

Original Article
Neuroscience



OPEN ACCESS

Received: Mar 14, 2024
Accepted: May 15, 2024
Published online: May 29, 2024

Address for Correspondence:

Si Un Lee, MD

Department of Neurosurgery, Seoul National University Bundang Hospital, Seoul National University College of Medicine, 82 Gumi-ro 173-beon-gil, Bundang-gu, Seongnam 13620, Republic of Korea.
Email: nsmidget@gmail.com





Hyung Soo Byoun, MD

Department of Neurosurgery, Chungnam National University Sejong Hospital, 20 Bodeum 7-ro, Sejong 30099, Republic of Korea.
Email: prettypig9@hanmail.net

© 2024 The Korean Academy of Medical Sciences.

This is an Open Access article distributed under the terms of the Creative Commons Attribution Non-Commercial License (<https://creativecommons.org/licenses/by-nc/4.0/>) which permits unrestricted non-commercial use, distribution, and reproduction in any medium, provided the original work is properly cited.

ORCID iDs

Yu Deok Won 
<https://orcid.org/0000-0002-8822-6631>
Hyung Soo Byoun 
<https://orcid.org/0000-0002-8242-7184>
Tae Won Choi 
<https://orcid.org/0000-0001-7914-3095>
Sang Hyo Lee 
<https://orcid.org/0000-0001-5508-7172>

Clinical Outcomes of Clipping and Coil Embolization for Ruptured Intracranial Aneurysms Categorized by Region and Hospital Size: A Nationwide Cohort Study in Korea

Yu Deok Won ¹, Hyung Soo Byoun ², Tae Won Choi ³, Sang Hyo Lee ³, Young Deok Kim ³, Seung Pil Ban ³, Jae Seung Bang ³, O-Ki Kwon ³, Chang Wan Oh ³, and Si Un Lee ³

¹Department of Neurosurgery, Hanyang University Guri Hospital, Hanyang University College of Medicine, Guri, Korea

²Department of Neurosurgery, Chungnam National University Sejong Hospital, Sejong, Korea

³Department of Neurosurgery, Seoul National University Bundang Hospital, Seoul National University College of Medicine, Seongnam, Korea

ABSTRACT

Background: To analyze the outcomes of clipping and coiling for ruptured intracranial aneurysms (RIAs) based on data from the National Health Insurance Service in South Korea, with a focus on variations according to region and hospital size.

Methods: This study analyzed the one-year mortality rates for patients with RIAs who underwent clipping or coiling in 2018. Coiling was further categorized into non-stent assisted coiling (NSAC) and stent assisted coiling (SAC). Hospitals were classified as tertiary referral general hospitals (TRGHs), general hospitals (GHs), or semi-general hospitals (sGHs) based on size. South Korea's administrative districts were divided into 15 regions for analysis.


Results: In 2018, there were 2,194 (33.1%) clipping procedures (TRGH, 985; GH, 827; sGH, 382) and 4,431 (66.9%) coiling procedures (TRGH, 1,642; GH, 2,076; sGH, 713) performed for RIAs treatment. Among hospitals performing more than 20 treatments, the one-year mortality rates following clipping or coiling were 11.2% and 16.0%, respectively, with no significant difference observed. However, there was a significant difference in one-year mortality between NSAC and SAC (14.3% vs. 19.5%, $P = 0.034$), with clipping also showing significantly lower mortality compared to SAC ($P = 0.019$). No significant differences in other treatment modalities were observed according to hospital size, but clipping at TRGHs had significantly lower mortality than at GHs ($P = 0.042$). While no significant correlation was found between the number of treatments and outcomes at GHs, at TRGHs, a higher volume of clipping procedures was significantly associated with lower total mortality ($P = 0.023$) and mortality after clipping ($P = 0.022$).

Conclusion: Using Korea NHIS data, mortality rates for RIAs showed no significant variation by hospital size due to coiling's prevalence. However, differences in clipping outcomes by hospital size and volume in TRGH highlight the need for national efforts to improve clipping skills and standardization. Additionally, the higher mortality rate with SAC emphasizes the importance of precise indications for its application.

Keywords: Intracranial Aneurysm; Subarachnoid Hemorrhage; Mortality; Korea

Young Deok Kim 

<https://orcid.org/0000-0002-0762-6300>

Seung Pil Ban 

<https://orcid.org/0000-0002-7774-0467>

Jae Seung Bang 

<https://orcid.org/0000-0001-9543-8758>

O-Ki Kwon 

<https://orcid.org/0000-0002-7379-9891>

Chang Wan Oh 

<https://orcid.org/0000-0001-7311-7072>

Si Un Lee 

<https://orcid.org/0000-0001-5788-2014>

Funding

This study was supported by the National Research Foundation of Korea (NRF) grant funded by the Korea government (MSIT) (No. RS-2022-00165988).

Disclosure

The authors have no potential conflicts of interest to disclose.

Author Contributions

Conceptualization: Lee SU, Byoun HS. Data curation: Byoun HS. Formal analysis: Won YD, Lee SU, Byoun HS, Choi TW, Kim YD. Funding acquisition: Won YD. Investigation: Won YD, Byoun HS, Choi TW, Lee SH. Methodology: Won YD, Lee SH, Ban SP. Project administration: Bang JS. Supervision: Bang JS, Kwon OK, Oh CW. Validation: Kim YD, Ban SP. Writing - original draft: Won YD, Lee SU.

INTRODUCTION

Advancements in diagnostic technologies for intracranial aneurysms (IAs), an increase in the treatment of unruptured intracranial aneurysms (UIAs), and control of hypertension have led to a decrease in the incidence of ruptured intracranial aneurysms (RIAs). However, despite these improvements, the number of cases of RIAs remains at a level similar to that of 10 years ago due to the increase in the elderly population.^{1,2} The evolution and increased accessibility of endovascular treatment modalities have led to a nationwide expansion in facilities capable of offering such interventions, subsequently elevating the total volume of interventions for RIAs. Concurrently, as endovascular treatment options become more prevalent, there has been a notable decline in the utilization and frequency of surgical clipping procedures.^{1,3}

In the expanding field of IAs treatment, particularly in endovascular intervention, the diversity in the location and capacity of healthcare facilities has led to varied outcomes. This variation in treatment outcomes for IAs, based on regional and hospital size differences, suggests that research analyzing these factors can aid in improving the healthcare system. In the United States, studies have been published analyzing the treatment outcomes for RIAs by region and hospital size.^{4,5} Despite the significance of RIA treatment outcomes within the emergency medical system, in South Korea, only studies on the treatment outcomes for UIAs have been reported.³

To address this gap, our study utilized data from the National Health Insurance Service (NHIS) of South Korea to evaluate the nationwide outcomes of RIAs treatments, analyzing the variations by region and hospital size.

METHODS

Data source

The NHIS database was employed to conduct a retrospective cohort study that assessed the clinical outcomes of clipping and coiling in patients with RIAs in 2018. The NHIS, which encompasses the health data of approximately 98% of the South Korean population, provides a comprehensive clinical data repository that includes diagnostic, therapeutic, and financial healthcare information, along with inpatient and outpatient records. The database's demographic homogeneity, which includes health records from around 50 million individuals of a single ethnic background, is particularly conducive to epidemiological and observational research, with its validity supported by a multitude of scientific publications. To ensure the robustness of the data, this study was restricted to information from tertiary referral general hospitals (TRGHs), general hospitals (GHs), and semi-general hospitals (sGHs) with primary healthcare data being intentionally excluded to minimize data variability.

