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Comparison of long-term clinical outcome after endovascular versus neurosurgical treatment of ruptured intracranial anterior circulation aneurysms: A single-centre experience

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ABSTRACT

Introduction: In patients with anterior circulation aneurysmal Subarachnoid Haemorrhage (aSAH), endovascular coiling is currently practiced more frequently than neurosurgical clipping. However, despite multiple previous studies, it is still uncertain whether coiling is favourable in terms of long-term clinical outcome.

Research question: What is the effect of clipping versus coiling on long-term functional outcome of patients with an aSAH?

Material and methods: All anterior circulation aSAH patients (2012–2015) treated with clipping or coiling in two hospitals in the Netherlands were studied up to five years after treatment. Functional outcome, survival, retreatment- and complication rate were measured. Survival analysis was performed in both groups. A multivariable regression model with covariate adjustment was performed to investigate the likelihood of unfavourable outcome (modified Rankin Scale >2).

Results: Out of 204 patients, 75 patients were clipped (37%) and 129 received coiling (63%). Coiling had a higher retreatment rate compared to clipping (7.8% vs. 0.0%). Unfavourable outcome at six, 12, 24 and 60 months after treatment was higher for patients after clipping compared to coiling, but was not significant after correcting for clinical severity as represented by the WFNS grade. In 60 months, no difference in survival was found between clipping and coiling.

Discussion and conclusion: No differences between clipping and coiling in survival and long-term functional outcome have been found in this study. More research with prospective design and large cohorts is needed to identify possible differences between the two treatments.

1. Background

In spontaneous subarachnoid haemorrhage (SAH), 85% of the cases are caused by the rupture of an intracranial aneurysm (Sweeney et al., 2016). The worldwide incidence of aneurysmal SAH (aSAH) is estimated to be 6.1 per 100.000 person-years (Etminan et al., 2019). ASAH is a life-threatening event with an in-hospital mortality rate of 30% (Nieuwkamp et al., 2009; Dutch Quality Registry for Neuro; Lovelock et al., 2010). Although mortality rates seem to be declining due to improved prehospital and hospitalised care, still only a third of all patients achieves a good functional outcome, typically defined as a Modified Rankin Scale (MRs) < 2[3,5].

The primary treatment goal in patients with aSAH is to prevent an early rebleed by exclusion of the ruptured aneurysm from the circulation (Pegoli et al., 2015). Traditionally, this has been achieved by neurosurgical clipping, which involves performing a craniotomy and placing a clip on the neck of the aneurysm to block the blood flow from entering the aneurysm dome (Al-Khindi et al., 2010). This surgical procedure involves certain risks of peri-procedural complications, such as haemorrhage (2.4%), infarction (6.7%) and infection (0.4%) (Alshekhlee et al., 2010; Ayling et al., 2015). In the past decades, endovascular coiling of the aneurysm has become an increasingly popular treatment method. This involves advancing a catheter through a peripheral artery to the aneurysm and subsequently inserting coiled titanium wires packing the aneurysm dome. As this procedure does not require a

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Abbreviations:

AVM	Arteriovenous malformation
AVF	Arteriovenous fistula
ACOM	Anterior communicating artery
ASAH	Aneurysmal subarachnoid haemorrhage
ASA	American Society of Anaesthesiologists
MRS	Modified Rankin Scale
WFNS	World Federation of Neurosurgical Societies
QRNS	Quality Registry Neurosurgery
PCOM	Posterior communicating artery
ACM	Middle cerebral artery
IRF	Inpatient Rehabilitation Facility
BRAT	Barrow Ruptured Aneurysm Trial
ISAT	International Subarachnoid Haemorrhage Trial
LOCF	Last Observation Carried Forward
EPR	Electronic Patient Record
IQR	Interquartile Range
TIA	Transient Ischaemic Attack
DVT	Deep Venous Thrombosis
CI	Confidence Interval

craniotomy, peri-procedural risks are generally considered to be lower, compared to neurosurgical clipping (Ayling et al., 2015). However, additional complications are seen, such as aneurysm perforation, aortic or peripheral dissections and thrombus formation (Al-Khindi et al., 2010; Lawton and Vates, 2017; Alshekhlee et al., 2010; Ayling et al., 2015). Traditional neurosurgical clipping is nowadays performed in a minority of the cases (Lovelock et al., 2010).

