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# Predictors of recanalization after endovascular treatment of posterior circulation aneurysms

Authors' Contribution:
A – Study Design
B – Data Collection
C – Statistical Analysis
D – Data Interpretation
E – Manuscript Preparation
F – Literature Search
G – Funds Collection
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**ABSTRACT:**

**Introduction.** Posterior circulation aneurysms account for approximately 30% of all intracranial aneurysms, and their rupture often causes aneurysmal subarachnoid hemorrhage (aSAH). Because surgical treatment of posterior circulation aneurysms is difficult, endovascular treatment is commonly indicated. However, simple coil embolization is associated with a high rate of recanalization. Our goal was to investigate morphometric aneurysmal features assessed on pre-embolization computed tomography angiography (CTA) as predictors of recanalization in patients with posterior circulation aneurysms.

**Material and Methods.** We retrospectively analyzed data of 24 patients who underwent coil embolization due to rupture of saccular posterior circulation aneurysms. The morphometric features of aneurysms were measured based on pre-embolization 3D-CTA-aneurysm models, and aneurysmal size and volume were measured on digital subtraction angiography (DSA) images. The effectiveness of initial endovascular treatment was determined visually with the modified Raymond Roy classification directly after embolization and on follow-up DSAs. Recanalization was diagnosed when, compared to the primary embolization aneurysm appearance, compaction and filling of the aneurysm occurred. Statistical analysis was performed with Statistica 13.1 software.

**Results**. Higher maximal aneurysm height perpendicular to the aneurysmal neck was associated with a greater aneurysm recanalization risk (12.12±5.13mm vs. 7.41±3.97mm, $p=0.039$), and this relationship remained significant after adjustment for patient's age, sex and aneurysm localization (OR=1.26, 95%CI: 1.01-1.60, $p=0.047$). Maximal aneurysm height perpendicular to the aneurysmal neck distinguished well between recanalized and non-recanalized aneurysms (AUC=0.755, 95%CI: 0.521-0.989, $p=0.033$).

**Conclusions**. Predictors of aneurysm recanalization can help choose best endovascular treatment strategies, which could reduce complication rates.

**KEYWORDS:** embolization, posterior circulation aneurysms, subarachnoid hemorrhage, predictors

## INTRODUCTION

Posterior circulation aneurysms account for approximately 30% of all intracranial aneurysms, and their rupture often causes aneurysmal subarachnoid hemorrhage (aSAH) [1,2,3]. Prevention of aSAH is essential to reducing mortality because patients with aSAH have an unfavorable prognosis. Compared to anterior circulation aneurysms, posterior circulation aneurysms are associated with a higher annual bleeding rate, have higher dome sizes, and more often develop into giant aneurysms [2]; moreover, posterior circulation aneurysms tend to have higher growth rates, especially among patients with multiple aneurysms [4].

Due to technical difficulties, surgery in patients with posterior circulation aneurysms is associated with high morbidity (12.9%) and mortality (3.0%) [2,5], and these figures are even higher in patients operated on due to rupture of posterior circulation aneurysms. Thus, endovascular treatment seems to be a better choice than microsurgery (MS) [6,7,8,9,10]. However, in patients with aneurysms who undergo endovascular treatment, recanalization is a common problem, and recurrent aneurysms may occur. Recanalization occurs more frequently after endovascular than surgical treatment [11,12]. Patients with significant recanalization may require repeated endovascular treatment or surgical clipping. Recanalization rates vary from 22.5% for unruptured aneurysms to 53.5% in ruptured aneurysms [11].

To date, among the many studied risk factors for aneurysm recanalization, such as age, sex, aneurysm size, primary packing density, and coil material, none proved significant. In this study, we assessed radiological aneurysmal features as predictors of recanalization in patients who underwent endovascular treatment due to rupture of posterior circulation aneurysms.

## MATERIAL AND METHODS

We retrospectively analyzed data of 24 patients who underwent coil embolization in 2013-2016 due to ruptured posterior circulation aneurysms in the Neurosurgical Department, Barlicki Hospital, Lodz, Poland. Data were gathered from medical records and included demographic factors, age, sex, comorbidities, three-dimensional computed tomography angiography (3D-CTA) images, digital subtraction angiography (DSA) images, surgical reports, and 6-month follow-up data. All patients were evaluated on the Hunt-Hess scale on admission, and SAH was assessed with the Fisher revised scale (FRS). In case of suspected aneurysms, preoperative 3D-CTA was performed. A multidisciplinary team, consisting of a neurosurgeon, a neuroradiologist, and an anesthesiologist, qualified patients for endovascular treatment. Follow-up DSAs were performed within 6 months. The analysis included only patients with single saccular intracranial aneurysms.

