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Clinical Practice Guideline for the Prehospital Stage of Acute Stroke : III. Initial Decision for Primary Treatment in Subarachnoid Hemorrhage

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Subarachnoid hemorrhage (SAH) is a stroke subtype with high mortality and poor functional outcomes. Prompt occlusion of a ruptured aneurysm at an early stage is crucial to prevent rebleeding, which can result in even higher mortality and more severe disabilities. The most critical initial decision in SAH management is the choice of treatment method with surgical clipping or endovascular coiling. We aimed to develop an evidence-based clinical guideline to select the optimal initial treatment in patients with SAH. We developed this guideline based on evidence from systematic reviews and meta-analyses via a *de novo* process. A systematic literature review was conducted across four databases (MEDLINE, Embase, Cochrane, and KoreaMed) to answer two population, intervention, comparison, outcome questions comparing clipping and coiling. The risk of bias was assessed using ROB 2.0 and the Newcastle-Ottawa Scale. The Preferred Reporting Items for Systematic Reviews and Meta-Analyses flow diagrams and meta-analyses were generated for functional outcome and mortality. We included six randomized control trials (RCTs) and 58 observational studies. Meta-analysis of RCTs showed that coiling improved functional outcomes compared to clipping (odds ratio [OR], 0.91; 95% confidence interval [CI], 0.86–0.97). No significant mortality difference was observed in RCTs (OR, 1.38; 95% CI, 0.91–2.09), but non-RCTs favored clipping for reduced mortality (OR, 0.77; 95% CI, 0.69–0.86). However, it is difficult to generalize these findings to all clinical situations, as patients with SAH have a highly variable clinical course. Final treatment decision should be tailored to the individual patient's status, including aneurysm location, morphology, and the expertise available at the treatment center. Such decisions are best made by specialists such as a board-certified physician and should be explained to the patient and their caregivers, along with the rationale for selecting the most appropriate treatment at the given hospital. Korea has many certified endovascular neurosurgeons, cerebrovascular surgeons, and certified cerebrovascular centers. Proper selection of the most suitable treatment method by certified physicians and centers would greatly benefit patient outcomes and healthcare professionals.

Key Words : Aneurysm · Stroke · Subarachnoid hemorrhage · Ruptured aneurysm · Surgical clip · Coiling.

INTRODUCTION

Subarachnoid hemorrhage (SAH) is a neurological emergency with high morbidity and mortality rates among patients with stroke. According to the International Subarachnoid Aneurysm Trial (ISAT) and Barrow Ruptured Aneurysm Trial (BRAT), early intervention is critical for improving outcomes; however, many survivors continue to experience long-term neurological deficits and reduced quality of life.

The treatment of ruptured intracranial aneurysms has evolved from surgical clipping to endovascular coiling. The ISAT trial reported that coiling is associated with a lower early morbidity rate than clipping, leading to a paradigm shift in aneurysm management. However, the BRAT trial highlighted that treatment outcomes can vary depending on aneurysm characteristics, patient-specific factors, and institutional expertise.

A major challenge of SAH management is choosing the best treatment option in an emergency because both methods have distinct advantages and disadvantages. Clipping offers a more durable solution, with lower recurrence and retreatment rates. However, it is associated with greater surgical risks, including vasospasm and longer recovery times. Contrarily, coiling is minimally invasive, with shorter recovery periods; however, it has a higher recurrence rate and low usefulness in intracranial pressure management. The treatment decision is further influenced by factors such as physician experience and skill, available hospital infrastructure, and patient-specific anatomical considerations.

Given the substantial impact of treatment choice on patient outcomes, patients and their families must understand the risks, benefits, and expected outcomes of each option. Physicians are also ethically and professionally obliged to clearly explain how each treatment affects functional prognosis and survival. This is essential for shared decision-making and optimal patient care.

Ongoing debates exist regarding the usefulness of the two treatment methods; patients or their caregivers generally prefer the less invasive coiling treatment, while experts focus more on the functional prognosis and mortality reduction. Therefore, treatment decisions may vary depending on each patient or hospital. In modern neurosurgery, endovascular coiling has considerably advanced and is now the most performed procedure because of its safety profile and comparable efficacy. Cur-

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rent treatment trends show that coiling is preferred over clipping in many cases, though patient selection remains crucial. Providing patients with specific and appropriate treatment guidelines based on a professional understanding of the two methods is essential. Thus, we developed this guideline to provide evidence-based recommendations for the optimal initial treatment for SAH. This guideline focuses on comparing the major outcomes of the two methods, thereby providing recommendations based on current evidence. Subsequently, the Korean NeuroEndovascular Society (KoNES) will continuously update and expand these guidelines beyond this initial version, incorporating new research and clinical developments.

To ensure a comprehensive and multidisciplinary approach, this guideline has been developed in collaboration with key medical societies, including the Korean Society of Emergency Medicine (KSEM), Korean Society of Cerebrovascular Surgery (KSCVS), and KoNES, as well as experts from neurology, radiology, and other relevant fields. Although this guideline is primarily intended for emergency physicians, neurosurgeons, paramedics, and medical staff at healthcare institutions, it also serves as an educational resource for medical students and healthcare professionals.

CLINICAL PRACTICE GUIDELINE DEVELOPMENT

Composition of the clinical practice guideline committee and multidisciplinary participation

The Clinical Practice Guideline Committee comprises an executive, a working, and internal and external review committees. The executive committee establishes the strategy and direction for guideline development, reviews and approves the budget, coordinates stakeholders, and ensures the independence of the development process. We described more details about members and progress in this guideline (Supplementary Material 1).

Clinical medical guideline development

This study is not the first attempt to develop stroke medical guidelines in Korea. Therefore, we reviewed existing medical guidelines to define the scope and target population of the new guidelines. Stroke is a broad topic; attempting to cover all aspects of stroke in the first edition of the guidelines might lead to an excessively extensive scope and potential overlap with existing international guidelines.

Stroke treatment is categorized into three phases : pre-hospital care, hospital treatment, and post-treatment management. Most previously established Korean guidelines focused on hospital-based treatment and were created by modifying or adapting existing international guidelines.