Study population and cohort design

Individuals subjected to clipping or coiling for RIAs were identified utilizing the International Classification of Diseases, 10th Revision (ICD-10) diagnostic codes, subsequently categorized according to the Korean Classification of Diseases (KCD) codes. To ensure the inclusion of patients treated specifically for RIAs rather than UIAs, only those diagnosed with RIA (e.g., ICD code I60) for the first time in an emergency department or during hospitalization in 2018 were selected, excluding any individuals with a documented history of RIA in the preceding five years. From this group, only patients who received clipping or coiling (e.g., KCD codes

S4641, S4642, M1661 and M1662) were included in the study cohort. Those with a history of intracranial pathologies such as brain trauma (e.g., ICD codes S06–S09), brain tumors (e.g., ICD codes C41.0, C75.2, C71, C79.3, D32.9–D333, D35.3, or D44.4), or infective endocarditis (e.g., ICD code I33) were excluded to eliminate cases of pseudoaneurysm or other lesions that could influence the treatment outcomes for RIAs.

Hospital classification was based on size and capability: TRGHs are defined as facilities with over 500 beds, more than 20 medical departments, and specialists in each department; GHs have over 100 beds and more than 7 departments; sGHs possess over 30 beds and also maintain more than 7 departments. Geographically, the Republic of Korea was divided into 15 regions according to administrative districts, with hospitals in each region being analyzed based on their classification.

Outcomes and study variables

Due to the accurate and error-free recording of death dates for all subjects in the NHIS database, clinical outcomes following clipping or coiling for RIAs were assessed using post-treatment mortality. To differentiate between short-term and long-term outcomes, mortality within 3 months and mortality within 1 year were established as the outcome variables. To encompass all deaths directly or indirectly related to RIA, all-cause mortality was included as a variable. Each of the aforementioned outcome variables was then analyzed in relation to the size of the hospitals within each region.

Validation of NHIS data with real-world data

To ascertain the reliability of the study, a comparative analysis was conducted utilizing real-world data. The data from the institute that performed the sixth-highest number of treatments for RIAs in 2018 in Korea served as the basis for comparison with the corresponding NHIS data. The compared variables encompassed the total number of patients who underwent clipping and coiling procedures for RIAs in 2018, as well as the mortality rates within three months post-procedure by modality. According to the records from this representative institute, 39 patients underwent clipping, and 43 patients underwent coiling for RIAs. Within three months post-procedure, mortality was observed in 3 (7.7%) patients following clipping and 1 (2.3%) patient following coiling. In contrast, the NHIS data indicated that 44 patients underwent clipping and 44 underwent coiling for RIAs, with mortality rates within three months post-procedure being 3 (6.8%) and 1 (2.3%) patients, respectively. Concordance rates between the NHIS data and the real-world data for each variable were determined to be 88.6%, 97.7%, 100%, and 100%, respectively.

Data analysis

Data manipulation and extraction procedures were performed using SAS software (version 9.4; SAS Institute Inc., Cary, NC, USA). The distributions of the data were assessed for normality using the Kolmogorov-Smirnov test and the Shapiro-Wilk test, confirming non-normal distributions. To compare mortality by treatment modality, the Mann-Whitney *U* test and the Wilcoxon signed-rank test were utilized. The Mann-Whitney *U* test was also employed to analyze mortality by treatment modality according to the size of the hospital. Correlations between the number of treatments and treatment outcomes were analyzed using Spearman rank correlation analysis. *P* values less than 0.05 were considered statistically significant.

Ethics statement

The Institutional Review Board of Seoul National University Bundang Hospital (X-1810/498-903) reviewed and approved the study, waiving the requirement for informed consent owing to the retrospective nature of the analysis.

RESULTS

Hospital and regional distribution of procedures for RIAs in 2018

In 2018, a total of 2,194 (33.1%) clipping procedures and 4,431 (66.9%) coiling procedures were performed for RIAs, in 398 and 572 hospitals, respectively. The regions with the highest number of clipping procedures included Seoul with 513 (23.4%), Gyeonggi-do with 387 (17.6%), and Gwangju with 298 (13.6%), while the most coiling procedures were performed in Gyeonggi-do (920, 20.8%), Seoul (832, 18.8%), and Busan (321, 7.2%). Clipping procedures for RIAs were performed by 40 TRGHs, 124 GHs, and 234 sGHs, with respective procedure volumes of 985 (44.9%), 827 (37.7%), and 382 (17.4%). Coiling procedures were conducted by 41 TRGHs, 151 GHs, and 380 sGHs, with respective volumes of 1,642 (37.1%), 2,076 (46.9%), and 713 (16.1%). (Table 1)

Comparison of mortality following procedures for RIAs by hospital size and region

Following clipping, the 3-month mortality rates were 7.82% at TRGH and 10.76% at GH, with a lower trend observed at TRGH nationwide, although the difference was not statistically significant ($P = 0.071$). In contrast, the 1-year mortality rates were 9.85% at TRGH and 14.15% at GH, which was significantly lower at TRGH ($P = 0.025$). After coiling, the 3-month mortality rates were 13.58% at TRGH and 14.88% at GH ($P = 0.792$), and the 1-year mortality rates were 16.80% at TRGH and 17.79% at GH ($P = 0.187$). There was no significant difference in mortality after coiling between TRGH and GH (Table 2).

Treatment outcomes at hospitals that performed more than 20 RIAs treatments according to treatment modality

An analysis was conducted on hospitals that had performed over 20 treatments for RIAs. In 2018, 38 TRGHs and 38 GHs treated more than 20 cases of RIAs. A total of 4,059 treatments were performed, with clipping accounting for 1,340 cases (33.0%) and coiling for 2,719 cases (67.0%). Of the coiling procedures, 1,970 (72.5%) were non-stent assisted coiling (NSAC) and 749 (27.5%) were stent assisted coiling (SAC) (Table 3). The overall 1-year mortality rate following treatment for RIAs was 14.4%, with the 1-year mortality rates post-clipping and post-coiling being 11.2% and 16.0%, respectively. There was no significant difference in mortality between the two treatment modalities ($P = 0.077$). The 1-year mortality rates following NSAC and SAC were 14.3% and 19.5%, respectively, with SAC showing significantly higher mortality ($P = 0.002$). There was no significant difference in mortality between clipping and NSAC ($P = 0.73$), however, clipping had significantly lower mortality compared to SAC ($P = 0.019$) (Table 4).

Treatment outcomes at hospitals that performed more than 20 RIAs treatments according to hospital size

Treatment for RIAs was performed in 2,429 cases (59.8%) at TRGH and 1,630 cases (40.2%) at GH, with a 1-year mortality of 13.6% at TRGH and 15.6% at GH, showing no significant statistical difference ($P = 0.275$). Clipping was performed in 865 cases (64.6%) at TRGH and

Table 1. Number of hospitals and procedures for ruptured intracranial aneurysms by region and hospital size in 2018