The decision between clipping and coiling is generally made after weighing individual risks and benefits in multidisciplinary consultations. Among others, aneurysm location (e.g. surgical accessibility of anterior versus posterior circulation aneurysms) and morphology (e.g. size, shape, having a sufficient base or neck) play a significant role (Alanen et al., 2018). Previous studies showed that coiling might be slightly superior to clipping in terms of short- and mid-term outcome (6 months until 3 years in the follow-up), but results did not remain significant when follow-up was prolonged to 3, 6 and 10 years (Spetzler et al., 2013, 2015, 2019; Molyneux et al., 2005; McDougall et al., 2012). There also appeared to be a higher incidence of rebleeding and retreatment in coiled patients (Spetzler et al., 2013, 2019). Choosing the appropriate treatment modality remains challenging due to the absence of conclusive evidence on the long-term outcomes for clipping and coiling.

This study aims to evaluate differences in long-term clinical outcome between clipping and coiling of patients with a SAH from a ruptured anterior circulation aneurysm.

2. Materials and methods

2.1. Study design and data acquisition

In this single-centre, retrospective cohort study, consecutive aSAH patients who were primarily treated with either clipping or coiling at the Haaglanden Medical Centre and the Leiden University Medical Centre in the Netherlands from 2012 to 2015 were evaluated. This period of patient inclusion was chosen to allow the investigation of long-term outcome. To increase comparability, only aneurysms from the anterior circulation will be investigated, as these aneurysms are comparably accessible for both clipping and coiling treatment. With exceptions, neurosurgical clipping of posterior circulation aneurysms is generally considered to be inferior to coiling treatment due to higher surgical risks (Belavadi et al., 2021). Inclusion criteria were: 1) SAH originating from a ruptured intracranial aneurysm of either the Anterior Communicating Artery (ACOM), Posterior Communicating Artery (PCOM), Middle Cerebral Artery (MCA) and the Pericallosal Artery, 2) aneurysm primarily treated by either neurosurgical clipping or endovascular coiling, 3) age ≥18 years at time of diagnosis.

All relevant data on (1) baseline patient characteristics, (2) treatment procedures, (3) follow-up and (4) survival was retrieved from the Dutch Quality Registry Neuro Surgery (QRNS) and electronic patient records. Patients primarily treated with either clipping or coiling, but who crossed-over to the other treatment remained in their original group for analysis. This study was approved by the responsible Medical Ethics Committee. The need for informed consent was waived due to its retrospective design.

2.2. Outcome measures

Baseline characteristics included age, gender, history of aSAH, history of hypertension, history of smoking, WFNS grade at admission, and details on the location and morphology of the aneurysm (Gaillard et al. a). The clinical condition of the included patients was classified using the American Society of Anaesthesiologists physical status (ASA).

In addition to survival, functional outcome was studied using the dichotomized modified Rankin scale (mRS) at six, 12, 24 and 60 months after primary treatment. The mRS ≤2 is considered to be a favourable functional outcome and mRS >2 to be an unfavourable outcome (Nobels-Janssen et al., 2022). The mRS was extracted or reconstructed from the electronic patient files. When available information was insufficient to reconstruct mRS, general practitioners of patients were called to assess the mRS.

Other clinical outcome parameters included cases of rebleed, peri-procedural complications, referral to a nursing home or inpatient rehabilitation facility (IRF) and retreatment within five years after initial treatment. A rebleed was defined by radiological confirmation of a rebleed or, when diagnostics were not available, in case of documented substantial clinical suspicion.