In Korea, emergency patient transfers are a social concern. Since February 2024, legislative conflicts about the rapid increase in medical school enrollment quotas have exacerbated the shortage of specialists, especially in essential medical services. Consequently, transferring patients between hospitals is challenging. The availability of treatment modalities for SAH, such as surgical clipping and endovascular coiling, varies by region and time; some hospitals are equipped to perform both procedures, while others can offer only one. Therefore, selecting and transferring patients to specialized centers that provide the most appropriate treatment may lead to better clinical outcomes in emergency situations. In Korea, the establishment of multiple stroke-specialized hospitals led to an increasing consideration of endovascular coiling as a viable treatment modality for SAH. However, a substantial gap exists between the expert's understanding and the general public's stroke treatment perception. In actual emergency rooms, controversy and confusion remain regarding the initial decision-making between clipping and coiling for SAH. During an emergency, medical staff may not have adequate time to explain the differences and potential benefits of each procedure. Patients and caregivers may experience dissatisfaction or regret regarding treatment decisions, especially when the outcome is unfavorable, regardless of the chosen intervention. Despite successful aneurysm occlusion, the mortality rate remains high. Experienced medical professionals must lead the treatment decision while respecting the values and preferences of patients and their caregivers. Considering the critical importance of early treatment decision-making in the management of SAH, this guideline aims to provide evidence-based recommendations to support the selection between clipping and coiling. We prepared this guideline in accordance with the Institutional Review Board (UC24ZISE0069), and the requirement for informed consent was waived.

Selecting key questions

Two main key questions for each recommendation were for-

mulated based on the PICO (population/patient, intervention, comparison, outcome) framework, and a systematic literature search was conducted accordingly. Our key questions were as follows : 1) how should the choice between coiling and clipping be made in patients with SAH?; 2) when choosing between clipping and coiling as an initial treatment for SAH, which option provides more benefit to the patient?; 3) does endovascular coiling improve functional outcomes compared to surgical clipping in patients with SAH?; and 4) does clipping reduce mortality more than coiling in patients with SAH? The clinical questions addressed in this guideline were structured according to the PICO format; we included patients diagnosed with SAH who underwent either endovascular coiling or surgical clipping. The intervention group consisted of patients who received endovascular coiling, and the comparison group consisted of patients who received surgical clipping. The primary outcomes evaluated were good functional outcome, defined as a modified Rankin scale (mRS) score of less than 3, and all-cause mortality within 1 year (Supplementary Table 1).

Literature search and selection

The literature search was conducted by methodology experts and the development committee members. An initial set of search terms was formulated, and a search strategy was established accordingly. Based on this strategy, searches were conducted on November 11, 2024, across four major databases : MEDLINE (PubMed), Embase, Cochrane Library, and KoreaMed. The selection of relevant studies was conducted separately for each key question, with seven development committee members assigned. Duplicate exclusion and literature selection followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses flowchart (Fig. 1). The inclusion

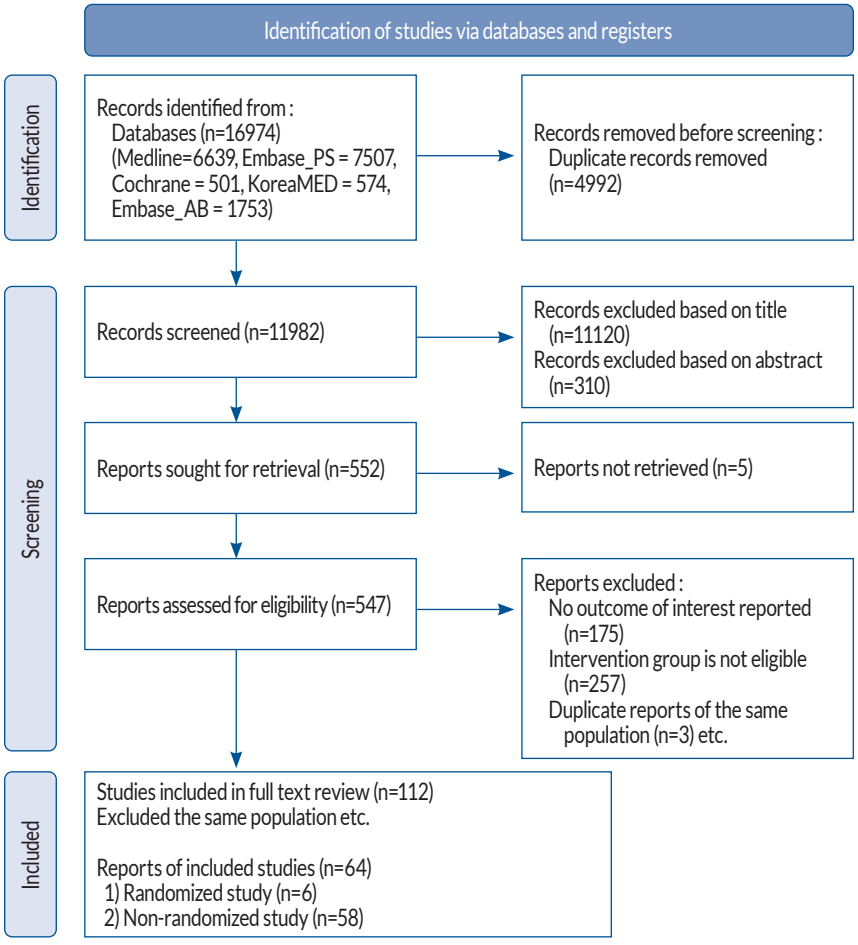

Fig. 1. The Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) flow diagram for systematic reviews and a meta-analysis. Modified from Page et al.[28]

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and exclusion criteria for each key question were formulated and applied based on the PICO framework.

Consensus and recommendation adoption

The guideline recommendations were derived from two major topics, resulting in two recommendations. The principle for determining recommendation grades within the internal committee required that at least 80% of committee members participate; moreover, a minimum of 70% approval was needed for a decision to be considered a consensus. If the approval rate was not up to 70%, the committee engaged in further discussions to draft a revised proposal, followed by a second round of voting. Recommendations that were not approved in the first round were revised and subjected to a second vote. During the second voting round, a consensus was reached regarding the two revised recommendations, and one final recommendation was adopted (Table 1).

Publication and future updates of the clinical practice guideline

This clinical practice guideline will be published in medical journals affiliated with KNS, KEMS, KSCVS, and KoNES. Additionally, it will be made publicly available on the official website, Instagram, and other online platforms of the society, ensuring that physicians, healthcare professionals, and the public can easily download and access the guideline.

The guideline will be registered on the official website of KoNES for promotional purposes. A summary booklet will also be produced and distributed at future academic conferences and events.

The KoNES Academic Committee and the Clinical Practice Guideline Committee will continue to monitor research findings in specific areas, including early diagnosis and transfer of emergency stroke cases, and SAH treatment selection. Further, they will track updates from international clinical guidelines. In the event of new research warranting additions or modifications to the recommendations, a Clinical Guideline Revision Committee under the society will be formed to revise the guideline every 5 years.