| Regions | No. of hospitals | | No. of procedures | |
|---|------------------|---------|-------------------|---------|
| | Clipping | Coiling | Clipping | Coiling |
| Tertiary referral general hospital | | | | |
| Overall | 40 | 41 | 985 | 1,642 |
| Seoul | 13 | 13 | 303 | 386 |
| Incheon | 3 | 3 | 47 | 186 |
| Gyeonggi-do | 5 | 5 | 136 | 229 |
| Gangwon-do | 1 | 1 | 5 | 33 |
| Busan | 4 | 4 | 81 | 187 |
| Daegu | 4 | 5 | 117 | 178 |
| Ulsan | 0 | 0 | 0 | 0 |
| Gyeongsangnam-do | 2 | 2 | 37 | 126 |
| Gyeongsangbuk-do | 0 | 0 | 0 | 0 |
| Gwangju | 2 | 2 | 146 | 40 |
| Jeollanam-do | 0 | 0 | 0 | 0 |
| Jeollabuk-do | 2 | 2 | 63 | 79 |
| Daejeon | 1 | 1 | 3 | 47 |
| Chungcheongnam-do | 2 | 2 | 19 | 56 |
| Chungcheongbuk-do | 1 | 1 | 28 | 7 |
| General hospital | | | | |
| Overall | 124 | 151 | 827 | 2,076 |
| Seoul | 20 | 22 | 152 | 335 |
| Incheon | 4 | 9 | 21 | 72 |
| Gyeonggi-do | 22 | 28 | 168 | 501 |
| Gangwon-do | 5 | 7 | 29 | 115 |
| Busan | 8 | 10 | 94 | 74 |
| Daegu | 4 | 2 | 31 | 46 |
| Ulsan | 2 | 5 | 11 | 96 |
| Gyeongsangnam-do | 6 | 12 | 19 | 112 |
| Gyeongsangbuk-do | 8 | 12 | 31 | 226 |
| Gwangju | 14 | 7 | 98 | 31 |
| Jeollanam-do | 12 | 5 | 59 | 19 |
| Jeollabuk-do | 7 | 6 | 42 | 43 |
| Daejeon | 5 | 8 | 21 | 151 |
| Chungcheongnam-do | 2 | 8 | 2 | 48 |
| Chungcheongbuk-do | 6 | 6 | 26 | 86 |
| Semi-general hospital | | | | |
| Overall | 234 | 380 | 382 | 713 |
| Seoul | 39 | 48 | 58 | 111 |
| Incheon | 13 | 22 | 25 | 54 |
| Gyeonggi-do | 54 | 104 | 83 | 190 |
| Gangwon-do | 7 | 10 | 7 | 13 |
| Busan | 21 | 32 | 33 | 60 |
| Daegu | 16 | 26 | 30 | 54 |
| Ulsan | 3 | 6 | 3 | 21 |
| Gyeongsangnam-do | 9 | 31 | 9 | 54 |
| Gyeongsangbuk-do | 6 | 26 | 8 | 33 |
| Gwangju | 22 | 13 | 54 | 17 |
| Jeollanam-do | 9 | 8 | 15 | 9 |
| Jeollabuk-do | 17 | 16 | 26 | 25 |
| Daejeon | 8 | 12 | 11 | 30 |
| Chungcheongnam-do | 1 | 10 | 3 | 12 |
| Chungcheongbuk-do | 7 | 7 | 12 | 3 |

475 cases (35.4%) at GH, with a 1-year mortality of 9.4% at TRGH compared to 14.5% at GH, which was significantly lower at TRGH ($P = 0.042$). On the other hand, coiling was performed in 1,564 cases (57.5%) at TRGH and 1,155 cases (42.5%) at GH, with a 1-year mortality of 15.9% at TRGH versus 16.1% at GH, showing no significant difference between TRGH and

Table 2. Comparison of mortality within 3 months and 1 year after clipping and coiling for ruptured aneurysms by hospital size according to region

| Regions | Clipping | | | | Coiling | | | |
|-------------------|----------------------|-------|---------------------|-------|----------------------|-------|---------------------|-------|
| | 3-month mortality, % | | 1-year mortality, % | | 3-month mortality, % | | 1-year mortality, % | |
| | TRGH | GH | TRGH | GH | TRGH | GH | TRGH | GH |
| P value | 0.071 | | 0.025 | | 0.792 | | 0.187 | |
| Overall | 7.82 | 10.76 | 9.85 | 14.15 | 13.58 | 14.88 | 16.80 | 17.79 |
| Seoul | 5.28 | 8.55 | 7.92 | 12.50 | 7.77 | 12.84 | 10.62 | 15.22 |
| Incheon | 12.77 | 9.52 | 14.89 | 14.29 | 16.67 | 16.67 | 18.28 | 19.44 |
| Gyeonggi-do | 6.62 | 13.69 | 7.35 | 17.86 | 10.04 | 12.38 | 12.23 | 14.17 |
| Gangwon-do | NA | 6.90 | NA | 10.34 | 18.18 | 12.17 | 24.24 | 13.91 |
| Busan | 9.88 | 8.51 | 13.58 | 13.83 | 16.04 | 14.86 | 20.86 | 21.62 |
| Daegu | 7.69 | 9.68 | 7.69 | 12.90 | 17.98 | 15.22 | 21.91 | 19.57 |
| Ulsan | NA | 18.18 | NA | 18.18 | NA | 14.58 | 0.00 | 15.63 |
| Gyeongsangnam-do | 8.11 | 26.32 | 10.81 | 26.32 | 16.67 | 18.75 | 19.05 | 20.54 |
| Gyeongsangbuk-do | NA | 16.13 | NA | 22.58 | NA | 21.24 | 0.00 | 25.22 |
| Gwangju | 8.90 | 4.08 | 10.27 | 5.10 | 12.50 | 19.35 | 17.50 | 29.03 |
| Jeollanam-do | NA | 6.78 | NA | 6.78 | NA | 15.79 | 0.00 | 21.05 |
| Jeollabuk-do | 9.52 | 14.29 | 11.11 | 19.05 | 16.46 | 4.65 | 20.25 | 16.28 |
| Daejeon | NA | 9.52 | NA | 14.29 | 19.15 | 13.25 | 19.15 | 14.57 |
| Chungcheongnam-do | 15.79 | NA | 21.05 | NA | 19.64 | 27.08 | 26.79 | 31.25 |
| Chungcheongbuk-do | 7.14 | 23.08 | 7.14 | 23.08 | 0.00 | 20.93 | 14.29 | 22.09 |

GH = general hospital, TRGH = tertiary referral general hospital, NA = not applicable.

Table 3. Treatment outcomes at hospitals that performed more than 20 ruptured intracranial aneurysms treatments in 2018