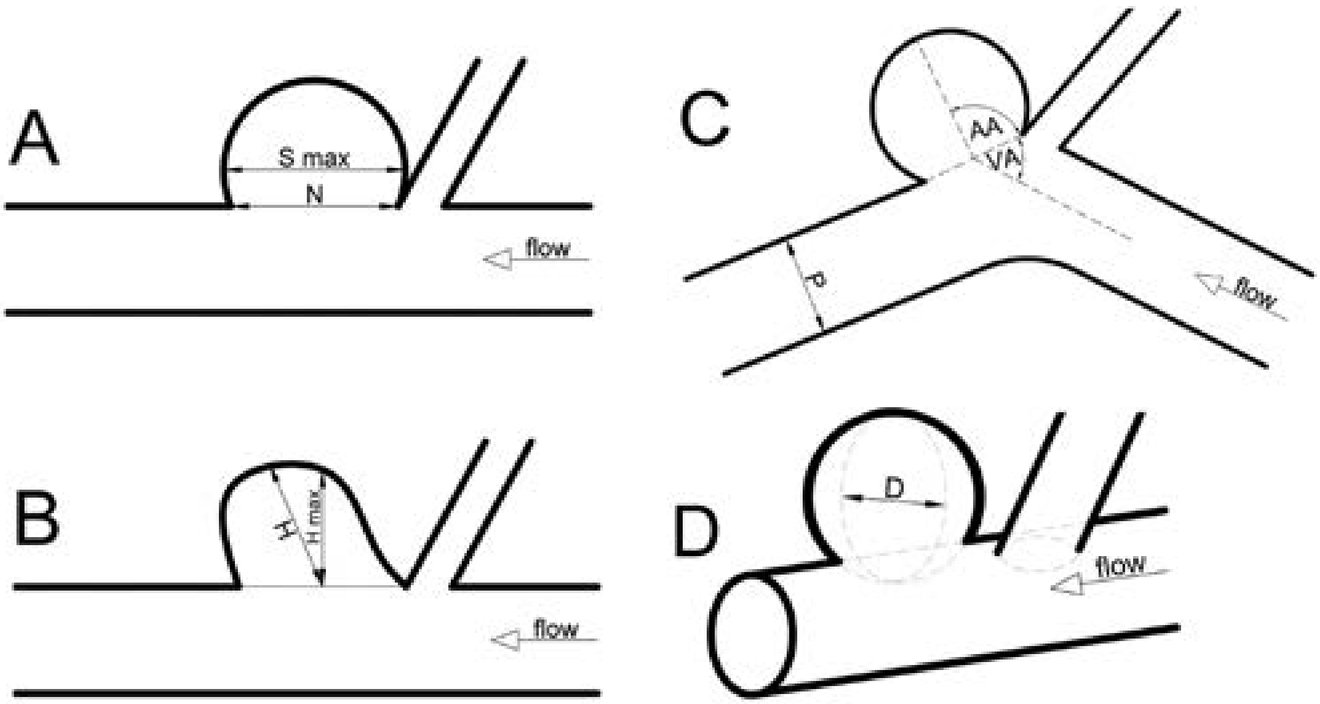


**Fig. 1.** Aneurysmal morphometric parameters (flow - blood flow direction):
A) S max – maximal aneurysm dome size, N - neck size;
B) H - Maximal aneurysm height, measured between the center of the aneurysm neck and the greatest distance to the aneurysm dome, H max - Maximal perpendicular height, the largest perpendicular distance from the neck of the aneurysm to the dome of the aneurysm;
C) AA – Aneurysm angle; VA – Vessel angle; P - parent artery diameter;
D) D - Maximal aneurysm depth;

On 3D-CTA aneurysm models, we measured the following features: aneurysm dome size; neck size; parent artery size; dome-to-neck ratio; neck-to-parent-artery ratio; aneurysm angle; vessel angle; flow angle; aspect ratio (AR), defined as the maximal perpendicular height, i.e., the largest perpendicular distance from the neck of the aneurysm to the dome of the aneurysm, divided by the aneurysmal neck width; and size ratio (SR), defined as the maximal aneurysm height between the center of the aneurysmal neck and the greatest distance to the aneurysm dome divided by vessel diameter (see Figure 1).

Two neuroradiologist performed diagnostic angiographies and embolizations under general anesthesia. Two types of spirals were used: bare platinum and bioactive coils, both available in two diameters (0.010" and 0.018") and in two coil forms [spatial (3D) and helical]. In each case, embolization risk was estimated as equal to the conventional risk or not. The aneurysm size was measured based on DSA images acquired in the anterior-posterior and lateral projections with a 22-cm magnification. The aneurysm volume and packing density (PD) were calculated with the angiocalc calculator (13). The effectiveness of the initial endovascular treatment was determined visually with modified Raymond Roy classification. Recanalization was diagnosed when, compared to primary embolization, compaction and filling of the aneurysm occurred. We also analyzed spontaneous aneurysm occlusion after incomplete treatment.

