		1		1	
Non-tertiary hospital	1.092 (0.994–1.199)	0.0653	0.987 (0.888–1.098)	0.816	1.121 (0.98–1.281)	0.0959	1.022 (0.878–1.189)	0.7791	0.769 (0.657–0.899)	0.001	1.023 (0.846–1.237)	0.8122
Transitional period												
Tertiary hospital	1		1		1		1		1		1	
Non-tertiary hospital	1.096 (1.004–1.195)	0.04	1.102 (0.998–1.218)	0.0543	1.023 (0.9–1.164)	0.7265	1.043 (0.905–1.202)	0.5604	0.841 (0.739–0.956)	0.0083	0.812 (0.694–0.949)	0.009
MT period												
Tertiary hospital	1		1		1		1		1		1	
Non-tertiary hospital	1.156 (1.052–1.27)	0.0026	1.01 (0.909–1.122)	0.8598	1.192 (1.061–1.34)	0.0032	1.091 (0.96–1.24)	0.183	1.045 (0.937–1.165)	0.4318	1.36 (1.19–1.555)	<0.0001

Adjusted for age, sex, comorbidities, and use of tissue plasminogen activator. MT, mechanical thrombectomy; HR, hazard ratio; OR, odds ratio; CI, confidence intervals.

18 increased by 23.7% in the tertiary hospital and 30.6% in the non-tertiary hospital compared to the previous period in the MT period, showing a larger increase in the non-tertiary hospital.

The risk of death was significantly higher in the non-tertiary hospital than in the tertiary hospital for the transitional period [hazard ratio (HR) 1.096, 95% confidence interval (CI): 1.004–1.195, P=0.04] and MT period (HR 1.156, 95% CI: 1.052–1.27, P=0.0026). However, it was not significant when we adjusted for confounding variables that included MT volume and SSI. The risk of disability was significantly higher in the non-tertiary hospital than in the tertiary hospital for MT period (HR 1.192, 95% CI: 1.061–1.34, P=0.0032). It was also not significant in the adjusted analysis (HR 1.091, 95% CI: 0.96–1.24, P=0.183). The adjusted odds ratio (OR) for discarhge to home in the transitional period was 0.812 when we compared non-teritiary hospitals with tertiary hospitals (OR 0.694–0.949, P=0.009). This ratio was inverted in the MT period. The adusted OR for home discharge during MT period was 1.36 when compared non-tertiary hospitals *vs.* tertiary hospitals (CI: 1.19–1.555, P<0.0001) (*Table 2*).

Discussion

Our analysis of nationwide data showed that the usage of MT markedly increased since 2015 when there was a substantial change in the clinical guidelines. The increase rate was higher in non-tertiary hospitals than in tertiary hospitals. Following the increase of MT procedures, the number of hospitals providing MT have increased gradually. The reasons for the increase in MT may include an aging population and an increase in comorbidities. Furthermore, patients who previously were not treated despite the correct indications can now be treated. As the procedure became available in more hospitals, it might have been performed in more patients with acute ischemic stroke. However, if the difference in treatment outcomes is significant across different hospitals, there is a need to develop a system to transfer patients to a hospital where more effective treatment methods are available. If there is no significant difference in patient outcomes, allowing more hospitals to perform the MT procedure might allow more patients with acute ischemic stroke to be treated more effectively.

In this study, no comorbidity of any statistical difference per hospital type occurred other than atrial fibrillation and dyslipidemia. The mean value of SSI which reflect the severity of ischemic stroke was higher in non-tertiary hospitals during all periods, but the median values showed no statistical difference between hospitals except for the off-label period. Patient age was also not different between groups except during the transitional period. After the introduction of the stent-retriever, when MT was proven to be effective, the mortality rate of patients treated in non-tertiary hospitals was still significantly higher than those in tertiary hospitals. However, in 2017, the 3-month mortality of non-tertiary hospital was decreased to make only 1.1% difference compared to the mortality of tertiary hospitals. The 3-month mortality of our study revealed similar results with the previous real-world clinical study, which had a mortality of 16% (19). The decrease in the difference of outcomes between hospitals may be contributed from an increase in the number of patients treated at hospitals whose annual volume is higher than the CSC threshold even in non-tertiary hospitals.

