

# Small Number of Coils With Extended Length in the Endovascular Treatment of Cerebral Aneurysm: Experience of 108 Cases in a Single-Center

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## Abstract

**Background:** Knowledge about the number and packing density of coils for aneurysm treatment affects the efficiency of health services and hospital financing. This study aimed to report case series with a small number of coils with longer lengths and impact on packing density.

**Methods:** We retrospectively analyzed the morphology of aneurysms (location and size) and the data of characteristic features of coils (numbers, diameter size, length, and packing density) from the cerebral aneurysm registry at a single center from January 2019 to June 2022. Kruskal-Wallis analysis was performed to identify the association between coil characteristics based on the size of the aneurysm.

**Results:** Of the 108 patients included in the study, 116 aneurysms were identified and coiled; 66 were small (< 5 mm), 42 were moderate (5 - 10 mm), and eight were large (> 10 mm). Most cases utilized framing first coil (in 64.65%) and helical coils (in 31.89%). The total length of framing coils (< 5 mm:  $6.76 \pm 4.14$  cm, 5 - 10 mm:  $11.28 \pm 6.93$  cm, > 10 mm:  $29.33 \pm 12.59$  cm) and helical coils (< 5 mm:  $5.95 \pm 2.82$  cm, 5 - 10 mm:  $11.66 \pm 7.3$  cm, > 10 mm:  $22.32 \pm 11.48$  cm) also increased with group size. The highest packing density (46.70%) was achieved in small aneurysms (< 5 mm).

**Conclusion:** In small aneurysm, one to three coils per aneurysm were required to achieve tight coil packing density by extending the length of coil.

**Keywords:** Coil embolization; Packing density; Cerebral aneurysm; Coil number; Coil length

## Introduction

Endovascular treatment for intracranial aneurysms has grown

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in recent years. Its goal is to form occlusion of the aneurysm, either complete or near complete. Studies have established that endovascular treatment offers lower risk of mortality and shorter hospitalization time. Aneurysm size, location, patient's medical history, and operator's experience are important factors to consider when performing endovascular treatment [1, 2]. Coil embolization is a standard endovascular treatment for aneurysms, especially for narrow-neck aneurysms, which entails filling the aneurysm sac with coils [3]. Fewer neurological complications associated with the procedure make endovascular coiling the most common treatment for aneurysms [4, 5].

In addition, coil packing density of at least 20% to 25% is known to be important for preventing recanalization following endovascular coiling [6]. However, coil embolization carries significant financial burden, and this is partly attributable to the coils themselves; the larger the aneurysm, the more coils needed, and, consequently, the higher the cost incurred [7, 8]. Despite this, most of the National Health Insurance in the developing countries does not provide full coverage of the costs associated with endovascular coiling. This is notable, as it means endovascular treatment remains financially inaccessible to many patients. On that account, knowledge on the appropriate number of coils needed in endovascular procedures, as well as coil packing density, is of paramount importance to ensure cost efficiency.

Therefore, this descriptive study aimed to report that a study a small number of coils with longer lengths could achieve good packing density at a tertiary comprehensive stroke center.

## Materials and Methods

### Ethics approval

Our retrospective study design and protocol were approved by the hospital's research ethics committee (No. LB.02.01/KEP/068/2022). This study was conducted in compliance with the Declaration of Helsinki.

### Inclusion criteria

Under institutional review board approval, we obtained data retrospectively from the cerebral aneurysm registry of the Indonesian largest comprehensive stroke center, Mahar Mardjono