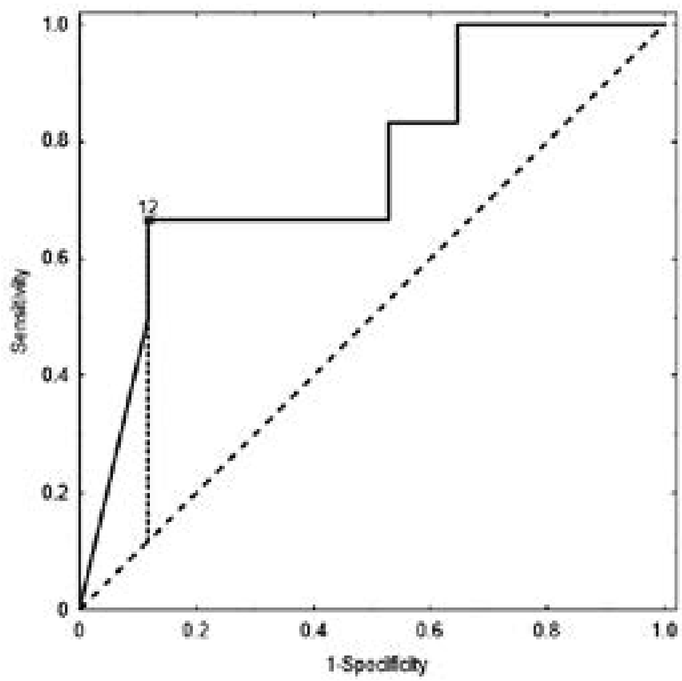


**Fig. 2.** ROC analysis for maximal aneurysm height perpendicular to the aneurysmal neck for all aneurysms.

## STATISTICAL ANALYSIS

Nominal variables were analyzed as numbers with percentages, whereas continuous variables were analyzed as means with standard deviations. The normality of distribution was verified with the Shapiro-Wilk test. Chi-square tests were used to determine associations between categorical variables. For pairwise comparisons of continuous variables, the Student's t-test was used. Receiver operating characteristic (ROC) curves were used to evaluate the accuracy of the tested classifiers and to determine optimal cutoffs. Multivariate logistic regression was used to determine independent risk factors for recanalization. P <0.05 was considered

**Tab. I.** Data presented as means±SD (all comparisons performed with two-tailed t-tests).

| | WITHOUT RECANALIZATION | RECANALIZATION | P VALUE |
|---|---|---|---|
| Age (years) | 57.00±5.96 | 61.00±16.50 | 0.390 |
| Depth (mm) | 6.58±3.24 | 6.83±2.93 | 0.866 |
| Height (mm) | 7.54±4.09 | 8.07±2.50 | 0.770 |
| Width (mm) | 6.46±3.26 | 7.12±2.59 | 0.664 |
| Neck size (mm) | 3.46±1.05 | 4.20±1.06 | 0.156 |
| Aneurysm volume (mm3) | 407.66±261.71 | 324.57±273.76 | 0.949 |
| Parent artery diameter (mm) | 3.57±0.92 | 3.17±0.77 | 0.349 |
| Maximum aneurysm size (mm) | 7.95±3.88 | 8.07±2.50 | 0.948 |
| SR ratio (Maximum aneurysm size / Parent artery diameter) | 2.40±1.43 | 2.58±0.63 | 0.771 |
| Neck-size-to-parent-artery ratio | 1.01±0.34 | 1.43±0.64 | 0.052 |
| Maximum aneurysm height perpendicular to aneurysmal neck (mm) | 7.41±3.97 | 12.12±5.13 | 0.031 |
| Aspect ratio (maximum aneurysm height perpendicular to neck /neck size) | 2.16±0.90 | 3.17±2.08 | 0.111 |
| Vessel angle (degrees) | 76.98±22.89 | 78.50±19.95 | 0.887 |
| Aneurysm angle (degrees) | 81.51±14.96 | 79.67±23.58 | 0.826 |
| Aneurysm-depth-to-neck=size ratio | 1.96±0.91 | 1.79±1.04 | 0.702 |
| Packing density (%) | 0.34±0.15 | 0.25±0.08 | 0.097 |

**Tab. II.** Area under the curve (AUC), sensitivity, specificity, and cutoff for ROC curve.

| MAXIMAL ANEURYSM HEIGHT PERPENDICULAR TO THE ANEURYSMAL NECK (MM) | | | | |
|---|---|---|---|---|
| Cutoff value (Youden method) | AUC (95% CI) | sensitivity | specificity | p |
| 12.0 mm | 0.755 (0.521-0.989) | 0.950 | 0.686 | 0.0325 |

statistically significant. Statistical analyses were performed with Statistica 13.1 software (StatSoft, Polska).