Peri-procedural complications were aneurysm rupture or perforation during clipping or coiling, vascular dissection, thrombosis and coil protrusion. Thrombosis after or during clipping was defined as diagnosed cases of venous- or arterial thrombosis, including a transient ischemic attack or deep venous thrombosis. Cases of thrombosis in coiling was defined as the formation of thrombi during the procedure.

Retreatment was defined as neurosurgical or endovascular intervention due to recanalization or late rebleeding of the previously treated aneurysm.

2.3. Imputation of missing data

Missing mRS scores were imputed through the method of Last Observation Carried Forward (LOCF). All cases without any documentation or registration of a retreatment in our EPD during follow-up were considered to have had no retreatment.

2.4. Statistical analysis

Statistical analyses were performed using IBM SPSS Statistics version 26. The analysis was performed by intention-to-treat. Categorical variables were reported as frequency (N) and percentage (%). Continuous variables were reported as mean and standard deviation or median and interquartile range (IQR), based on the normality of the distribution. For categorical variables, odds ratios were calculated with corresponding 95% confidence intervals. For continuous variables, the mean difference was calculated with corresponding 95% confidence interval. Statistical comparisons were performed with χ^2 test or Fisher's exact test for categorical variables and Student's *t*-test or the Mann-Whitney *U* test for continuous variables.

To identify independent predictors for unfavourable outcome, multivariate analyses through binary logistic regression models with corresponding 95% confidence intervals were performed. Possible confounders of the relation between the primary treatment modality and outcome (i.e. age, history of hypertension, smoking, aneurysm location and size, WFNS grading at admission) were added as covariates. Kaplan Meier analysis was used to compare overall survival in patients being either clipped or coiled. Statistical significance for survival was determined using the log-rank test. All tests used in the analysis were two-sided. Cox-regression models, with the same covariates with primary treatment as independent variable, were used to assess and compare survival. Statistical significance was defined as $P < 0.05$.

3. Results

3.1. Baseline characteristics

A total of 204 patients were studied (Figure A.1), of which 75 patients received neurosurgical clipping as primary treatment (37%), and 129 patients endovascular coiling (63%; Table A.1). Two patients (1.6%) from the coiling group crossed-over to the clipping group due to inadequate coil deposition. Median age was 67 (IQR: 57–75) and 69% was female. Smoking (40%) and hypertension (36%) were common and nearly half of all patients were ASA 2. Three patients (1.5%) had received previous aSAH treatment. Most patients had a WFNS of I (47%). The distribution of the WFNS score was not different between the coiling and clipping group. The majority of patients being clipped had an aSAH originating from the ACM (61.3%) while the ACOM was the most frequent (57%) origin in the coiling cohort. Clipped patients had more frequent hematoma evacuations (30%) and decompressive craniotomies (9.3%) compared to the coiling group (2.5 and 1.3% respectively).

3.2. Survival

In-hospital mortality was 11% in the clipping cohort and 4.7% in the coiling cohort. After twelve months, 80% and 89% of the patients in the clipping- and coiling group respectively were still alive. At five years after treatment, survival was 79% and 87% for clipping and coiling respectively ($P = 0.06$; Figure A.2).

3.3. Functional outcome

Unfavourable outcome (mRS >2) at six months follow-up was 40% for the clipping group and 23% for the coiling group ($P = 0.03$; Table A.2). After two years, 28% of the clipped patients and 19% of the coiled patients had unfavourable outcome ($P = 0.00$). At 5 years after treatment unfavourable outcome increased slightly in the clipped group (33%) and improved to 17% in the coiled group ($P = 0.014$).