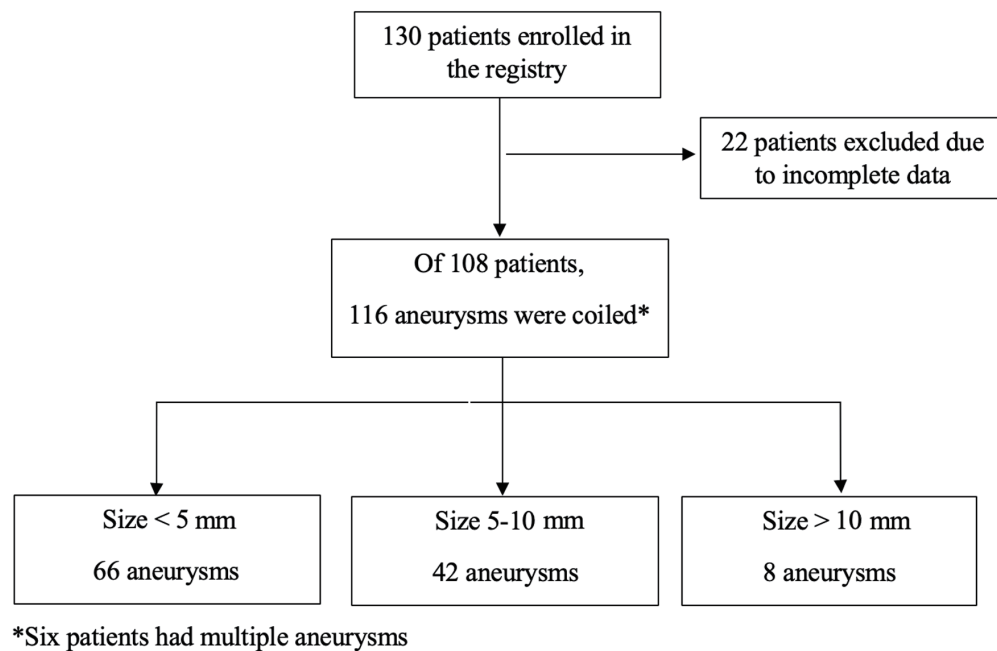


Figure 1. Patients flow diagram.

National Brain Center Hospital, East Jakarta between January 2019 and June 2022. We included all patients who underwent endovascular coiling. Patients with incomplete records (missing morphological data, coil profile) were excluded. We reviewed patients' clinical characteristics (age, gender, vascular risk factors and mortality), aneurysmal morphology (location and size), and the characteristic features of coils (number, size, and packing density).

### Angiography and aneurysmal morphology

The parameters of aneurysmal morphology analyzed in this study included aneurysmal location and size - neck (mm) and dome (mm), which were obtained with the biplane digital subtraction angiography (DSA) and 3D rotational angiography: the Philips Allura Xpert FD 20 X-ray system with 258° complex rotation scan. Aneurysm was classified based on site and size as follows: small (< 5 mm), medium (5 - 10 mm), and large (> 10 mm).

### Endovascular coiling and packing density

In our center, two major coil brands were used in the endovascular procedure: Optima Coil System (Balt, France) and Axium Prime (Medtronic, USA). A combination of coil brands might be used in the same procedure. Coil embolization by four experienced operators (three interventional neurologists and one neurosurgeon) was performed on all cases (simple coiling) without the usage of balloons or stents, as wide-neck aneurysms were treated with surgical clipping in our institution. Complex or 3D-shaped coils were deployed as the initial

framing coil, followed by helical coils as filling. Coiling was deemed adequate when sufficient occlusion of the aneurysm was seen angiographically. The number of coils placed and their packing density (%) - calculated with AngioCalc (Cerebral and Peripheral Aneurysm Calculator) [9] - were taken as data for analysis based on the morphology of the cerebral aneurysm and on the characteristics of the coils.

### Statistical analysis

Data were analyzed and tabulated using the software STATA (version 17.0; StataCorp, Texas, USA). Subjects were divided into three groups, based on the aforementioned aneurysmal diameter classification (small, medium, and large). Coil features (number, size, length, and packing density) were obtained as numbers and presented as mean and standard deviation (SD). Since the size of the aneurysm that was used provided ordinal level data that are not normally distributed, all analyses in the present study were performed using Kruskal-Wallis to find differences between groups and established a  $P < 0.05$  as the threshold of statistical significance, with 95% confidence intervals (CIs).

### Results

We reported 130 patients treated with endovascular coiling, 22 patients were excluded due to incomplete data, and 108 patients were included in the study (eight patients have multiple aneurysm); 116 aneurysms were identified and coiled: 66 were small (< 5 mm), 42 were moderate (5 - 10 mm), and eight were large (> 10 mm) (Fig. 1). By age, the group of 50 - 59 years old

was the most common in our study population, the mean was 53 years old (SD: 11.46), with female gender predominance (62%). Hypertension was the most frequently found vascular risk factor (78%) among patients, followed by dyslipidemia (34%) and diabetes mellitus (16%) (Table 1).