| Hospital size | Region | Total number | Clipping, No. (%) | Coiling, No. (%) | Coiling | | 1-year mortality, % | | | | |
|---------------|----------------|--------------|-------------------|------------------|---------------|--------------|---------------------|----------|---------|------|------|
| | | | | | NSAC, No. (%) | SAC, No. (%) | Total | Clipping | Coiling | NSAC | SAC |
| 1 TRGH | Gyeongsang-do | 124 | 35 (28.2) | 89 (71.8) | 65 (73.0) | 24 (27.0) | 8.6 | 10.5 | 7.9 | 4.6 | 16.7 |
| 2 TRGH | Jeolla-do | 102 | 68 (66.7) | 34 (33.3) | 23 (67.6) | 11 (32.4) | 7.7 | 5.6 | 11.8 | 13.0 | 9.1 |
| 3 TRGH | Gyeongsang-do | 101 | 15 (14.9) | 86 (85.1) | 46 (53.5) | 40 (46.5) | 14.7 | 5.6 | 16.3 | 17.4 | 15.0 |
| 4 TRGH | Gyeonggi-do | 100 | 15 (15.0) | 85 (85.0) | 68 (80.0) | 17 (20.0) | 10.7 | 11.1 | 10.6 | 7.4 | 23.5 |
| 5 TRGH | Gyeongsang-do | 97 | 19 (19.6) | 78 (80.4) | 49 (62.8) | 29 (37.2) | 11.1 | 9.1 | 11.5 | 10.2 | 13.8 |
| 6 TRGH | Gyeonggi-do | 88 | 44 (50.0) | 44 (50.0) | 35 (79.5) | 9 (20.5) | 5.4 | 8.5 | 2.3 | 0.0 | 11.1 |
| 7 TRGH | Chungcheong-do | 85 | 5 (5.9) | 80 (94.1) | 46 (57.5) | 34 (42.5) | 22.2 | 37.5 | 21.3 | 23.9 | 17.6 |
| 8 TRGH | Gyeonggi-do | 84 | 38 (45.2) | 46 (54.8) | 41 (89.1) | 5 (10.9) | 10.5 | 4.9 | 15.2 | 14.6 | 20.0 |
| 9 TRGH | Jeolla-do | 79 | 72 (91.1) | 7 (8.9) | 6 (85.7) | 1 (14.3) | 9.9 | 5.3 | 57.1 | 13.6 | 18.2 |
| 10 TRGH | Gyeonggi-do | 76 | 11 (14.5) | 65 (85.5) | 52 (80.0) | 13 (20.0) | 12.9 | 7.1 | 13.8 | 15.4 | 7.7 |
| 11 TRGH | Gyeongsang-do | 75 | 32 (42.7) | 43 (57.3) | 37 (86.0) | 6 (14.0) | 20.4 | 22.9 | 18.6 | 18.9 | 16.7 |
| 12 GH | Jeolla-do | 73 | 49 (67.1) | 24 (32.9) | 16 (66.7) | 8 (0.0) | 14.8 | 7.7 | 29.2 | 18.8 | 50.0 |
| 13 GH | Gyeongsang-do | 71 | 52 (73.2) | 19 (26.8) | 11 (47.4) | 8 (42.1) | 17.4 | 21.8 | 5.3 | 0.0 | 12.5 |
| 14 GH | Ulsan | 70 | 3 (4.3) | 67 (95.7) | 40 (59.7) | 27 (40.3) | 15.0 | 16.7 | 14.9 | 17.5 | 11.1 |
| 15 TRGH | Seoul | 70 | 22 (31.4) | 48 (68.6) | 37 (77.1) | 11 (22.9) | 12.2 | 16.0 | 10.4 | 8.1 | 18.2 |
| 16 TRGH | Jeolla-do | 69 | 40 (58.0) | 29 (42.0) | 24 (82.8) | 5 (17.2) | 17.0 | 9.3 | 27.6 | 29.2 | 20.0 |
| 17 TRGH | Gyeongsang-do | 67 | 18 (26.9) | 49 (73.1) | 29 (59.2) | 20 (40.8) | 16.0 | 9.5 | 18.4 | 17.2 | 20.0 |
| 18 TRGH | Seoul | 67 | 37 (55.2) | 30 (44.8) | 18 (60.0) | 12 (40.0) | 11.2 | 17.5 | 3.3 | 5.6 | 0.0 |
| 19 TRGH | Jeolla-do | 66 | 17 (25.8) | 49 (74.2) | 40 (81.6) | 9 (18.4) | 16.0 | 15.0 | 16.3 | 12.5 | 33.3 |
| 20 TRGH | Seoul | 65 | 21 (32.3) | 44 (67.7) | 31 (70.5) | 13 (29.5) | 5.8 | 8.3 | 4.5 | 3.2 | 7.7 |
| 21 TRGH | Gyeonggi-do | 65 | 14 (21.5) | 51 (78.5) | 42 (82.4) | 9 (17.6) | 13.6 | 5.9 | 15.7 | 14.3 | 22.2 |
| 22 GH | Gyeongsang-do | 64 | 2 (3.1) | 62 (96.9) | 30 (48.4) | 32 (51.6) | 10.0 | 20.0 | 9.7 | 10.0 | 9.4 |
| 23 GH | Gyeonggi-do | 64 | 17 (26.6) | 47 (73.4) | 41 (87.2) | 6 (12.8) | 6.3 | 0.0 | 8.5 | 7.3 | 16.7 |
| 24 GH | Gyeongsang-do | 64 | 23 (35.9) | 41 (64.1) | 32 (78.0) | 9 (22.0) | 18.0 | 15.4 | 19.5 | 18.8 | 22.2 |
| 25 GH | Gyeonggi-do | 62 | 8 (12.9) | 54 (87.1) | 45 (83.3) | 9 (16.7) | 10.0 | 27.3 | 7.4 | 6.7 | 11.1 |
| 26 TRGH | Gyeonggi-do | 61 | 9 (14.8) | 52 (85.2) | 34 (65.4) | 18 (34.6) | 32.8 | 33.3 | 32.7 | 29.4 | 38.9 |
| 27 TRGH | Seoul | 61 | 13 (21.3) | 48 (78.7) | 39 (81.3) | 9 (18.8) | 7.9 | 6.3 | 8.3 | 10.3 | 0.0 |
| 28 GH | Seoul | 60 | 9 (15.0) | 51 (85.0) | 36 (70.6) | 15 (29.4) | 29.2 | 16.7 | 31.4 | 27.8 | 40.0 |
| 29 GH | Gyeonggi-do | 60 | 2 (3.3) | 58 (96.7) | 47 (81.0) | 11 (19.0) | 8.0 | 40.0 | 6.9 | 6.4 | 9.1 |
| 30 TRGH | Gyeongsang-do | 59 | 16 (27.1) | 43 (72.9) | 24 (55.8) | 19 (44.2) | 24.6 | 15.8 | 27.9 | 20.8 | 36.8 |
| 31 TRGH | Gyeongsang-do | 57 | 45 (78.9) | 12 (21.1) | 8 (66.7) | 4 (33.3) | 12.2 | 2.1 | 50.0 | 9.5 | 35.7 |
| 32 GH | Gangwon-do | 56 | 8 (14.3) | 48 (85.7) | 39 (81.3) | 9 (18.8) | 8.9 | 0.0 | 10.4 | 12.8 | 0.0 |

(continued to the next page)

Table 3. (Continued) Treatment outcomes at hospitals that performed more than 20 ruptured intracranial aneurysms treatments in 2018