NATIONALE OF RECOMMENDATION

The two primary treatment options for acute SAH are clipping and coiling. Selecting the appropriate intervention to improve functional outcomes and reduce mortality is a crucial as-

Table 1. Summary of key questions and recommendations

Key question	Recommendation	GOR	LOE
How should the choice between coiling and clipping be made in patients with subarachnoid hemorrhage? When choosing between clipping and coiling as an initial treatment for subarachnoid hemorrhage, which option provides more benefit to the patient?			
Does endovascular coiling improve functional outcomes compared to surgical clipping in patients with subarachnoid hemorrhage?	The choice between endovascular coiling and surgical clipping should be individualized based on the expertise of neurosurgeons and endovascular neurosurgeons, as well as patient's status and institutional factors. Therefore, the appropriate initial treatment should be determined in consultation with a qualified specialist to improve the functional outcome. In centers where both coiling and clipping are feasible based on the judgment of specialists, either modality-coiling or clipping-may be considered an appropriate treatment option. When endovascular coiling is feasible as initial treatment, prioritizing coiling is considered a rational and acceptable clinical strategy.	A	High
Does clipping reduce mortality more than coiling in patients with subarachnoid hemorrhage?	The choice between clipping or coiling does not significantly affect the overall mortality in patients with subarachnoid hemorrhage. Both treatment modalities contribute to reducing mortality. In certain patients, surgical clipping may reduce mortality, suggesting that clipping can be beneficial. Treatment decisions should be guided by expert consensus and institutional capacity to provide both endovascular and surgical interventions.	C	Low

GOR : grade of recommendation, LOE : level of evidence

pect of the treatment decision for SAH. This decision must be made in the emergency department; however, not all medical institutions are equipped to offer both methods.

During clipping, craniotomy is performed, the brain is dissected, and the ruptured aneurysm is secured with a clip. Contrarily, during coiling, a catheter is inserted through the femoral artery, allowing coil placement inside the aneurysm or stent deployment in the parent artery. These two approaches have distinct complications, advantages, and disadvantages. Craniotomy or craniectomy with clipping involves bone removal for simultaneous hematoma evacuation, facilitating intracranial pressure control. Coiling is a minimally invasive endovascular approach that isolates the ruptured aneurysm while minimizing direct brain injury. Consequently, prognosis and treatment outcomes differ. As SAH is a high-mortality condition with poor prognoses, patients, physicians, and caregivers should be fully informed about the impact of both methods on functional outcomes and survival.

Functional outcome

The two primary therapeutic options for SAH, endovascular coiling and surgical clipping, must be carefully evaluated. The appropriate initial treatment should be determined in consultation with a qualified specialist to improve the functional outcome. The final treatment decision for SAH should be tailored to individual patient factors, including aneurysm location, morphology, and expertise available at the treatment center, based on the expertise of neurosurgeons and endovascular neurosurgeons, as well as patient's status and institutional factors. Such decisions should be explained and shared with the patient and their caregivers, along with the rationale for selecting the most appropriate treatment at the given hospital (level of evidence [LOE], high; grade of recommendation [GOR], A). In centers where both coiling and clipping are feasible based on the judgment of specialists, either modality-coiling or clipping could be considered an appropriate treatment option. When endovascular coiling is feasible as initial treatment, prioritizing coiling is considered a rational and acceptable clinical strategy to obtain a good functional outcome (LOE, high; GOR, A).

A systematic review of the literature identified six RCTs and 58 non-randomized studies comparing clipping and coiling outcomes in acute SAH treatment. These studies investigated functional outcomes within 1 year after treatment, analyzing results based on the mRS and the Glasgow outcome scale. For this analysis, a good functional outcome was defined as an mRS score of 2 and a Glasgow outcome scale score of ≥4. Data were collected and compared to assess the efficacy of both treatment modalities in optimizing patient recovery following SAH. Through a quality assessment, six RCTs and 58 non-randomized studies were selected for analysis. The RCTs included 2940 patients; 1699 (57.7%) demonstrated good functional outcomes.

A meta-analysis of RCTs comparing the functional outcomes of clipping and coiling demonstrated that coiling improved the achievement of good functional outcomes by approximately 9% compared with clipping. This difference was statistically significant (odds ratio [OR], 0.91; 95% confidence interval [CI], 0.86–0.97; Fig. 2). No heterogeneity was observed, and the quality assessment of the included trials indicated a high LOE. In non-randomized studies, 40386 patients were analyzed; 26222 (64.9%) achieved good functional outcomes. A meta-analysis comparing functional outcomes following clipping and coiling

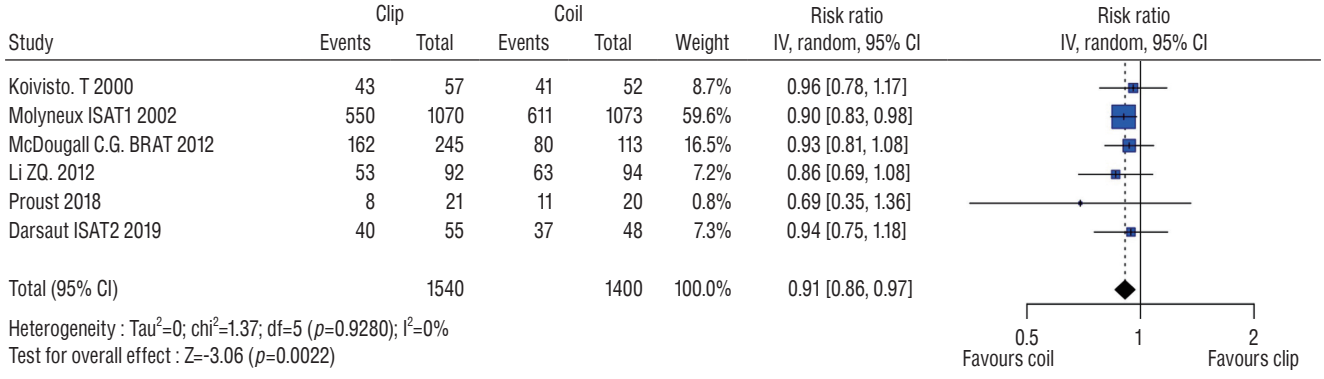

Fig. 2. Forest plot of functional outcome between clipping and coiling for subarachnoid hemorrhage patients on randomized control study. CI : confidence interval.