After imputation, the proportion of patients with mRS >2 at all follow-up points remained higher in the clipping group: 44% in clipping and 26% in coiling at six months ($P = 0.010$), 41% and 23% at one year ($P = 0.007$), 45% and 24% at two years (0.002), 45% and 25% at five years after treatment (0.003; Table A.2). Notable is that all but one patient with aSAH originating from the pericallosal artery had unfavourable outcome during follow-up (88%). After clipping, 51% of survivors were referred to an IRF or nursing home, compared to 38% after coiling. ($P = 0.01$).

3.4. Retreatment and complications

Ten out of 204 patients received retreatment during follow-up (4.9%). All of these patients were initially coiled (7.8% of coiling group), and there was no retreatment in the clipping group ($P = 0.002$).

Rebleeds occurred in 25 patients (12%), of which 10 in the clipping group (13%) and 15 in the coiling group (12%) ($P = 0.72$). As much as 92% of rebleeds were pre-treatment, and the two rebleeds post-treatment were in the coiling group. Peri-procedural aneurysm rupture occurred in 23% of clipping cases, and 5.4% of patients in the coiling group ($P = 0.001$; Table A.2). Coil protrusion was described in 4 patients (3.1% of the coiling group). Peri-procedural thrombi formation was noticed in 11% of coiling patients. In the clipping group, arterial or venous embolisms occurred in 2.7% of cases.

3.5. Multivariate analysis

After correction for confounding by multivariate analysis, no association was found between primary treatment and survival (HR 0.32; 95% CI 0.06–1.73 compared to clipping).

The multivariate analysis of the imputed data showed no independent correlation between primary treatment and unfavourable outcome (Table A.3). Age was identified as an independent predictor for unfavourable outcome at six months and five years after treatment, but with minimally higher odds ratios (OR 1.05, 95% CI 1.00–1.09; OR 1.06 95% CI 1.01–1.10). WFNS grade III was associated with unfavourable outcome at one, two and five years after treatment (OR 7.53, 95% CI 1.47–38.59; OR 2.80, 95% CI 0.55–14.22; OR 2.74, 95% CI 0.53–14.30) and WFNS grade V had this correlation for two years after treatment (OR 10.18, 95% CI 1.75–59.21). To prevent unreliable results, cases with an aSAH originating from the arteria pericallosa were not selected for the multivariate analysis Due to a very low incidence of patients with this particular type of aneurysm originating (4% in the total cohort), unmeasurable odds were calculated for this specific group.

4. Discussion

In this study, patients with aSAH underwent endovascular coiling with greater frequency than neurosurgical clipping. There were no differences in survival or long-term functional outcome between clipping and coiling groups. Notably, advanced age and a higher clinical severity as measured by WFNS grade at admission emerged as independent prognostic indicators for unfavourable outcome. Retreatment rate was significantly higher in the coiling group.

The observed mortality rates aligned closely with those reported in existing literature (Xia et al., 2017; Zhu et al., 2022; Park et al., 2022; Zhao et al., 2016; Ahmed et al., 2019; Lindgren et al., 2018, 2019). Furthermore, the absence of mortality differences between clipping and coiling groups was corroborated by the majority of meta-analyses (Xia et al., 2017; Zhu et al., 2022; Park et al., 2022). A comprehensive meta-analysis of prospective studies reported a non-significant relative risk of 1.07 for mortality following clipping versus coiling (95% CI: 0.91–1.26) (Park et al., 2022), while others reported a slightly higher mortality in the coiling group (Lindgren et al., 2018, 2019). One reported an OR 1.17, 95% CI 1.04–1.32 in favour of clipping (Lindgren et al., 2019), and another found higher odds for 14-day (1.7, 95% CI 1.1–2.7) and 90-day fatality (1.3,95% CI 0.91–1.82) after coiling (Lindgren et al., 2018). Nevertheless, direct comparison of these results from meta-analyses with our study findings remains challenging due to disparities in included studies, inclusion criteria, and distinct methodological approaches – such as the adoption of a substantially shorter follow-up period of one year (Xia et al., 2017; Zhu et al., 2022), inclusion of only high-grade aSAH patients (Zhu et al., 2022), or only patients with minor neurological deficits (Park et al., 2022).