| Hospital size | Region | Total number | Clipping, No. (%) | Coiling, No. (%) | Coiling | | 1-year mortality, % | | | | |
|---------------|----------------|--------------|-------------------|------------------|---------------|--------------|---------------------|----------|---------|------|------|
| | | | | | NSAC, No. (%) | SAC, No. (%) | Total | Clipping | Coiling | NSAC | SAC |
| 33 GH | Gyeonggi-do | 55 | 13 (23.6) | 42 (76.4) | 15 (35.7) | 27 (64.3) | 19.3 | 12.5 | 21.4 | 20.0 | 22.2 |
| 34 TRGH | Seoul | 55 | 21 (38.2) | 34 (61.8) | 21 (61.8) | 13 (38.2) | 18.0 | 4.2 | 26.5 | 23.8 | 30.8 |
| 35 TRGH | Gyeonggi-do | 54 | 24 (44.4) | 30 (55.6) | 25 (83.3) | 5 (16.7) | 12.6 | 7.4 | 16.7 | 12.0 | 40.0 |
| 36 TRGH | Gyeongsang-do | 53 | 17 (32.1) | 36 (67.9) | 22 (61.1) | 14 (38.9) | 12.9 | 5.0 | 16.7 | 9.1 | 28.6 |
| 37 TRGH | Seoul | 53 | 25 (47.2) | 28 (52.8) | 23 (82.1) | 5 (17.9) | 12.8 | 7.1 | 17.9 | 17.4 | 20.0 |
| 38 GH | Jeju-do | 52 | 10 (19.2) | 42 (80.8) | 36 (85.7) | 6 (14.3) | 22.2 | 15.4 | 23.8 | 25.0 | 16.7 |
| 39 TRGH | Gyeongsang-do | 50 | 8 (16.0) | 42 (84.0) | 35 (83.3) | 7 (16.7) | 19.8 | 36.4 | 16.7 | 8.6 | 57.1 |
| 40 GH | Seoul | 50 | 5 (10.0) | 45 (90.0) | 32 (71.1) | 13 (28.9) | 34.5 | 25.0 | 35.6 | 31.3 | 46.2 |
| 41 TRGH | Seoul | 50 | 19 (38.0) | 31 (62.0) | 20 (64.5) | 11 (35.5) | 3.7 | 4.5 | 3.2 | 5.0 | 0.0 |
| 42 GH | Seoul | 50 | 13 (26.0) | 37 (74.0) | 33 (89.2) | 4 (10.8) | 9.6 | 6.3 | 10.8 | 12.1 | 0.0 |
| 43 GH | Gyeonggi-do | 49 | 8 (16.3) | 41 (83.7) | 36 (87.8) | 5 (12.2) | 12.6 | 27.3 | 9.8 | 11.1 | 0.0 |
| 44 GH | Gyeonggi-do | 49 | 9 (18.4) | 40 (81.6) | 34 (85.0) | 6 (15.0) | 11.7 | 8.3 | 12.5 | 14.7 | 0.0 |
| 45 TRGH | Gyeonggi-do | 48 | 4 (8.3) | 44 (91.7) | 32 (72.7) | 12 (27.3) | 11.6 | 14.3 | 11.4 | 6.3 | 25.0 |
| 46 TRGH | Seoul | 46 | 17 (37.0) | 29 (63.0) | 19 (65.5) | 10 (34.5) | 8.7 | 0.0 | 13.8 | 15.8 | 10.0 |
| 47 TRGH | Seoul | 45 | 40 (88.9) | 5 (11.1) | 5 (100) | 0 (0.0) | 10.5 | 9.3 | 20.0 | 20.0 | NA |
| 48 TRGH | Chungcheong-do | 42 | 25 (59.5) | 17 (40.5) | 7 (41.2) | 10 (58.8) | 11.4 | 7.1 | 17.6 | 14.3 | 25.0 |
| 49 GH | Chungcheong-do | 42 | 9 (21.4) | 33 (78.6) | 31 (93.9) | 2 (6.1) | 22.6 | 16.7 | 24.2 | 22.6 | 50.0 |
| 50 GH | Seoul | 41 | 21 (51.2) | 20 (48.8) | 17 (85.0) | 3 (15.0) | 6.7 | 8.3 | 5.0 | 5.9 | 0.0 |
| 51 GH | Gyeonggi-do | 41 | 9 (22.0) | 32 (78.0) | 30 (93.8) | 2 (6.3) | 8.5 | 16.7 | 6.3 | 6.7 | 0.0 |
| 52 TRGH | Seoul | 41 | 17 (41.5) | 24 (58.5) | 18 (75.0) | 6 (25.0) | 4.5 | 5.0 | 4.2 | 5.6 | 0.0 |
| 53 GH | Gyeongsang-do | 39 | 3 (7.7) | 36 (92.3) | 28 (77.8) | 8 (22.2) | 6.4 | 16.7 | 5.6 | 3.6 | 12.5 |
| 54 GH | Gyeonggi-do | 38 | 34 (89.5) | 4 (10.5) | 4 (100.0) | 0 (0.0) | 16.9 | 18.9 | 0.0 | 0.0 | NA |
| 55 TRGH | Seoul | 38 | 8 (21.1) | 30 (78.9) | 21 (70.0) | 9 (30.0) | 7.2 | 9.1 | 6.7 | 4.8 | 11.1 |
| 56 TRGH | Seoul | 37 | 14 (37.8) | 23 (62.2) | 15 (65.2) | 8 (34.8) | 10.8 | 0.0 | 17.4 | 20.0 | 12.5 |
| 57 GH | Gangwon-do | 37 | 7 (18.9) | 30 (81.1) | 24 (80.0) | 6 (20.0) | 22.7 | 20.0 | 23.3 | 16.7 | 50.0 |
| 58 GH | Gyeongsang-do | 37 | 6 (16.2) | 31 (83.8) | 17 (54.8) | 14 (45.2) | 21.6 | 0.0 | 25.8 | 29.4 | 21.4 |
| 59 GH | Gyeongsang-do | 35 | 8 (22.9) | 27 (77.1) | 19 (70.4) | 8 (29.6) | 25.5 | 36.4 | 22.2 | 15.8 | 37.5 |
| 60 GH | Jeolla-do | 35 | 29 (82.9) | 6 (17.1) | 2 (33.3) | 4 (66.7) | 21.0 | 21.9 | 16.7 | 0.0 | 25.0 |
| 61 TRGH | Gangwon-do | 35 | 2 (5.7) | 33 (94.3) | 25 (75.8) | 8 (24.2) | 27.4 | 80.0 | 24.2 | 20.0 | 37.5 |
| 62 GH | Jeolla-do | 34 | 23 (67.6) | 11 (32.4) | 7 (63.6) | 4 (36.4) | 17.0 | 7.7 | 36.4 | 28.6 | 50.0 |
| 63 TRGH | Seoul | 33 | 10 (30.3) | 23 (69.7) | 18 (78.3) | 5 (21.7) | 10.7 | 15.4 | 8.7 | 5.6 | 20.0 |
| 64 TRGH | Chungcheong-do | 31 | 8 (25.8) | 23 (74.2) | 16 (69.6) | 7 (30.4) | 61.9 | 27.3 | 73.9 | 68.8 | 85.7 |
| 65 GH | Gyeongsang-do | 30 | 3 (10) | 27 (90) | 23 (85.2) | 4 (14.8) | 30.0 | 33.3 | 29.6 | 34.8 | 0.0 |
| 66 GH | Gyeonggi-do | 30 | 4 (13.3) | 26 (86.7) | 21 (80.8) | 5 (19.2) | 23.8 | 28.6 | 23.1 | 19.0 | 40.0 |
| 67 GH | Seoul | 29 | 8 (27.6) | 21 (72.4) | 19 (90.5) | 2 (9.5) | 9.4 | 9.1 | 9.5 | 5.3 | 50.0 |
| 68 GH | Seoul | 28 | 4 (14.3) | 24 (85.7) | 17 (70.8) | 7 (29.2) | 3.6 | 0.0 | 4.2 | 0.0 | 14.3 |
| 69 GH | Gyeongsang-do | 26 | 16 (61.5) | 10 (38.5) | 6 (60.0) | 4 (40.0) | 7.1 | 5.3 | 10.0 | 16.7 | 0.0 |
| 70 GH | Seoul | 25 | 16 (64.0) | 9 (36.0) | 7 (77.8) | 2 (22.2) | 10.7 | 10.5 | 11.1 | 5.6 | 0.0 |
| 71 GH | Ulsan | 25 | 2 (8.0) | 23 (92.0) | 15 (65.2) | 8 (34.8) | 17.6 | 20.0 | 17.4 | 6.7 | 37.5 |
| 72 GH | Chungcheong-do | 23 | 12 (52.2) | 11 (47.8) | 7 (63.6) | 4 (36.4) | 27.0 | 26.7 | 27.3 | 20.0 | 40.0 |
| 73 GH | Seoul | 23 | 12 (52.2) | 11 (47.8) | 9 (81.8) | 2 (18.2) | 19.1 | 20.0 | 18.2 | 20.0 | 0.0 |
| 74 GH | Gyeonggi-do | 22 | 1 (4.5) | 21 (95.5) | 10 (47.6) | 11 (52.4) | 18.2 | 0.0 | 19.0 | 30.0 | 9.1 |
| 75 GH | Jeolla-do | 21 | 15 (71.4) | 6 (28.6) | 4 (66.7) | 2 (33.3) | 4.0 | 5.6 | 0.0 | 0.0 | 0.0 |
| 76 GH | Gyeonggi-do | 20 | 2 (10.0) | 18 (90.0) | 14 (77.8) | 4 (22.2) | 12.0 | 20.0 | 11.1 | 6.7 | 20.0 |
| Total | | 4,059 | 1,340 (33.0) | 2,719 (67.0) | 1,970 (72.5) | 749 (27.5) | 14.4 | 11.2 | 16.0 | 14.3 | 19.5 |

NSAC = non-stent assisted coiling, SAC = stent assisted coiling, TRGH = tertiary referral general hospital, GH = general hospital.

GH ($P = 0.775$). Similarly, no significant difference in 1-year mortality was observed between hospital sizes for NSAC ($P = 0.93$) and SAC ($P = 0.457$) (Table 5).