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Study	Clip Events	Clip Total	Coil Events	Coil Total	Weight	Odds ratio IV, random, 95% CI
Rabinstein 2003	247	339	56	76	2.0%	0.96 [0.55, 1.69]
Fukui 2004	100	142	21	38	1.5%	1.93 [0.93, 4.02]
Hoh 2004	227	413	27	79	2.2%	2.35 [1.42, 3.89]
M. HIROHATA 2004	62	101	143	179	2.1%	0.40 [0.23, 0.69]
Niskanen 2004	86	103	55	68	1.4%	1.20 [0.54, 2.65]
Flett.M 2005	33	67	33	46	1.4%	0.38 [0.17, 0.85]
Yu 2007	59	89	60	80	1.7%	0.66 [0.34, 1.28]
Kaku 2010	37	48	37	52	1.2%	1.36 [0.55, 3.36]
Klompenhouwer 2011	122	173	163	230	2.5%	0.98 [0.64, 1.52]
Sung 2011	42	65	56	84	1.7%	0.91 [0.46, 1.80]
Tenjin 2011	61	77	21	36	1.3%	2.72 [1.15, 6.44]
Chalouhi 2012	34	60	55	82	1.6%	0.64 [0.32, 1.28]
Premananda, R. M. 2012	115	204	47	64	1.8%	0.47 [0.25, 0.87]
Shim 2012	47	56	37	44	0.9%	0.99 [0.34, 2.90]
Liao 2013	26	44	34	66	1.4%	1.36 [0.63, 2.94]
Liu 2013	217	325	154	229	2.7%	0.98 [0.68, 1.40]
Sandstrom 2013	45	83	24	60	1.7%	1.78 [0.91, 3.48]
Suzuki.H 2013	211	282	228	297	2.6%	0.90 [0.61, 1.32]
Kanamaru 2015	177	273	182	264	2.7%	0.83 [0.58, 1.19]
Mortimer 2016	35	66	44	69	1.6%	0.64 [0.32, 1.28]
Bunc, G. 2016	18	40	56	85	1.5%	0.42 [0.20, 0.91]
Zanaty 2016	36	70	91	182	2.0%	1.06 [0.61, 1.84]
Zhao 2016	42	129	61	133	2.2%	0.57 [0.34, 0.94]
Galea 2017	397	596	1881	2600	3.3%	0.76 [0.63, 0.92]
Li J. 2017	68	85	65	77	1.4%	0.74 [0.33, 1.67]
Kurogi 2018	2069	3624	852	1590	3.5%	1.15 [1.02, 1.30]
Rackauskaite 2018	27	40	58	111	1.5%	1.90 [0.89, 4.06]
A. Lindgren 2019	439	649	595	852	3.2%	0.90 [0.72, 1.13]
Hayashi 2020	170	416	79	180	2.8%	0.88 [0.62, 1.26]
Henrik Constantin Bäcker 2020	29	45	37	71	1.5%	1.67 [0.77, 3.59]
Ikawa 2020	7059	10467	2948	4457	3.6%	1.06 [0.98, 1.14]
Kim 2020	62	78	119	153	1.7%	1.11 [0.57, 2.16]
Roquer 2020	32	69	150	242	2.1%	0.53 [0.31, 0.91]
Harris 2021	13	19	80	113	1.0%	0.89 [0.31, 2.55]
Uche 2021	73	90	7	11	0.7%	2.45 [0.64, 9.34]
A. D. Wong 2022	69	95	217	287	2.1%	0.86 [0.51, 1.45]
Catapano 2022	77	202	62	149	2.5%	0.86 [0.56, 1.33]
Duangprasert 2022	150	229	73	102	2.2%	0.75 [0.45, 1.26]
Hanalioglu 2022	50	80	26	61	1.7%	2.24 [1.14, 4.43]
Justin R. Mascitelli 2022	69	84	127	140	1.4%	0.47 [0.21, 1.05]
K. Irie 2022	511	792	240	417	3.2%	1.34 [1.05, 1.71]
Yuan 2022	322	414	367	429	2.7%	0.59 [0.41, 0.84]
Diestro 2023	41	81	43	57	1.5%	0.33 [0.16, 0.70]
Ishikawa 2023	93	316	116	316	2.8%	0.72 [0.52, 1.00]
Ding 2024	812	1078	778	971	3.3%	0.76 [0.61, 0.93]
H. Aineskog 2024	93	251	182	520	2.9%	1.09 [0.80, 1.50]
Hamming 2024	41	75	82	129	2.0%	0.69 [0.39, 1.23]
Lee 2024	19	50	46	84	1.6%	0.51 [0.25, 1.03]
M. Yang 2024	208	275	235	275	2.5%	0.53 [0.34, 0.82]
Total (95% CI)		23449		16937	100.0%	0.88 [0.78, 0.99]

Heterogeneity : Tau^2=0.102; chi^2=146.29; df=48 (p<0.0001); I^2=67%
Test for overall effect : Z=-2.05 (p=0.0403)

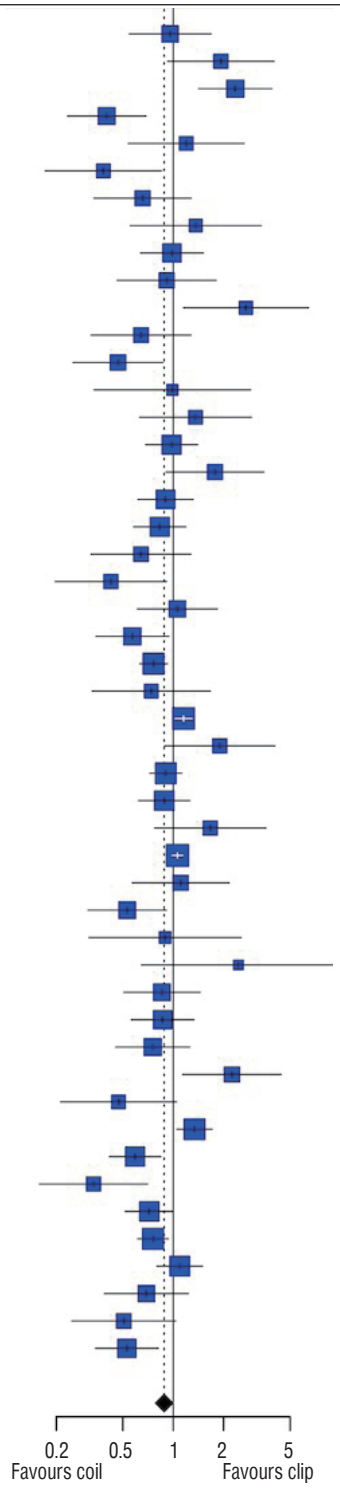

Fig. 3. Forest plot of functional outcome between clipping and coiling for subarachnoid hemorrhage patients on non-randomized control study. CI : confidence interval.

showed that coiling improved the achievement of good functional outcomes by approximately 12% compared with clipping (OR, 0.88; 95% CI, 0.78–0.99; Fig. 3). However, high heterogeneity was observed among the studies, and the LOE was assessed as low. Despite these limitations, the findings from non-randomized studies were consistent with the results from RCTs, supporting the association between coiling and better functional outcomes.