Our long-term outcome results were consistent with findings from many retrospective cohort studies, randomized controlled trials and meta-analyses, which demonstrate no statistically significant differences between coiling and clipping in aSAH patients (Molyneux et al., 2005; McDougall et al., 2012; Spetzler et al., 2013; Spetzler et al., 2019; Belavadi et al., 2021; Gaillard et al.a; Zhu et al., 2022; Zhao et al., 2016; Gaillard et al.b). For instance, the Multicentre Poor-Grade Aneurysm Study (AMPAS), focusing exclusively on poor-grade aSAH with WFNS grade IV or V, revealed no difference in functional outcome following clipping or coiling treatment (Zhao et al., 2016). One meta-analysis including only ruptured basilar apex aneurysms found no significant differences in outcome between clipping and coiling (Fotakopoulos et al., 2021). Another one, while excluding patients with low grade aSAH (Hunt and Hess grade 1–3 or WFNS grade I and II), reported no differences in outcome in non-RCT studies (OR, 1.49; 95% CI, 0.95–2.36) and RCTs (OR, 1.15; 95% CI, 0.59–2.25) (Zhu et al., 2022).

Several studies have reported favourable outcomes associated with endovascular coiling. Notably, the large International Subarachnoid Haemorrhage Trial (ISAT) suggested the superiority of coiling over clipping, demonstrating absolute and relative risk reduction for death or dependency of 6.9% (95% CI 2.5–11.3%) and 22.6% (95% CI 8.9–34.2%), respectively (Molyneux et al., 2005). However, concerns regarding the generalizability of these findings arise due to the over-representation of neurologically relatively good patients with small calibre anterior circulation aneurysms. The Barrow Ruptured Aneurysm Trial (BRAT) showed a significantly higher risk of poor outcome (defined as mRS >2 at 1-year follow-up) in the clipping group compared to coiling (OR 1.68, 95% CI 1.08–2.61). Limitations of the BRAT study include its exclusive focus on saccular aneurysms from the anterior and posterior circulation (Spetzler et al., 2013, 2015, 2019; McDougall et al., 2012), and a high crossover to clipping treatment (37.7%), despite using an intention-to-treat analysis (Spetzler et al., 2019). Furthermore, differences in outcome did not maintain significance beyond one-year follow-up, persisting until ten years after treatment (Spetzler et al., 2019).

In addition, a meta-analysis concluded that coiling was associated with a reduced rate of poor outcome at one year compared to clipping (RR 1.27, 95% CI: 1.16–1.39). However, this advantage in overall prognosis was not significant among patients presenting with a poor neurological condition at admission (Park et al., 2022). A 2018 Cochrane Review supported these finding, reporting a lower incidence of poor long-term outcome with coiling compared to clipping (RR 0.81, 95% CI 0.70–0.92), but also included concerns regarding the quality of evidence (Lindgren et al., 2018).

The association between advanced age and higher WFNS grade with poor outcome in patients with aSAH is well-documented in literature. A retrospective analysis of the BRAT trial found that patients over 65 years old were at increased risk for poor neurological outcomes compared to their younger counterparts (Catapano et al., 2020). Similarly, the three-year follow-up of the BRAT identified age and Hunt and Hess scale >2 as significant predictors of outcome (Spetzler et al., 2013). Other studies also reported that higher Hunt and Hess and Fisher scale scores are associated with poor outcomes (Gaillard et al.b; Acioly et al., 2019) and increased rates of neurological and clinical complications (Cedzich and Roth, 2005). Although both scales were not included in the multivariate analysis of our study, these finding are consistent with our observation of worse outcomes in patients with higher WFNS. This correlation between WFNS grade and outcome is further supported by literature indicating that independent risk factors for poor outcome include age, WFNS grade, Fisher scale score, and aneurysm size (Van Donkelaar et al., 2019). Also, a Cochrane review identified a poor clinical condition (WFNS 3–5) as significant predictor of outcome (Lindgren et al., 2018). Conversely, the ISAT did not specify risk factors for poor outcome (Molyneux et al., 2005).