Correlation analysis between hospital size, RIA treatment volume, and treatment outcomes

In the TRGH group, as the number of clipping procedures for RIAs increased, both the total 1-year mortality ($P = 0.023$; $\rho = -0.368$) and the one-year mortality after clipping ($P = 0.022$; $\rho = -0.370$) significantly decreased. In contrast, for coiling, there was no significant

Table 4. Treatment outcomes at hospitals that performed more than 20 ruptured intracranial aneurysms treatments according to treatment modality

| Treatment modality | No. of patients | 1-year mortality, % | P value | |
|--------------------|-----------------|---------------------|---------------------|---------------------------|
| | | | Mann-Whitney U test | Wilcoxon signed-rank test |
| Clipping | 1,340 | 11.2 | 0.077 | 0.135 |
| Coiling | 2,719 | 16.0 | | |
| NSAC | 1,970 | 14.3 | 0.034 | 0.002 |
| SAC | 749 | 19.5 | | |
| Clipping | | | 0.730 | 0.821 |
| NSAC | | | | |
| Clipping | | | 0.019 | 0.003 |
| SAC | | | | |

NSAC = non-stent assisted coiling, SAC = stent assisted coiling.

Table 5. Treatment outcomes at hospitals that performed more than 20 ruptured intracranial aneurysms treatments according to hospital size

| Treatment modality | Hospital size | No. of patients | 1-year mortality (%) | P value |
|--------------------|---------------|-----------------|----------------------|---------|
| Total | TRGH | 2,429 | 13.6 | 0.275 |
| | GH | 1,630 | 15.6 | |
| Clipping | TRGH | 865 | 9.4 | 0.042 |
| | GH | 475 | 14.5 | |
| Coiling | TRGH | 1,564 | 15.9 | 0.775 |
| | GH | 1,155 | 16.1 | |
| NSAC | TRGH | 1,116 | 13.9 | 0.93 |
| | GH | 854 | 14.8 | |
| SAC | TRGH | 448 | 20.1 | 0.457 |
| | GH | 301 | 18.6 | |

TRGH = tertiary referral general hospital, GH = general hospital, NSAC = non-stent assisted coiling, SAC = stent assisted coiling.

correlation between the number of procedures performed and total one-year mortality ($P = 0.288$; $\rho = 0.177$) or one-year mortality after coiling ($P = 0.109$; $\rho = -0.264$) (Fig. 1).

In the GH group, unlike in the TRGH group, there was no significant correlation between the number of clipping procedures performed and treatment outcomes. However, for coiling, a higher volume of treatments at a hospital was associated with increased total one-year mortality ($P = 0.009$; $\rho = 0.417$), but there was no significant correlation with one-year mortality after coiling ($P = 0.559$; $\rho = 0.098$) (Fig. 2).

DISCUSSION

Several studies have demonstrated the impact of hospital size and procedural volume on the treatment outcomes of RIAs. Lindgren et al.⁴ conducted an analysis of treatment outcomes, categorizing hospitals based on an annual case volume of 8,525 patients treated for aneurysmal subarachnoid hemorrhage (SAH) at a large tertiary medical center between 2007 and 2014. Hospitals with an annual case volume exceeding 41 exhibited a low fatality rate irrespective of the chosen treatment modality. Another study, utilizing National Inpatient Sample data from the United States during 2010 to 2011, demonstrated an improvement in outcomes for SAH patients as the number of hospital cases increased, with hospitals conducting more than 35 SAH cases per year consistently achieving superior outcomes.⁵

In our study, utilizing data from the Korean NHIS database in 2018, we observed 2,194 (33.1%) clipping procedures and 4,431 (66.9%) coiling procedures for RIAs, carried out

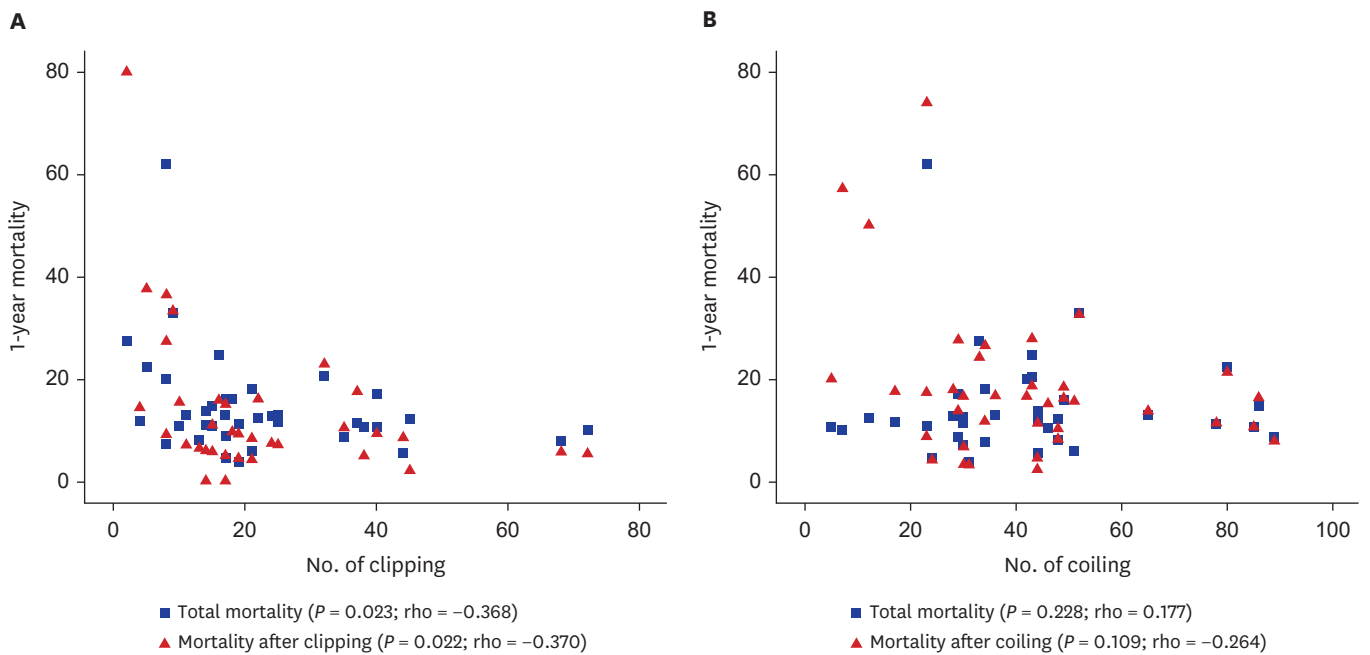


Fig. 1. Analysis of the correlation between the number of treatments and 1-year mortality at TRGH that performed more than 20 RIAs treatments. **(A)** As the number of clipping procedures for RIAs increased, both the total 1-year mortality ($P = 0.023$; $\rho = -0.368$) and the one-year mortality after clipping ($P = 0.022$; $\rho = -0.370$) significantly decreased. **(B)** There was no significant correlation between the number of coiling procedures performed and treatment outcomes. TRGH = tertiary referral general hospital, RIA = ruptured intracranial aneurysm.