Considering the results from the RCTs and non-randomized studies, coiling appears to improve functional outcomes compared with clipping in acute SAH treatment. Therefore, coiling may be prioritized as the initial treatment option. In addition to our findings, the 2012 American Heart Association/American Stroke Association (AHA/ASA) Guidelines for the Management of SAH state the following : for patients with ruptured aneurysms judged to be technically amenable to both endovascular coiling and neurosurgical clipping, endovascular coiling should be considered (class I; LOE, B)[6]. Furthermore, according to the updated 2023 AHA/ASA guidelines, in the treatment of good-grade SAH due to ruptured aneurysms located in the anterior circulation suitable for both primary coiling and clipping, primary coiling is recommended over clipping to improve the 1-year functional outcome (class I; LOE, A)[17]. For good-grade SAH from ruptured aneurysm on the anterior circulation, suitable for both primary coiling and clipping, both treatment options are reasonable to achieve a favorable long-term outcome (class I; LOE, B–R). The 2018 SAH guidelines in Korea state that for patients with ruptured aneurysms judged to be technically amenable to both endovascular coiling and neurosurgical clipping, endovascular coiling should be considered (class I; LOE, B in AHA/ASA 2012)[4]. In cases where the aneurysm appears to be equally effectively treated either by coiling or clipping, coiling is the preferred treatment (LOE, I; level A; European Stroke Organisation 2013). These results are consistent with those of established guidelines.

However, in our study, the observed difference was approximately 9%; given the substantial variability in aneurysm location, size, cerebral edema, patient condition at admission, and post-treatment complications, generalizing treatment recommendations for all patients remains challenging. The choice of treatment for SAH is influenced by patient-specific factors (age, comorbidities, presence of intracerebral hemorrhage, World Federation of Neurosurgical Societies (WFNS) grade, aneurysm size, location, and configuration), the operator's opinion, and institutional resources. Previous guidelines provided additional detail on these considerations. Microsurgical clipping may receive increased consideration in patients presenting with large (>50 mL) intraparenchymal hematomas and middle cerebral artery (MCA) aneurysms. Endovascular coiling may receive increased consideration in the elderly (>70 years of age), in those presenting with poor-grade (WFNS classification IV/V) SAH, and in those with aneurysms of the basilar apex (class IIb; LOE, C)[6].

Therefore, an expert panel recommended that treatment decisions should be individualized by specialists, considering patient, operator, and institutional factors, to optimize functional outcomes. In centers where both endovascular coiling and microsurgical clipping are technically feasible based on specialist judgment, either modality may be considered an appropriate treatment option. When endovascular coiling is feasible as the initial treatment, prioritizing coiling is a rational and acceptable clinical strategy to achieve favorable functional outcomes (LOE, high; GOR, A).

Mortality

The choice between clipping and coiling does not significantly affect the overall mortality in SAH. While both endovascular coiling and surgical clipping are primary treatment options, surgical clipping may be a reasonable option in selected patients when it is expected to reduce mortality. To suggest that clipping can be beneficial, treatment decisions should be guided by expert specialists and institutional capacity to provide both endovascular and surgical interventions to reduce mortality (LOE, low; GOR, C).

A systematic review of four RCTs and 50 non-randomized studies comparing mortality outcomes after clipping and coiling in patients with acute SAH was conducted. In the RCTs, 439 patients were analyzed, with 73 deaths (16.6%). In the non-randomized studies, 70,894 patients were included, with 8912 deaths (12.6%). A meta-analysis of RCTs comparing mortality outcomes between clipping and coiling found no statistically significant difference between the two groups (OR, 1.38; 95% CI, 0.91–2.09; Fig. 4). No heterogeneity was observed among the studies, and the LOE was high. Contrarily, a meta-analysis of non-randomized studies showed that clipping was significantly associated with a 22% reduction in mortality compared with coiling (OR, 0.77; 95% CI, 0.69–0.86; Fig. 5). However, significant heterogeneity was observed among the studies, and the

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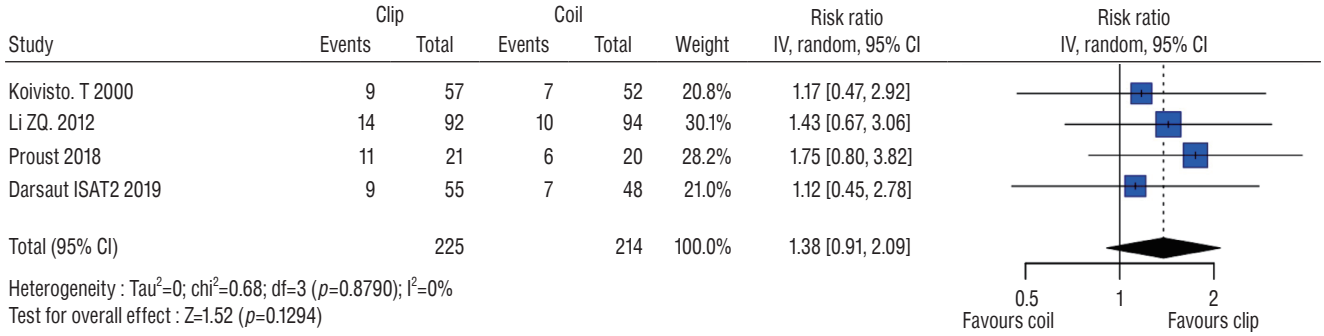

Fig. 4. Forest plot of mortality between clipping and coiling for subarachnoid hemorrhage patients on randomized control study. CI : confidence interval.

LOE was assessed as low. The comparison of mortality outcomes between clipping and coiling yielded different results depending on the study design. As RCTs provide high-quality evidence, we concluded that no significant difference in mortality reduction was observed between both SAH treatment modalities (LOE, high). However, despite the lower LOE, non-randomized studies indicated that surgical clipping significantly reduced mortality compared with coiling (LOE, low). This finding suggests that in certain patient populations, clipping may offer survival benefits (OR, 0.77; 95% CI, 0.69–0.86). Therefore, although coiling and clipping remain primary treatment options, surgical clipping should be considered in selected cases where it may provide an advantage in reducing mortality (GOR, C).

Previous guidelines have also addressed the utility of surgical intervention and the necessity of surgical clipping. The 2023 ASA/AHA SAH guideline states that for patients with SAH deemed salvageable and with a depressed level of consciousness due to a large intraparenchymal hematoma, emergency clot evacuation should be performed to reduce mortality outcome (class I; LOE, B–R)[17]. The requirement for surgical treatment to control intracranial pressure in certain patients remains consistent. Although coiling and clipping remains a primary treatment option, surgical clipping should be considered in selected cases where it may provide an advantage in reducing mortality. To suggest that clipping can be beneficial, treatment decision should be guided by expert specialists and institutional capacity to provide both endovascular and surgical interventions to reduce mortality (LOE, low; GOR, C).

Additionally, we reviewed and summarized the advantages and disadvantages of both methods from various perspectives. The factors examined included old age, poor grade SAH, location, rebleeding & retreatment, vasospasm, and shunt-dependent hydrocephalus. The analysis followed a systematic review format, and conclusions were drawn based on expert consensus.