A higher retreatment and post-treatment rebleeding rate was observed in the coiling subgroup, consistent with findings in existing literature. The ISAT showed a greater risk of aneurysm recanalization and subsequent rebleeding in coiled patients (2.6%) compared to patients undergoing clipping (1.0%) (Molyneux et al., 2005). Similarly, the BRAT found more complete aneurysm obliteration following clipping (87% vs. 52% in coiling, $P < 0.001$) alongside a significantly higher retreatment rate in the coiling subgroup (20% vs. <1% in clipping, $P < 0.001$) (Spetzler et al., 2019). These findings align with a meta-analysis indicating a significantly lower retreatment rate following clipping (3.8% vs. 13% with coiling, $P < 0.0001$) (Zhu et al., 2022). The pre-treatment rebleeding rate of 12% was slightly higher compared to literature. Reasons may include a low threshold of registration of rebleed as complication (i.e. in case of new headaches) and a relatively high frequency of repeat imaging after arrival to our referral centre with further distribution of subarachnoid haemorrhage interpreted as potential sign of rebleed. Time from ictus to treatment was not included in our database, but is generally within the same day, or early the next morning. The higher number of hematoma evacuations and decompressive craniectomies in the clipping cohort suggests a more acute treatment of these patients.

Despite the reduced risk of aneurysm recanalization and rebleeding associated with clipping, studies generally report a higher incidence of complications compared to coiling. These complications include periprocedural aneurysm rupture, infection, postoperative bleeding and thromboembolic events, consistent our study findings and previous literature (Alshekhlee et al., 2010; Ayling et al., 2015; Alanen et al., 2018). Radiologic hydrocephalus was also noted to occur significantly more frequently in post-coiling patients, supported by a meta-analysis in which clipping treatment was found to be associated with a lower risk of developing shunt dependency, potentially attributed to periprocedural blood clot removal (Zhao et al., 2016; De Oliveira et al., 2007).

In the management of aSAH, balancing between the elevated risk of recurrence and rebleeding associated with endovascular coiling and the increased surgical morbidity accompanying clipping is paramount in determining the optimal treatment approach. Despite extensive previous research efforts, the distinct impacts of clipping and coiling on long-term outcomes remains uncertain, leading to a lack of standardization in the overall treatment strategy for aSAH, and difficulties in the treatment decision-making process. When considering aneurysm repair, factors including the expertise of the clinical team, patient and caregiver preferences, specific aneurysm characteristics play crucial roles in the decision-making process between clipping and coiling (Korkmaz Dilmen and Bonhomme, 2023; Connolly et al., 2012). Available guidelines only provide limited guidance.

Recent guidelines from organizations such as the American Heart/American Stroke association highlight the multifaceted nature of treatment and surveillance during aSAH care, emphasizing the varying management approaches across healthcare institutions due to the absence of consensus and ongoing research (Korkmaz Dilmen and Bonhomme, 2023; Connolly et al., 2012). Factors such as hydrocephalus, vasospasms, delayed cerebral ischemia (DCI), blood pressure management, and cerebral perfusion pressure are reported to be managed differently between healthcare institutions, further underscoring the need for more evidence-based consensus (Connolly et al., 2012).

Conducting a RCT to study clipping versus coiling is no likely longer feasible given the heterogeneity of aSAH and the existence of established treatment strategies. For decades, the rate of coiling treatment for ruptured intracranial aneurysms has been around 60% (SVIN et al., 2022). As an alternative for RCT, a longitudinal prospective cohort study focusing on variations in care across treatment centres represents the optimal approach to comparing clipping and coiling in terms of long-term outcomes (Hamming et al., 2024). Utilizing these variations in care on a national or international scale has the potential to uncover significant differences in treatment effectiveness between centres. Furthermore, incorporating this variation into statistical analyses could help adjust for additional unmeasured confounding factors, ultimately advancing our understanding of aSAH management and guiding the development of optimal treatment strategies.