Of the 108 patients, 116 aneurysms were identified and coiled. Most patients (n = 98; 84%) had ruptured aneurysms. Of the 116 aneurysms, 66 (57%) were small (< 5 mm), 42 (36%) were moderate (5 - 10 mm), and eight (7%) were large (> 10 mm). Mean neck size was 2.98 mm, while mean dome size was 5.09 mm. There were 85 aneurysms (75.3%) in the anterior circulation and most of the coiled aneurysms originated from the anterior communicating artery followed by the internal carotid artery, while in the posterior circulation, most aneurysms originated from the posterior communicating artery (Table 2).

The coil was divided into two parts: framing and helical. Mean number of framing coils saw a slight increase with group size (< 5 mm:  $0.86 \pm 0.55$ , 5 - 10 mm:  $0.97 \pm 1.5$ , > 10 mm:  $1.12 \pm 1.64$ ), but there was no statistically significant difference ( $P = 0.799$ ). Mean diameter size of framing coil, however, increased considerably with group size (< 5 mm:  $3.19 \pm 1.01$  mm, 5 - 10 mm:  $4.64 \pm 1.79$  mm, > 10 mm:  $9.67 \pm 3.46$  mm), and this was statistically significant ( $P = 0.015$ ). Both helical coil's number (< 5 mm:  $1.5 \pm 0.94$ , 5 - 10 mm:  $2.52 \pm 0.81$ , > 10 mm:  $2.75 \pm 1.9$ ) and size (< 5 mm:  $2.69 \pm 1.03$  mm, 5 - 10 mm:  $4.17 \pm 1.94$  mm, > 10 mm:  $7 \pm 3.16$  mm) increased with group size, with statistical significance ( $P < 0.001$  for both). The total length of framing coil increased with group size (< 5 mm:  $6.76 \pm 4.14$  cm, 5 - 10 mm:  $11.28 \pm 6.93$  cm, > 10 mm:  $29.33 \pm 12.59$  cm), and the total length of helical coil also increased with group size (< 5 mm:  $5.95 \pm 2.82$  cm, 5 - 10 mm:  $11.66 \pm 7.3$  cm, > 10 mm:  $22.32 \pm 11.48$  cm). Packing density, meanwhile, tended to decrease with group size (< 5 mm:  $46.70 \pm 3.15\%$ , 5 - 10 mm:  $33.06 \pm 0.26\%$ , > 10 mm:  $35.46 \pm 0.31\%$ ), with significant difference between groups ( $P < 0.001$ ) (Table 3). In most of the treated aneurysms, only one

**Table 1.** Clinical Characteristics of Patients

| Variables             | n  | %  |
|-----------------------|----|----|
| Age (years)           |    |    |
| < 40                  | 12 | 11 |
| 40 - 49               | 29 | 27 |
| 50 - 59               | 37 | 34 |
| 60 - 69               | 20 | 19 |
| $\geq 70$             | 10 | 9  |
| Gender                |    |    |
| Female                | 67 | 62 |
| Male                  | 41 | 38 |
| Risk factors          |    |    |
| Hypertension          | 84 | 78 |
| Diabetes mellitus     | 17 | 16 |
| Dyslipidemia          | 37 | 34 |
| Smoking/former        | 16 | 15 |
| Family history        | 7  | 6  |
| Aneurysms status      |    |    |
| Ruptured              | 98 | 84 |
| Unruptured            | 18 | 16 |
| In-hospital mortality |    |    |
| Survive               | 92 | 85 |
| Not survive           | 16 | 15 |
| Aneurysms size        |    |    |
| < 5 mm                | 66 | 57 |
| 5 - 10 mm             | 42 | 36 |
| > 10 mm               | 8  | 7  |

**Table 2.** Location and Size of Aneurysms

| Location   | Size            |                    |                 |
|------------|-----------------|--------------------|-----------------|
|            | < 5 mm (n = 66) | 5 - 10 mm (n = 42) | > 10 mm (n = 8) |
| Anterior   |                 |                    |                 |
| ACA        | 3 (4.54%)       | 2 (4.76%)          | 0 (0%)          |
| MCA        | 9 (13.64%)      | 7 (16.67%)         | 1 (12.50%)      |
| ACoA       | 27 (40.90%)     | 10 (23.81%)        | 2 (25.00%)      |
| Carotid    | 12 (18.18%)     | 8 (19.05%)         | 3 (37.50%)      |
| Ophthalmic | 1 (1.52%)       | 0 (0%)             | 0 (0%)          |
| Posterior  |                 |                    |                 |
| PCoA       | 10 (15.15%)     | 13 (30.95%)        | 2 (25.00%)      |
| PCA        | 1 (1.52%)       | 0 (0%)             | 0 (0%)          |
| SCA        | 1 (1.52%)       | 0 (0%)             | 0 (0%)          |
| Vertebral  | 2 (3.03%)       | 2 (4.76%)          | 0 (0%)          |

ACA: anterior cerebral artery; ACoA: anterior communicating artery; MCA: middle cerebral artery; PCA: posterior cerebral artery; PCoA: posterior communicating artery; SCA: superior cerebral artery.