SYSTEMATIC REVIEW

The Clinical Practice Guidelines Executive Committee designated at least two responsible reviewers for each subtopic. Subsequently, a systematic review was conducted based on the key questions, literature selection processes, supporting evidence, and meeting records.

Two reviewers independently evaluated each subtopic to ensure the objective validation of the drafted content. The manuscript drafted by the Clinical Practice Guideline Development Committee was reviewed by two independent stroke emergency experts who were not involved in the guideline development process.

Old age

Young patients exhibit good prognoses with both methods; however, clipping is preferred because of its lower recurrence rate. However, in older patients, postoperative complications and cognitive impairment may hinder recovery, making the risk of complications a more substantial issue than recurrence.

A review of studies comparing coiling and clipping in older patients yielded the following findings : among patients aged ≥65 years, intraoperative complications showed a significant difference only in the incidence of intraoperative aneurysm rupture[1]. Intraoperative aneurysm rupture occurred in 6.4% and 16.7% of patients undergoing coil embolization and surgi-

Study	Clip Events	Clip Total	Coil Events	Coil Total	Weight	Odds ratio IV, random, 95% CI
Rabinstein 2003	26	339	12	76	1.7%	0.44 [0.21, 0.92]
Niskanen 2004	10	103	8	68	1.1%	0.81 [0.30, 2.16]
Fukui 2004	1	142	12	38	0.3%	0.02 [0.00, 0.12]
M. HIROHATA 2004	5	101	16	179	1.0%	0.53 [0.19, 1.49]
Hoh 2004	38	413	20	79	2.2%	0.30 [0.16, 0.55]
Panayiotis 2006	13	135	7	48	1.1%	0.62 [0.23, 1.67]
Yu 2007	9	89	3	80	0.7%	2.89 [0.75, 11.07]
S.K.Natarajan 2008	9	105	18	87	1.4%	0.36 [0.15, 0.85]
Kaku 2010	6	48	5	52	0.7%	1.34 [0.38, 4.72]
Tenjin 2011	2	77	5	36	0.4%	0.17 [0.03, 0.90]
Sung 2011	3	65	3	84	0.5%	1.31 [0.25, 6.70]
Klompenhouwer 2011	20	173	40	230	2.3%	0.62 [0.35, 1.11]
Chalouhi 2012	3	60	7	82	0.6%	0.56 [0.14, 2.28]
Premananda 2012	42	204	8	64	1.5%	1.81 [0.80, 4.10]
Liao 2013	3	44	6	66	0.6%	0.73 [0.17, 3.09]
Sandstrom 2013	14	83	17	60	1.5%	0.51 [0.23, 1.15]
Liu 2013	25	325	27	229	2.3%	0.62 [0.35, 1.11]
McDonald 2014	146	1227	154	1227	4.4%	0.94 [0.74, 1.20]
Walendy 2014	766	5595	824	5357	5.3%	0.87 [0.78, 0.97]
Kanamaru 2015	26	273	29	264	2.4%	0.85 [0.49, 1.49]
Bekelis 2015	117	1513	264	2585	4.5%	0.74 [0.59, 0.93]
Zanaty 2016	13	70	30	182	1.8%	1.16 [0.56, 2.37]
Zhao 2016	24	129	27	133	2.2%	0.90 [0.49, 1.66]
Li 2017	4	85	4	77	0.6%	0.90 [0.22, 3.73]
Stienen 2017	77	699	119	948	4.0%	0.86 [0.64, 1.17]
Rackauskaite 2018	6	40	44	111	1.2%	0.27 [0.10, 0.69]
Kurogi 2018	315	3624	198	1590	4.8%	0.67 [0.55, 0.81]
Zhao 2019	4	65	3	46	0.5%	0.94 [0.20, 4.41]
A. Lindgren 2019	37	649	77	852	3.3%	0.61 [0.41, 0.91]
Henrik 2020	1	45	3	71	0.2%	0.52 [0.05, 5.11]
Kim 2020	2	78	12	153	0.5%	0.31 [0.07, 1.42]
Roquer 2020	19	69	49	242	2.2%	1.50 [0.81, 2.77]
Ikawa 2020	659	10467	449	4457	5.2%	0.60 [0.53, 0.68]
Catapano 2021	1	48	1	11	0.2%	0.21 [0.01, 3.70]
Harris 2021	4	19	14	113	0.8%	1.89 [0.55, 6.50]
Y. L. Lo 2021	812	4051	736	4051	5.2%	1.13 [1.01, 1.26]
Hanalioglu 2022	18	80	24	61	1.7%	0.45 [0.21, 0.93]
Majewska 2022	5	84	5	99	0.7%	1.19 [0.33, 4.26]
Justin 2022	4	84	1	140	0.3%	6.95 [0.76, 63.26]
Duangprasert 2022	34	229	16	102	2.0%	0.94 [0.49, 1.79]
A. D. Wong 2022	18	95	54	287	2.2%	1.01 [0.56, 1.82]
Diestro 2023	9	81	10	57	1.1%	0.59 [0.22, 1.55]
Ishikawa 2023	33	316	40	316	2.8%	0.80 [0.49, 1.31]
Lee 2024	10	50	6	84	0.9%	3.25 [1.10, 9.58]
Hamming 2024	8	75	6	129	0.9%	2.45 [0.82, 7.35]
M. Yang 2024	27	275	46	275	2.7%	0.54 [0.33, 0.90]
H. Aineskog 2024	40	251	68	520	3.2%	1.26 [0.83, 1.92]
Ding 2024	28	1078	35	971	2.7%	0.71 [0.43, 1.18]
Yu DW 2024	150	1340	435	2719	4.7%	0.66 [0.54, 0.81]
Omar 2024	333	1794	936	4022	5.1%	0.75 [0.65, 0.86]
Total (95% CI)		37084		33810	100.0%	0.77 [0.69, 0.86]

Heterogeneity : Tau^2=0.063; chi^2=156.67; df=49 (p<0.0001); I^2=69%
Test for overall effect : Z=-4.44 (p<0.0001)