5. Strenghts and limitations

This retrospective study allows an evaluation of long-term outcome differences after clipping and coiling of patients with aSAH. The broad inclusion criteria employed in this study enhance the generalizability of its findings, while the mono-institutional aspect might limit this. Multivariate analysis has been used to minimize the risk for confounding variables. Nevertheless, several limitations are acknowledged. The retrospective nature of this study renders its results susceptible to confounding. Moreover, the modest sample size constraints the extent to which definitive conclusions can be drawn. The specific characteristics of the aneurysm, the extent of subarachnoid haemorrhage, and other unmeasured treatment specifics may have introduced other confounding. Also, non-aneurysm or subarachnoid haemorrhage related reasons for worse outcome in subgroups could have negatively influenced outcome, which was especially the case in our subgroup of pericallosal artery aneurysm patients. The imbalance between study group size, attributed to a higher proportion of patients undergoing coiling treatment, could also have impacted results. Additionally, the reported long-term outcomes of anterior circulation aneurysm treatments may not be applicable to specific aneurysm locations, as a higher proportion of ACOM aneurysms were coiled, whereas ACM aneurysms were more frequently clipped. Last, the presence of missing data necessitated imputation for several crucial variables.

6. Conclusion

In conclusion, coiling emerges as the predominant treatment modality for ruptured intracranial anterior circulation aneurysms, surpassing clipping. There were no discernible disparities in survival rates or long-term functional outcomes between clipping and coiling. Advancing age and a higher clinical severity, as measured by WFNS grade at admission, independently correlate with unfavourable outcomes. The retreatment rate was significantly higher in the coiling group. More research with a prospective design and large cohorts are needed to identify possible differences between the two treatments.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

W. Peul reports a relationship with The European Union seventh Framework Program that includes: funding grants (grant 602150). W. Peul reports a relationship with Hersenstichting Nederland (Dutch Brain Foundation) that includes: funding grants. The authors have no other relevant affiliations with any organization or entity that have a financial conflict with the subject matter discussed in the manuscript. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. . Supplementary datae

The following is/are the supplementary data to this article:

Table A.1Baseline characteristics

Baseline characteristics		Total		Clipping		Coiling	
		N	%	N	%	N	%
Total number of patients		204	100	75	37	129	63
Age	**Median (IQR)**	67 (57–75)		67 (57–76)		66 (57–74)	
Gender	**Female**	141	69	52	69	89	69
	Male	63	31	23	31	40	31
ASA-score	**1**	34	17	11	15	23	18
	2	98	48	37	49	61	47
	3	51	25	19	25	32	25
	4	19	9.3	6	8.0	13	10
	5	2	1.0	2	2.7	0	0.0
SAH treatment in history	**No**	201	99	72	96	129	100
	Yes	3	1.5	3	4.0	0	0.0
Smoking	**No**	45	22	12	16	33	26
	Yes	82	40	31	41	51	40
	Unknown	77	38	32	43	45	35
Hypertension	**No**	130	64	44	59	86	67
	Yes	74	36	31	41	43	33
WFNS	**I**	95	47	34	45	61	47.3
	II	35	17	14	19	21	16.3
	III	17	8.3	8	11	9	7.0
	IV	31	15	11	15	20	16
	V	26	13	8	11	18	14
Aneurysm location	**ACM**	55	27	46	61.3	9	7.0
	ACOM	92	45	18	24	74	57
	PCOM	49	24	6	8.0	43	33
	Pericallosa	8	3.9	5	6.7	3	2.3
Aneurysm largest diameter in millimeter	**Median (IQR)**	6.0 (4.2–9.0)		7.0 (4.0–10)		6.0 (4.3–8.8)	