**Table 3.** Characteristic Features of Coils and Size of Aneurysms

| Coil features              | Size            |                    |                  | P-value |
|----------------------------|-----------------|--------------------|------------------|---------|
|                            | < 5 mm (n = 66) | 5 - 10 mm (n = 42) | > 10 mm (n = 8)  |         |
| Framing coil               |                 |                    |                  |         |
| Number, mean ± SD          | 0.86 ± 0.55     | 0.97 ± 1.5         | 1.12 ± 1.64      | 0.799   |
| Diameter size, mean ± SD   | 3.19 ± 1.01 mm  | 4.64 ± 1.79 mm     | 9.67 ± 3.46 mm   | 0.015   |
| Length, ± SD               | 6.76 ± 4.14 cm  | 11.28 ± 6.93 cm    | 29.33 ± 12.59 cm | < 0.001 |
| Helical coil               |                 |                    |                  |         |
| Number, mean ± SD          | 1.5 ± 0.94      | 2.52 ± 0.81        | 2.75 ± 1.9       | < 0.001 |
| Diameter size, mean ± SD   | 2.69 ± 1.03 mm  | 4.17 ± 1.94 mm     | 7.0 ± 3.16 mm    | < 0.001 |
| Length, ± SD               | 5.95 ± 2.82 cm  | 11.66 ± 7.3 cm     | 22.32 ± 11.48 cm | < 0.001 |
| Packing density, mean ± SD | 46.70±3.15%     | 33.06±0.26%        | 35.46±0.31%      | < 0.001 |

SD: standard deviation.

coil (in 64.65% of cases) and more coils (in 31.89% of cases) were deployed. We provide a case illustration of a ruptured anterior communicating artery (ACoA) aneurysm in a patient treated with two coils: framing and helical coil (Fig. 2).