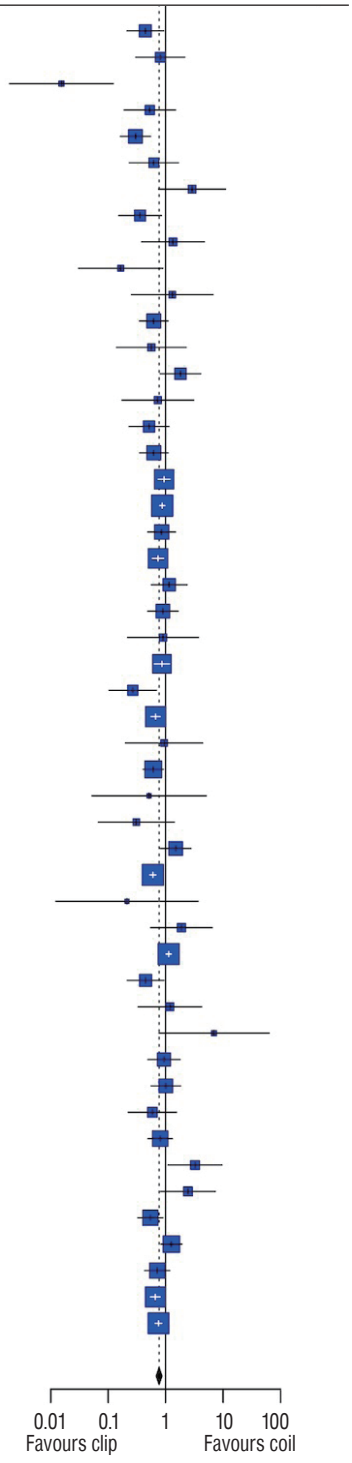

Fig. 5. Forest plot of mortality between clipping and coiling for subarachnoid hemorrhage patients on non-randomized control study. CI : confidence interval.

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cal clipping, respectively. Among postoperative complications, epilepsy and pneumonia showed significant differences. The incidence of epilepsy was 0.7% and 12.9% in the coil embolization and clipping groups, respectively, while pneumonia occurred in 5.1% and 15.0% of patients, respectively. Similar to the overall patient population, the cohort of patients aged ≥65 years demonstrated that coil embolization was associated with a lower incidence of complications. This suggests that in older patients, the risk of postoperative complications is higher with clipping than with coiling. Thus, the choice of surgical method should be made with careful consideration of the associated risks.

The optimal treatment method may vary depending on the aneurysm location. In the study comparing surgical outcomes in patients aged ≥65 years, the surgical method associated with favorable functional outcomes, depending on aneurysm location, was identified[1]. Regarding aneurysms located in the anterior cerebral artery and anterior communicating artery, no significant difference in functional outcomes (mRS, 0–2) was observed between the two surgical groups. However, regarding aneurysms located in the internal carotid artery (ICA) and posterior communicating artery (PComA), 1-year follow-up results demonstrated that 72% and 52% of patients who underwent coil embolization and clipping, respectively, achieved favorable outcomes, with significant differences. Similarly, regarding aneurysms located in the MCA, 1-year follow-up results showed that 45.5% of patients treated with coil embolization and 86.7% of those treated with clipping had significant favorable outcomes. Based on these findings, in older patients with ruptured aneurysms, the choice between coil embolization and surgical clipping should be based on aneurysm location. Regarding aneurysms in the ICA and PComA, coiling showed better functional outcomes than clipping. Conversely, clipping demonstrated better functional outcomes than coiling for aneurysms in the MCA. Thus, in patients aged ≥65 years, clipping may be considered a viable option for treating MCA aneurysms.

Location

The BRAT compared outcomes in 238 and 233 patients who underwent surgical clipping and endovascular coiling, respectively, finding no significant difference in functional outcomes for anterior circulation aneurysms[2]. However, for posterior circulation aneurysms, patients in the surgical clipping group had significantly worse outcomes (mRS score >2; OR, 5.09; 95% CI, 1.63–15.9; p=0.005).

Furthermore, a retrospective study found that postoperative third cranial nerve palsy was significantly more common in the microsurgical clipping group (7.7% [6/78] vs. 2.0% [3/153], p=0.01).

Surgical access is generally easier in anterior circulation aneurysms than in posterior ones; as such, clipping is performed more frequently than coiling. As studies indicate no significant difference in functional outcomes, either treatment method may be selected based on patient-specific factors.

However, in posterior circulation aneurysms, surgical access is more difficult, and securing an adequate operative space during clipping is challenging. Consequently, clipping tends to yield worse postoperative outcomes than coiling. Therefore, coiling should be prioritized for posterior circulation aneurysms whenever feasible.

Ultimately, treatment selection should not only consider aneurysm location but also complication risks, ensuring that the most appropriate approach is selected.

Poor-grade SAH

Patients with poor-grade SAH, defined as WFNS grades IV and V, present a substantial challenge in aneurysm management. The optimal treatment method remains elusive owing to controversial evidence[5]. Coiling may be advantageous in poor-grade patients owing to its less invasive nature and potential for faster recovery[7,36]. However, clipping has shown benefits in achieving more complete aneurysm occlusion and reducing rebleeding rates[8].

A multicenter study specifically focusing on poor-grade aneurysms found no significant difference in long-term outcomes between coiling and clipping in selected patients[5]. The choice between coiling and clipping for patients with poor-grade SAH should be based on multiple factors, including patient age, aneurysm location and morphology, presence of intraparenchymal hemorrhage, and available expertise at the treatment center.

Rebleeding and retreatment

Clipping and coiling are widely utilized treatment modalities for intracranial aneurysms, demonstrating efficacy in preventing rebleeding. However, a higher recurrence and retreatment rate has been observed in coiling.

The ISAT investigated the need for retreatment within 1 year

among 2143 patients, reporting that 121 cases occurred after coiling, whereas only 33 occurred in the clipping group[8]. During the 1st year, rebleeding from the target aneurysm was reported in 45 patients undergoing coiling and 39 undergoing clipping. Beyond the 1st year, rebleeding was identified in seven patients in the coiling group, compared with only two in the clipping group. Although this difference was not significant, a higher recurrence rate following coiling was observed. The BRAT reported no rebleeding cases within the 1st year following coiling[3]. However, among 113 patients who underwent coiling, 12 (10.62%) required retreatment within the 1st year, a significantly higher rate than that observed in the clipping group (OR, 2.57; 95% CI, 0.98–6.55; p=0.03). In a 7-year follow-up study, the retreatment rate remained significantly higher in the coiling group, with 20% (23/115) of patients requiring additional intervention, compared with <1% (2/241) in the clipping group[10].

This highlights the need for long-term follow-up evaluations following coiling, as an increased risk of recurrence and retreatment may exist. Thus, adopting a patient-specific risk assessment strategy that considers factors such as age, aneurysm size, packing density ratio, and treatment modality is imperative. Regular imaging surveillance is recommended to monitor recurrence and guide clinical decision-making, ensuring optimal long-term outcomes after coiling[9,11-14].

Vasospasm

Vasospasm is a risk factor for complications in patients with SAH[15]. However, no clear consensus on the most effective treatment exists.

The ISAT randomly assigned 2,143 patients to either surgical clipping (n=1070) or endovascular coiling (n=1073)[16]. The incidence of vasospasm showed no significant differences between the two groups. Even in patients with poor-grade subarachnoid hemorrhage, no clear difference was observed in the incidence of vasospasm between the two treatment modalities[18].