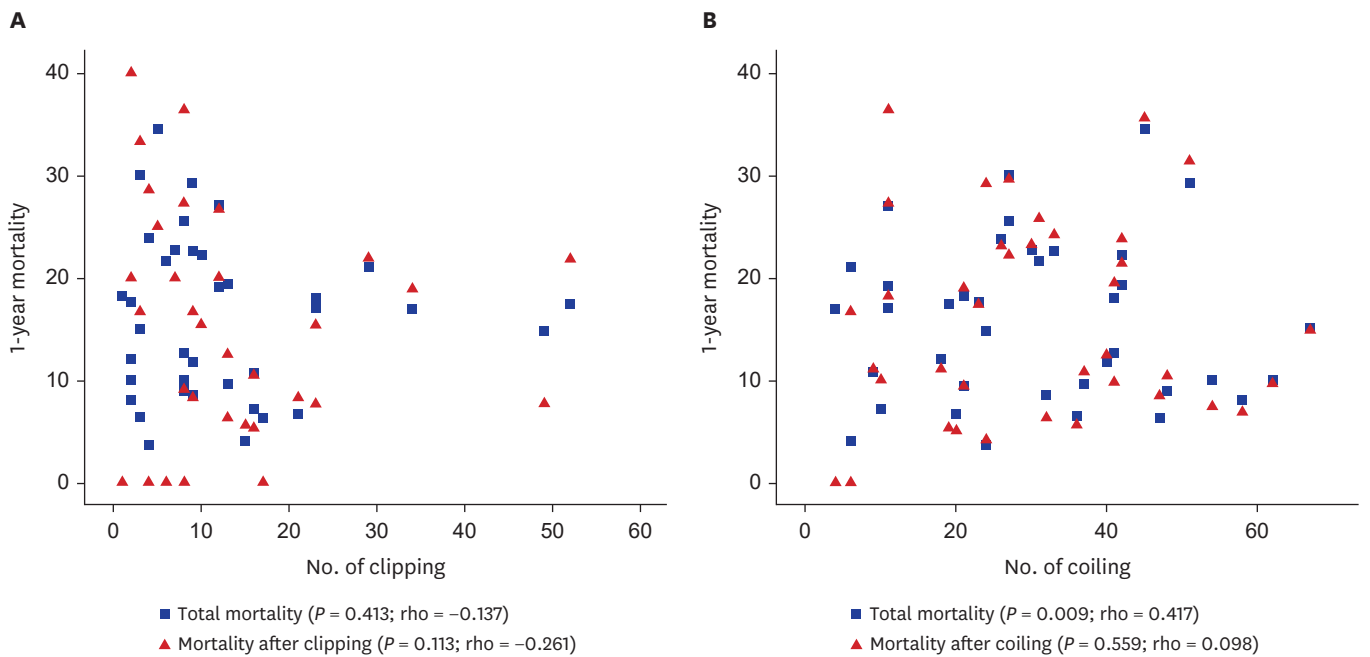


Fig. 2. Analysis of the correlation between the number of treatments and 1-year mortality at GH that performed more than 20 RIAs treatments. **(A)** There was no significant correlation between the number of clipping procedures performed and treatment outcomes. **(B)** A higher volume of coilings at a GH was associated with increased total one-year mortality ($P = 0.009$; $\rho = 0.417$), but there was no significant correlation with 1-year mortality after coiling ($P = 0.559$; $\rho = 0.098$). GH = general hospital, RIA = ruptured intracranial aneurysm.

across 398 and 572 hospitals, respectively. Nationwide, the 1-year mortality rates for total cases and coiling cases did not show significant differences between TRGH (total, 13.6%; coiling, 16.8%) and GH (total, 15.6%; coiling, 17.8%). However, for clipping procedures, the mortality was significantly lower in TRGH (9.9%) compared to GH (14.2%). When analyzing only hospitals that performed more than 20 procedures per year, the average 1-year mortality was 14.4%. In the case of TRGH, the number of coiling procedures did not show a significant correlation with 1-year mortality, whereas a higher volume of clipping procedures was associated with significantly lower mortality. This suggests that for RIAs, the volume of coiling procedures does not significantly affect the outcomes of coiling, although outcomes for UIAs demonstrated a positive correlation with the number of procedures.³ Meanwhile, an increase in clipping procedures for RIAs significantly improves the outcomes of clipping itself.

In contrast, for GHs that performed more than 20 procedures per year, the number of clipping procedures does not significantly influence the overall 1-year mortality, whereas a higher volume of coiling procedures is associated with a significant deterioration in the overall outcome. This could be due to the significantly lower number of clipping procedures in GH compared to TRGH, likely making it statistically insignificant. This observation could therefore postulate potential issues with the indications for coiling or with the quality management of coiling procedures. Particularly, the 1-year mortality rate for SAC at 19.5% was significantly higher than for clipping at 11.2% and NSAC at 14.3%, indicating the need for careful consideration in treatment decisions.

Several studies demonstrating a more favorable outcome of coiling compared to clipping in RIAs have positioned coiling as a crucial treatment modality, alongside clipping, for managing patients with SAH.⁶⁻¹⁰ Based on these findings, coiling has been the preferred approach over surgical clipping for treating SAH since 2013 in South Korea, and this preference continues to grow annually.¹ However, the application of stents in RIAs raises concerns due to the associated risk of complications arising from the use of antiplatelet drugs.¹¹⁻¹³ In a systematic review, Bodily et al.¹⁴ reported that stenting of RIAs was linked to a 6% incidence of clinically significant thromboembolic events, 14% adverse outcomes, and 19% mortality. On the other hands, in the case of small, RIAs (3 mm or less in size), stenting exhibited similar long-term outcomes to coil embolization but carried a significantly higher rate of hemorrhagic complications.¹⁵ Meanwhile, recent studies report that the development of low-profile stents and the adjustment of antiplatelet agent use are reducing complications in endovascular surgery. However, due to the lack of large-scale or prospective studies, it is still challenging to justify the use of stent-assisted coiling in the treatment of ruptured cerebral aneurysms.¹⁶⁻¹⁹

Early intervention, recognized as a pivotal strategy in enhancing treatment outcomes for RIAs, holds potential to mitigate rebleeding risk and facilitate the effective management of vasospasm.²⁰⁻²⁴ Fortunately, the majority of RIAs can be treated with coiling, and the outcomes of overall treatments and coiling for RIAs do not significantly vary by region or hospital size, making it reasonable to seek prompt treatment at the nearest facility. However, the results of clipping differ significantly depending on the hospital size and the number of procedures performed, suggesting a need for nationwide improvements in the outcomes of clipping. If clipping becomes more widespread and its outcomes improve, it could lead to more careful decision-making regarding SAC, prevent the concentration of cases in specific regions, and enhance treatment outcomes across the country.

There are several limitations to this study. First, because the NHIS data is based on insurance claims, it is challenging to ascertain patients' neurological status prior to treatment and to access imaging results, making it impossible to obtain morphological information about the aneurysms. Secondly, the variability in hospitals' criteria for selecting treatment methods significantly complicates direct comparisons of treatment outcomes across different institutions. Moreover, there is a potential for overestimation of mortality rates in GHs, given that 41.1% of GHs performed fewer than five coilings for RIAs. To mitigate this bias, we conducted an additional analysis on hospitals performing more than 20 procedures, aiming to more accurately reflect treatment efficacy. Thirdly, the 1-year mortality includes all causes of death, so the possibility of deaths due to causes other than RIAs cannot be excluded. Finally, it should be acknowledged that this analysis relies solely on data from the year 2018, without accounting for potentially influential variables such as gender and age. However, given the study's aim to compare treatment outcomes across different regions and hospital sizes, the decision to use data from a single year was deemed to still provide valuable insights.

In conclusion, in a study using data from the Korea NHIS, it was found that the mortality rates for overall cases and specifically for coiling cases of RIAs do not significantly vary by hospital size, attributed to the widespread use of coiling. However, the observed differences in clipping outcomes, depending on hospital size and the procedure volume in TRGH, underscore the necessity for national initiatives aimed at enhancing the skill and generalization of clipping practices. Moreover, with the higher mortality rate associated with SAC, establishing precise indications for its use becomes crucial.