## Discussion

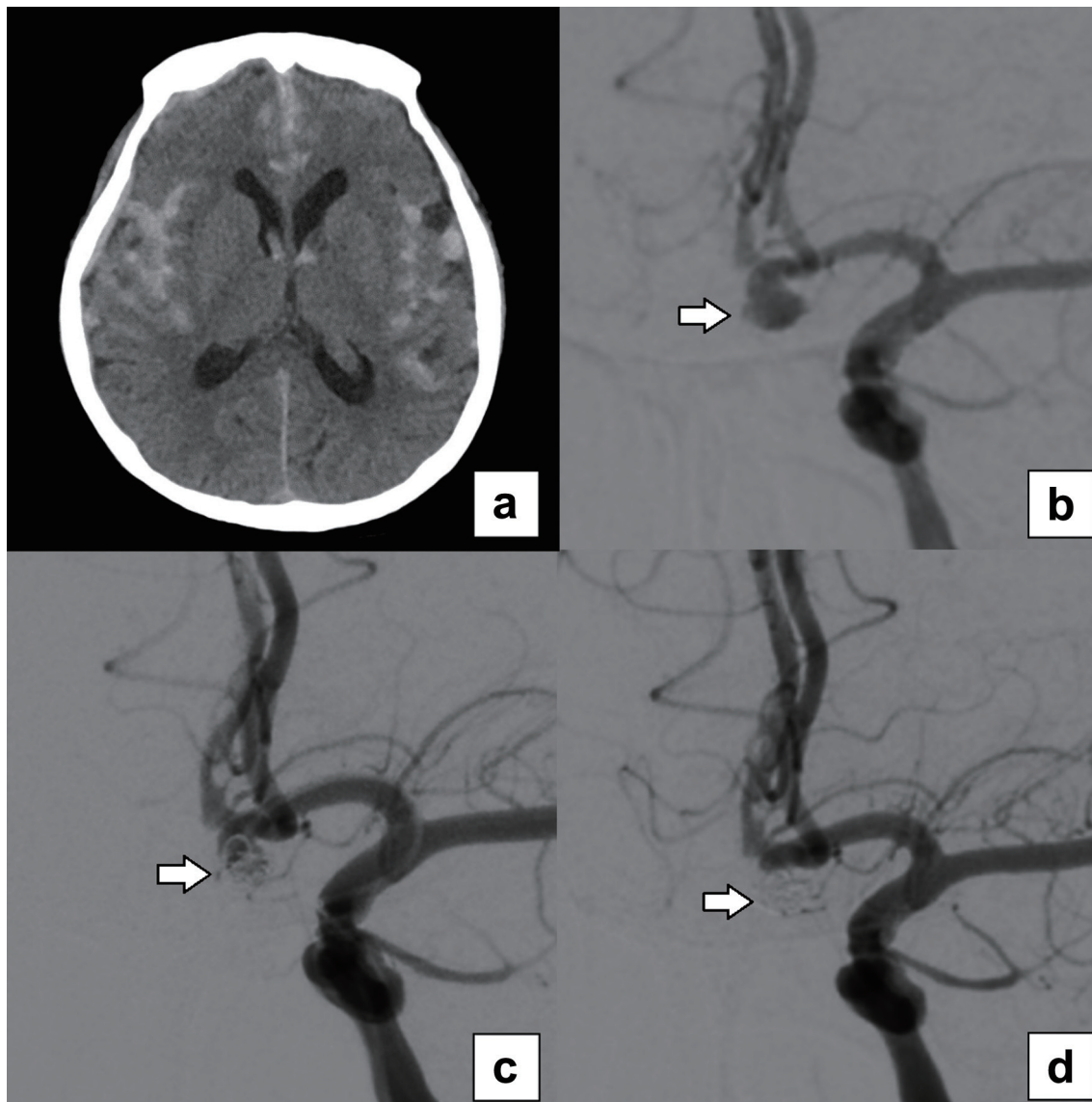
We reported that more than half (56.8%) of the cerebral aneurysms in our study had a size of less than 5 mm, with the anterior cerebral circulation as the most common site of origin. This is in coherence with studies conducted in Hong Kong, Singapore, as well as a previous Indonesian study [10-12]. Meanwhile, in Finland, ruptured aneurysms had an average size of 7 mm, and a Brazilian study reported that most aneurysms (67.7%) were between 5 and 10 mm [13, 14]. This suggests that Asian populations generally have smaller aneurysms than Western populations. As such, the number of coils necessitated in endovascular treatment may also vary between them.

In our study, both helical coil number and size increased with aneurysmal size ( $P < 0.001$ ). However, while framing coil size increased with aneurysmal size ( $P = 0.015$ ), framing coil number did not ( $P = 0.799$ ), and most cases (64.65%) needed only one framing coil. In smaller aneurysm sizes, some treatments used helical coil without framing, significantly when the morphology was elongated shape. In other words, while larger aneurysms may need more helical coils, in most cases, adequate coiling was achievable with one framing coil and two helical coils, allowing for an average coil number of 1 - 3 in our experience, through larger coil size. Vanzin et al also found that the number of coils needed is directly proportional to the aneurysmal size. However, they reported an average number of coils of 8 per aneurysm [7].

The number of coils needed in the endovascular treatment of aneurysms is influenced by several factors, such as coil length, thickness, type, aneurysmal shape, as well as operator's skill and experience [7, 15]. Endovascular treatment with larger coils can prevent failure in the complete occlusion of aneurysms, and a stiffer framing coil or a larger coil diameter can help prevent aneurysm recanalization [16, 17]. The

percentage of framing coil from total coil volume has been demonstrated to be a statistically significant predictor of aneurysm recurrence post-coiling [18]. Using large-sized coil, Zhang et al were able to achieve similar occlusion rates while significantly decreasing the average number of coils per aneurysm to  $2.98 \pm 1.09$  - a number similar to our finding - and lowering the recurrence rate at follow-up. They postulated the use of a large-sized coil as the initial embolization might be a new strategy for endovascular treatment [19]. The larger first coil has sufficient expansion and adhesion to the aneurysm inner wall, which is similar to the advantage provided by a flow-diverting stent with 30-35% surface area coverage [20, 21]. Kaesmacher et al also reported that aneurysmal occlusion using higher-volume coils led to the use of fewer coils - without a significant difference in the incidence of side effects - as well as higher packing density compared to when using lower-volume coils, thus leading to more complete aneurysm occlusion [22]. Our study confirmed these findings; we were able to achieve adequate occlusion of larger aneurysms with fewer framing coils by using larger-sized coils.