## RESULTS

All aneurysms were located in the posterior circulation. Among 24 patients, aneurysms were mainly located in the basilar artery (n=18). One aneurysm was located in the posterior inferior cerebellar artery (PICA), one, in the superior cerebellar artery (SCA), one, in the posterior cerebral artery (PA), and 3, in the vertebral artery (VA). The mean age was 58.8±9.53 years, there were 18 women (75%) and 6 men (25%). Descriptive statistics are presented in Table 1. The mean packing density was 31.7±13.8%. Initial interventions resulted in complete occlusions in 20 (83.33%) patients. The overall recanalization rate was 25% (n=6), and recanalization occurred at the aneurysmal neck.

Univariate analysis revealed that the maximal aneurysmal height perpendicular to the aneurysmal neck was higher in patients who had recanalizations compared to patients without recanalizations (12.12±5.13mm vs. 7.41±3.97mm, p=0.039, Table 1). The neck-size-to-parent-artery ratio was also higher in patients with recanalization (1.43±0.64 vs. 1.01±0.34, p=0.052), whereas the packing density in patients with recanalization was lower than in those without recanalizations (0.25±0.08% vs. 0.34±0.15%, p=0.097).

On multivariate logistic regression, we found that the maximal aneurysm height perpendicular to the aneurysmal neck remained a significant risk factor for recanalization after adjustment for age, sex, and aneurysm localization (OR=1.26, 95%CI:1.01-1.60, p=0.047).

We did not note spontaneous occlusions after incomplete embolization in our patients.

ROC analyses determined that the maximal aneurysm height perpendicular to the aneurysmal neck distinguished well between patients with recanalized aneurysms and those with non-recanalized aneurysms (AUC=0.755, 95%CI: 0.521-0.989, p=0.033, see Figure 2, Table 2).

The effect of coil type on recanalization rate was not evaluated due to a small sample size (7 bare platinum coils, 2 bioactive coils).

## DISCUSSION

Our study confirmed that recanalization risk for ruptured posterior circulation aneurysm is higher than for unruptured posterior circulations aneurysm (approximately 25% in previous research) [11].

Recanalization in patients treated due to ruptured posterior aneurysms often requires re-treatment by either re-coiling (with or without stent/balloon assistance) or surgical clipping. That is because unruptured aneurysms are more likely to have thick intima-like walls, in contrast to ruptured aneurysms, which are more likely to have thin walls with hyaline deposits [14]. Additionally, inflammation (infiltration of macrophages and T-cells as well as smooth muscle cell proliferation) observed in ruptured-aneurysm walls may lead to wall instability [15]. It was shown that wall instability increased intra-aneurysmal pulsatile pressure, which caused coil compaction or recanalization and aneurysm rupture [16,17].

Recanalization is an underestimated clinical problem, although it carries a risk of aSAH.

In our study, maximum aneurysm height perpendicular to the aneurysmal neck, packing density, and initial aneurysm occlusion were significant predictors of recanalization.

Our analysis showed that recanalization was more likely in women aged > 50 years and in patients with incomplete occlusion. Notably, even in case of complete aneurysm obliteration observed on angiography, small open spaces between coil loops at the aneurysm neck are present, which is more frequent in large aneurysms, probably due to delayed thrombus organization and delayed endothelialization; these processes elevate recanalization risk [18,19].

In patients undergoing endovascular treatment due to posterior circulation aneurysms, the maximum aneurysm height perpendicular to the aneurysmal neck greater than 12 mm incurs an increased recanalization risk.

Packing density indicates occlusion effectiveness, and lower packing density is associated with a higher frequency of aneurysm recurrence [20,21]. Recent studies have shown that a high packing density (24%) protects against recanalization in aneurysms smaller than 600 mm3 [20]. Our analysis also demonstrated that a high packing density (>26.3%) protects against recanalization.

Although recanalization occurred in our patients, hemorrhage did not recur, which could be due to repeated treatment in patients with significant recanalizations. A good outcome (Glasgow outcome score of 4) was achieved in the majority of patients. We noted three deaths (one due to a significant vasospasm, two due to large infarcts).

Our study was limited by a small number of patients. It was performed in a single center, was retrospective, which could have introduced selection or measurement bias. However, evaluations were performed by the same operator to minimize these effects.

## CONCLUSIONS

Different factors can influence recanalization of posterior circulation aneurysms. In patients with aneurysms characterized by morphometric features indicating a high recanalization risk, alternative endovascular treatment strategies different than simple embolization could be considered.

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