Imamura et al.[19] analyzed nine studies comparing surgical clipping with endovascular coiling, reporting no significant difference in vasospasm risk techniques (risk ratio [RR], 1.21; 95% CI, 0.99–1.48). Jones et al.[20] reviewed eight RCTs involving 3585 patients with SAH (1792 underwent coiling, and 1773 underwent clipping). Their comprehensive quantitative analysis indicated that the coiling group had a significantly lower rate of vasospasm (OR, 0.58; 95% CI, 0.36–0.92; p=0.02).

Surgical clipping may contribute to hematoma removal in the arachnoid space, which could influence vasospasm development. Contrarily, endovascular coiling involves minimal manipulation of cerebral blood vessels, which aids in vasospasm prevention[21].

Given the conflicting findings across studies, the risk of vasospasm alone should not be the primary factor in treatment method selection[22-25]. The decision should be based on available resources, patient's overall condition, and surgeon expertise to ensure selection of the most appropriate approach.

Shunt-dependent hydrocephalus

Hydrocephalus is a complication of SAH due to a ruptured aneurysm. In clipping, thick subarachnoid hematomas can be removed during surgery; however, this procedure may induce an inflammatory response in the arachnoid space. Coiling does not allow for the direct removal of thick subarachnoid hematomas but may have a relatively lesser direct impact on cerebrospinal fluid circulation.

To evaluate the impact of treatment modality on shunt-dependent hydrocephalus development, data were collected based on its established definition. Several studies have investigated the comparative effects of clipping and coiling on shunt-dependent hydrocephalus incidence; however, the findings remain inconclusive.

A meta-analysis including 10 high-quality studies revealed a significant higher incidence of shunt-dependent hydrocephalus in the clipping than in the coiling group (17.1% vs. 14.8%; RR, 1.16; 95% CI, 1.09–1.23)[26,27,29-35,37]. A single-center retrospective study by Zaidi et al.[38] showed a trend toward a higher incidence of shunt-dependent hydrocephalus in the clipping group; however, the difference was not significant (early surgery : 23.2% [29 of 125] vs. early endovascular treatment : 17.7% [11 of 62]; p=0.45). Zeng et al.[39] reported a higher incidence of shunt-dependent hydrocephalus in the clipping group than in the coiling group; however, the difference was not significant (clipping vs. coiling: 37.1% vs. 29.7%).

Zhao et al.[40] conducted a meta-analysis on shunt-dependent hydrocephalus incidence based on treatment modality (clipping vs. coiling) in patients with SAH. The analysis included 13 studies with 13751 patients (8444 clipped and coiled aneurysms, respectively), reporting no significant difference between the groups (clipping vs. coiling, 11.4% vs. 12.0%, respectively; RR, 0.92; 95% CI, 0.84–1.01). This trend persisted when

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RCTs were analyzed separately (shunt-dependent hydrocephalus rate : clipping vs. coiling, 23.3% vs. 20.1%; RR, 1.12; 95% CI, 0.91–1.38). Ultimately, the direct impact of clipping and coiling on shunt-dependent hydrocephalus incidence remains controversial and inconclusive. The predictability of hydrocephalus does not appear to be a primary factor in treatment modality selection. Individual patient characteristics, aneurysm location, and institutional expertise should be prioritized when selecting the optimal intervention strategy.

Status of emergency transfers and hospital selection for treatable conditions in South Korea

Between February 26 and December 31, 2024, 650 cardiovascular and cerebrovascular emergency patients were transferred nationwide via the regional network provided by the National Cardiovascular Center. Among them, 244 (37.5%) were hemorrhagic strokes, 213 (32.8%) were ischemic strokes, 164 (25.2%) were myocardial infarctions, and 29 (4.5%) were aortic syndromes. The ratio of hemorrhagic to ischemic stroke cases transferred through the platform was 1.15 : 1. By region, hemorrhagic stroke referrals exceeding 20 cases per year occurred in the following order : Gyeonggi, Seoul, Jeonnam, Daegu, Gangwon, and Busan (source : Kang-min Kim). These results indicate a high demand for hospitals capable of performing both craniotomy and endovascular procedures and the urgent need for neurosurgeons on duty. In fact, a national survey in Korea showed that neurosurgeons were responsible for nearly 100% of key treatments for cerebral hemorrhages—including craniotomies, endovascular procedures, and patient care—and that a high dependence on on-call specialists existed[41].

In SAH, promptly occluding the cerebral aneurysm is crucial, making rapid medical judgment and the choice of a hospital capable of either coiling or clipping treatment extremely important. As such, the KSCVS has implemented a certification system for cerebrovascular surgeons capable of performing clipping procedures (https://www.kscvs.org/certification/index1.html?gubun=4; Supplementary Table 2). Further, the KoNES has established certification systems for neuro-endovascular surgeons and stroke intervention-certified hospitals capable of performing coiling procedures (https://www.konesonline.or.kr/certification/certiList.php; Supplementary Table 3).

As of November 29, 2024, 311 certified stroke interventionists and 106 certified institutions existed. In Korea, the treatment of SAH is structured around a system of certified hospitals and qualified specialists. Based on this infrastructure, a cooperative network—comprising KSCVS, KoNES, KSEM, and the Ministry of Health and Welfare—has been established to facilitate the timely transfer and management of SAH patients. This national collaboration plays a vital role in improving public health outcomes for patients with SAH.

Following expert consensus, the following recommendation can be made. When a hospital is equipped to perform both clipping and coiling procedures, coiling is considered as one of the initial treatment options, as well as clipping. Both clipping and coiling are appropriate and standard initial treatments for SAH. Therefore, the optimal treatment strategy should be determined by a neurosurgical specialist, considering the specific clinical situation and institutional capabilities of hospitals. This approach could help reduce overcrowding in the emergency departments of specific hospitals. Effective coordination between certified physicians and institutions and the national emergency service (119) is crucial for faster and more efficient patient transfers.

AUTHOR'S DECLARATION

Conflicts of interest

Won-Sang Cho has been editorial board of JKNS since September 2021 and Sukh Que Park has been editorial board of JKNS since May 2017. They were not involved in the review process of this original article. No potential conflict of interest relevant to this article was reported.

Informed consent

This type of study does not require informed consent.

Author contributions

Conceptualization : JSO; Data curation : JSO, JML; Formal analysis : JSO; Funding acquisition : JSO; Methodology : JSO; Project administration : JSO, YJ, JML, HSA, JJK, KMJ, GYY, JHK, DS, HJL, JJ, KCC, YSC, SJK, JP, WSC, DWK, HK, YWK, SHS, SWL, JWL, TGK, SKH, SQP, SCK; Visualization : JSO; Writing - original draft : JSO, JML; Writing - review & editing : JSO, YJ

Data sharing

None

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- **Supplementary materials**

The online-only data supplement is available with this article at https://doi.org/10.3340/jkns.2025.0108.

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