A higher packing density during unassisted coil embolization is linked to more long-lasting occlusion of the aneurysm [23, 24]. We found a mean packing density of 38.41% in occluded aneurysms in our study. Packing density differed significantly between group sizes ( $P < 0.001$ ), tending to decrease with increasing aneurysmal size. Packing density has been shown to affect the recurrence of intracranial aneurysms, in addition to hemodynamic factors and vascular geometry [25]. Packing density more than 19% was the main predictor of complete occlusion of aneurysms [26]. In coherence, using computer-generated aneurysmal models to simulate hemodynamics, recurrent aneurysms had significantly lower coil packing density and higher uncoiled aneurysmal volume, the latter of which was an independent predictor for recurrence [3]. Vogler et al corroborated this, demonstrating a high success rate of occlusion from the use of high-packing density coils [27]. However, a study in Japan found that aneurysm volume (odds ratio (OR): 15.3;  $P < 0.001$ ) and residual volume (OR: 30.9;  $P < 0.001$ ) were significant predictors for recanalization, not packing density (OR: 0.98;  $P = 0.341$ ) [6]. Furthermore,



**Figure 2.** Case illustration of aneurysmal SAH of a 66-year-old female who underwent simple endovascular coiling. CT scan revealed a diffuse SAH (a). DSA showed a saccular cerebral aneurysm located in ACoA with neck 1.07 mm, dome 3.88 × 2.55 mm (arrow) (b). The first coil (4 mm × 10 cm framing coil) was inserted (c), followed by the second coil (3 mm × 10 cm helical coil) (arrow). Packing density was achieved by 30.53% (arrow) (d). ACoA: anterior communicating artery; CT: computed tomography; DSA: digital subtraction angiography; SAH: subarachnoid hemorrhage.

Lee et al also found no correlation between volume packing density and recanalization, and Piotin et al found no difference in the effect of coil packing density between patients who had recurrence and those who did not [28, 29]. Apart from the contradictory findings of the aforementioned studies, based on our research, high packing density influences the success of aneurysm occlusion based on the size of the aneurysm.

The higher cost of endovascular coiling was attributable to the more costly coil devices, when compared to clips [8, 30]. It stands to reason that extending the length of coils could be an effective strategy in decreasing total hospital costs. However, cost-reduction plans often enhance issues related to restricting the types of coils. The types, numbers of coils, and perceived ef-

ficacy have an impact on coil selection, but no studies have proven that a single coil is more efficacious than the other [31, 32].

In this study, we found that fewer number of coils, with extended size and high packing density, did not reduce the efficacy of treatment. That being the case, our findings may serve as a consideration for healthcare providers in Indonesia to determine the predictive value of the number of coils *vis-a-vis* their efficacy. The use of a minimum number of coils by extending the coil size may be an alternative strategy to maintain proper coil packing density. This approach could be applied if long-term durability is not a major problem, especially in older patients. However, in younger who require long-term durability, this strategy must be considered on a case-by-case basis.

## Study limitations

Our study has limitations. It was conducted in a single center. In this study, the number of samples was only 116, which may not be generalized, especially for large aneurysms, which were only eight samples. However, in the small aneurysm group, the proportion is quite large. Furthermore, this is a descriptive study with no comparator or control group with a standard number of coils. This study is also limited to “narrow neck aneurysms” and “simple coiling”. Some interventionalists might take a different approach to using framing coils. Thus, further multicenter investigations with larger prospective and two arms are still needed as well as adequate follow-up to evaluate the perioperative complication and obliteration rate (Raymond-Roy occlusion classification).

## Conclusion

This study found that fewer coils per aneurysm could achieve good packing density by extending the length, especially the smaller dome size. These strategies might be considered to provide cost-reduction with acceptable endovascular treatment of cerebral aneurysms.

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## Financial Disclosure

No funding was received for this study.

## Conflict of Interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships which could be construed as a potential conflict of interest.

## Informed Consent

The ethics committee decided that informed consent for this study was not required, as no personal information of patients was included.

## Author Contributions

BTP, BR, and RGK contributed to the conception, design, and acquisition of the study. BR conducted the data analysis and

wrote the manuscript. RGK and BTP contributed to the manuscript revision. All authors contributed to reading and approving the submitted version of the manuscript.

## Data Availability

All data generated or analyzed during this study are included in this article. Further inquiries can be directed to the corresponding author.

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