REFERENCES

1. Lee SU, Kim T, Kwon OK, Bang JS, Ban SP, Byoun HS, et al. Trends in the incidence and treatment of cerebrovascular diseases in Korea : Part I. Intracranial aneurysm, intracerebral hemorrhage, and arteriovenous malformation. *J Korean Neurosurg Soc* 2020;63(1):56-68. [PUBMED](#) | [CROSSREF](#)
2. Lee SH, Lee SU, Kwon OK, Bang JS, Ban SP, Kim T, et al. Clinical outcomes of clipping and coiling in elderly patients with unruptured cerebral aneurysms: a national cohort study in Korea. *J Korean Med Sci* 2021;36(26):e178. [PUBMED](#) | [CROSSREF](#)
3. Ryu BG, Lee SU, Shim HS, Park JM, Lee YJ, Kim YD, et al. Clinical outcomes of coil embolization for unruptured intracranial aneurysms categorized by region and hospital size : a nationwide cohort study in Korea. *J Korean Neurosurg Soc* 2023;66(6):690-702. [PUBMED](#) | [CROSSREF](#)
4. Lindgren A, Burt S, Bragan Turner E, Meretoja A, Lee JM, Hemmen TM, et al. Hospital case-volume is associated with case-fatality after aneurysmal subarachnoid hemorrhage. *Int J Stroke* 2019;14(3):282-9. [PUBMED](#) | [CROSSREF](#)
5. Leifer D, Fonarow GC, Hellkamp A, Baker D, Hoh BL, Prabhakaran S, et al. Association between hospital volumes and clinical outcomes for patients with nontraumatic subarachnoid hemorrhage. *J Am Heart Assoc* 2021;10(15):e018373. [PUBMED](#) | [CROSSREF](#)
6. Li H, Pan R, Wang H, Rong X, Yin Z, Milgrom DP, et al. Clipping versus coiling for ruptured intracranial aneurysms: a systematic review and meta-analysis. *Stroke* 2013;44(1):29-37. [PUBMED](#) | [CROSSREF](#)
7. Shao B, Wang J, Chen Y, He X, Chen H, Peng Y, et al. Clipping versus coiling for ruptured intracranial aneurysms: a meta-analysis of randomized controlled trials. *World Neurosurg* 2019;127:e353-65. [PUBMED](#) | [CROSSREF](#)
8. Lanzino G, Murad MH, d'Urso PI, Rabinstein AA. Coil embolization versus clipping for ruptured intracranial aneurysms: a meta-analysis of prospective controlled published studies. *AJNR Am J Neuroradiol* 2013;34(9):1764-8. [PUBMED](#) | [CROSSREF](#)
9. Molyneux AJ, Kerr RS, Yu LM, Clarke M, Sneade M, Yarnold JA, et al. International subarachnoid aneurysm trial (ISAT) of neurosurgical clipping versus endovascular coiling in 2143 patients with ruptured intracranial aneurysms: a randomised comparison of effects on survival, dependency, seizures, rebleeding, subgroups, and aneurysm occlusion. *Lancet* 2005;366(9488):809-17. [PUBMED](#) | [CROSSREF](#)

10. Molyneux AJ, Kerr RS, Birks J, Ramzi N, Yarnold J, Sneade M, et al. Risk of recurrent subarachnoid haemorrhage, death, or dependence and standardised mortality ratios after clipping or coiling of an intracranial aneurysm in the International Subarachnoid Aneurysm Trial (ISAT): long-term follow-up. *Lancet Neurol* 2009;8(5):427-33. [PUBMED](#) | [CROSSREF](#)
11. Kim CH, Kim YH, Sung SK, Son DW, Song GS, Lee SW. Clinical safety and effectiveness of stent-assisted coil embolization with neuroform atlas stent in intracranial aneurysm. *J Korean Neurosurg Soc* 2020;63(1):80-8. [PUBMED](#) | [CROSSREF](#)
12. Bechan RS, Sprengers ME, Majoie CB, Peluso JP, Sluzewski M, van Rooij WJ. Stent-assisted coil embolization of intracranial aneurysms: complications in acutely ruptured versus unruptured aneurysms. *AJNR Am J Neuroradiol* 2016;37(3):502-7. [PUBMED](#) | [CROSSREF](#)
13. Chalouhi N, Jabbour P, Singhal S, Drueding R, Starke RM, Dalyai RT, et al. Stent-assisted coiling of intracranial aneurysms: predictors of complications, recanalization, and outcome in 508 cases. *Stroke* 2013;44(5):1348-53. [PUBMED](#) | [CROSSREF](#)
14. Bodily KD, Cloft HJ, Lanzino G, Fiorella DJ, White PM, Kallmes DF. Stent-assisted coiling in acutely ruptured intracranial aneurysms: a qualitative, systematic review of the literature. *AJNR Am J Neuroradiol* 2011;32(7):1232-6. [PUBMED](#) | [CROSSREF](#)
15. Zhang G, Wu Y, Wei Y, Xue G, Chen R, Lv N, et al. Stent-assisted coiling vs. coiling alone of ruptured tiny intracranial aneurysms: a contemporary cohort study in a high-volume center. *Front Neurol* 2022;13:1076026. [PUBMED](#) | [CROSSREF](#)
16. Jiang W, Zuo Q, Xue G, Zhang X, Tang H, Duan G, et al. Low profile visualized intraluminal support stent-assisted Hydrocoil embolization for acutely ruptured wide-necked intracranial aneurysms: a propensity score-matched cohort study. *Clin Neurol Neurosurg* 2022;218:107302. [PUBMED](#) | [CROSSREF](#)
17. Russo R, Bradac GB, Castellani L, Gallesio I, Garbossa D, Iannucci G, et al. Neuroform Atlas stent-assisted coiling of ruptured intracranial aneurysms: a multicenter study. *J Neuroradiol* 2021;48(6):479-85. [PUBMED](#) | [CROSSREF](#)
18. Liu C, Guo K, Wu X, Wu L, Cai Y, Hu X, et al. Utility of low-profile visualized intraluminal support (LVIS™) stent for treatment of acutely ruptured bifurcation aneurysms: a single-center study. *Front Neurol* 2023;14:1050369. [PUBMED](#) | [CROSSREF](#)
19. Jin Y, Guo X, Quan T, Chen Z, Liu C, Guan S. Safety and efficacy of endovascular treatment for tiny ruptured intracranial aneurysms with low-profile visualized intraluminal support stents. *Interv Neuroradiol* 2023;29(2):141-7. [PUBMED](#) | [CROSSREF](#)
20. Phillips TJ, Dowling RJ, Yan B, Laidlaw JD, Mitchell PJ. Does treatment of ruptured intracranial aneurysms within 24 hours improve clinical outcome? *Stroke* 2011;42(7):1936-45. [PUBMED](#) | [CROSSREF](#)
21. Siddiq F, Chaudhry SA, Tummala RP, Suri MF, Qureshi AI. Factors and outcomes associated with early and delayed aneurysm treatment in subarachnoid hemorrhage patients in the United States. *Neurosurgery* 2012;71(3):670-7. [PUBMED](#) | [CROSSREF](#)
22. de Gans K, Nieuwkamp DJ, Rinkel GJ, Algra A. Timing of aneurysm surgery in subarachnoid hemorrhage: a systematic review of the literature. *Neurosurgery* 2002;50(2):336-40. [PUBMED](#) | [CROSSREF](#)
23. Germans MR, Coert BA, Vandertop WP, Verbaan D. Time intervals from subarachnoid hemorrhage to rebleed. *J Neurol* 2014;261(7):1425-31. [PUBMED](#) | [CROSSREF](#)
24. Nieuwkamp DJ, de Gans K, Algra A, Albrecht KW, Boomstra S, Brouwers PJ, et al. Timing of aneurysm surgery in subarachnoid haemorrhage--an observational study in The Netherlands. *Acta Neurochir (Wien)* 2005;147(8):815-21. [PUBMED](#) | [CROSSREF](#)