In this study, we could not exclude the possibility that a difference in the levels of hospital facilities and workforce might have increased the mortality rate in non-tertiary hospitals compared with that in tertiary hospitals. A previous study reported a difference in mortality risk based related to hospital size and the presence or absence of medical resident training (20). Hospitals with stroke unit had a lower 1-year mortality rate than those without stroke unit (21). Such departments exist in all tertiary hospitals but not all non-tertiary hospitals. Whereas all tertiary hospitals had medical resident training, only one-third of non-tertiary hospitals, which is the primary focus of this study, had neurological and neurosurgical resident. This confirmed that there is a greater workforce participating in MT in tertiary hospitals than in non-tertiary hospitals (22).

The statistical difference in rates of patients discharged home decreased to insignificance over time. When analyzed considering the number of procedures per year, patients were more likely to be discharged home from non-tertiary hospitals. Since MT was performed on patients with a wider standard in the tertiary hospitals than the non-tertiary hospitals (22), there may be patients who did not recover enough to be discharged home even if the MT was successfully performed. The increase in the proportion of patients who received treatment in non-tertiary hospitals performing MT more than 18 cases per year may have affected the increase in the proportion of patients with good prognosis. The solitaire stent is an effective treatment tool that can be used by physicians with relatively little experience (23), potentially explaining the potential improvement in non-tertiary hospitals that began to provide this treatment procedure. With the introduction of more effective treatment methods such as these, the number of patients with an expected favorable outcome may have increased regardless of the hospital they visited.

The rate of a good outcome in this study was higher than a study using other insurance claims data but was slightly lower when compared to the ratio of patients with modified Rankin scale (mRS) 0–2 at three months (7,8,24). In this study, some patients who were not discharged home may have received treatments in a rehabilitation hospital and then recovered to mRS 0–2 at three months. Additionally, the number of patients with disability registration was lower than the mRS 3–5 at three months, as previously reported. The ratio of patients with mRS 3–5 at three months was 38.6% in the meta-analysis of clinical studies using a stent-retriever and 34.8% in real-world data (24,25). This is because some of the patients who were mRS 3–5 at three months may have recovered to the level where disability registration was unnecessary, related to long-term rehabilitation treatment after ischemic stroke, similar to patients who were not discharged home.

The incidence rate of cerebral hemorrhage with neurological deterioration was 4.4% in a meta-analysis (24). In real-world data, the rate was higher, 8% (26). Our study was based on insurance claims data that did not verify the imaging data. Instead, we identified the percentage of patients who underwent surgery for cerebral hemorrhage. This percentage was lower than the previous reports of cerebral hemorrhage incidence. This percentage did not include patients whose hemorrhage event was minor and who did not need surgical treatment or those whose event was too severe and did not receive surgery.

This study had some limitations. First, we used insurance claims data rather than real-world clinical data. Therefore, we could not identify related factors revealed by previous studies, such as the time from the symptom onset to the point of recanalization, the anatomical location of the occlusion, the result of recanalization, or initial NIHSS. Second, we were unable to verify the precise number of MT patients in the period when the solitaire stent—the most common MT instrument—was off-label and the period when the solitaire stent was not covered by insurance. Despite such limitations, our study has some advantages because it investigated nationwide dataset and used variables with high accuracies, such as hospital classifications, mortality, and disability registration.

Conclusions

Using data from the whole nation of South Korea, the present study confirmed the trend of an improved treatment outcome as the stent-retriever came into use in tertiary hospitals and non-tertiary hospitals. Currently, the range of indications for MT has been extended up to 24 hours after symptom onset. More ischemic stroke patients will be treated with MT hereafter. The results of this study suggest that fostering non-tertiary hospitals capable of thrombectomy in areas with poor access to tertiary hospitals serving as referral centers can be helpful to the national health system. More hospitals will be able to provide MT for the treatment of patients with acute ischemic stroke in the future, and as a consequence, more patients are expected to benefit from good prognosis by receiving proper treatment.

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Footnote

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Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). This study was approved by the Institutional Review Board of the National Health Insurance Service Ilsan

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