Table A.2
Clinical outcome and follow-up characteristics

Clinical outcome and follow-up characteristics		Total		Clipping		Coiling		*p*
		N = 204	%	N = 75	%	N = 129	%	
Hospital stay in days	**Median (IQR)**	18 (12–27)		19 (14–27)		18 (12–25)		0.326

(*continued on next page*)

Table A.2 (*continued*)

Clinical outcome and follow-up characteristics

		Total		Clipping		Coiling		*p*
		N = 204	%	N = 75	%	N = 129	%	
Vasospasm	**No**	137	67	50	67	87	67	0.909
	Yes	67	33	25	33	42	33	
Hydrocephalus	**No**	115	56	45	60	70	54	0.426
	Yes	89	44	30	40	59	46	
Rebleed	**No**	179	88	65	87	114	88	0.720
	Yes	25	12	10	13	15	12	
Complications	**None**	159	78	56	75	103	80	0.001*
	Aneurysm rupture or perforation	24	12	17	23	7	5.4	
	Thrombosis	16	7.8	2	2.7	14	11	
	Dissection	1	0.5	0	0.0	1	0.8	
	Coil protrusion	4	2.0	0	0.0	4	3.1	
Additional intervention	**None**	66	49	19	35	47	59	0.000*
	Hematoma evacuation	18	13	16	30	2	2.5	
	Decompressive craniotomy	6	4.5	5	9.3	1	1.3	
	External Ventricle Drain	34	25	8	15	26	33	
	Additional coiling or clipping	10	7.5	6	11	4	5.0	
Location after hospital	**Home**	86	42	25	33	61	47	0.099
	Rehabilitation centre	47	23	16	21	31	24	
	Nursing home	34	17	18	24	16	12	
	Hospice	1	0.5	0	0.0	1	0.8	
	Diseased in hospital	14	6.9	8	10.7	6	4.7	
	Unknown	22	11	8	10.7	14	11	
Retreatment	**No**	194	95	75	100	119	92	0.015*
	Yes	10	4.9	0	0.0	10	7.8	0.015*
	Unknown	194	95	75	100	119	92	
MRS at 6 months	**≤2**	123	60	41	55	82	64	0.030*
	>2	60	29	30	40	30	23	
	Unknown	21	10	4	5.3	17	13	
MRS at 6 months (imputed)	**≤2**	**137**	**67**	**42**	**56**	**95**	**74**	**0.010***
	>2	**67**	**33**	**33**	**44**	**34**	**26**	
MRS at 1 year	**≤2**	113	55	37	49	76	59	0.014*
	>2	51	25	27	36	24	19	
	Unknown	40	20	11	15	29	22	
MRS at 1 year (imputed)	**≤2**	**143**	**70**	**44**	**59**	**99**	**77**	**0.007***
	>2	**61**	**30**	**31**	**41**	**30**	**23**	
MRS at 2 years	**≤2**	96	47	27	36	69	53	0.003*
	>2	51	25	27	36	24	19	
	Unknown	57	28	21	28	36	28	
MRS at 2 years (imputed)	**≤2**	**139**	**68**	**41**	**55**	**98**	**76**	**0.002***
	>2	**65**	**32**	**34**	**45**	**31**	**24**	
MRS at 5 years	**≤2**	86	42	27	36	59	46	0.014*
	>2	47	23	25	33	22	17	
	Unknown	71	35	23	31	48	37	
MRS at 5 years (imputed)	**≤2**	**138**	**68**	**41**	**55**	**97**	**75**	**0.003***
	>2	**66**	**32**	**34**	**45**	**32**	**25**	

IQR, inter quartile range; *N,* number of patients; *MRS,* Modified Rankin Scale.

Table A.3

Multivariate analysis for unfavourable outcome (modified Rankin Scale >2) (imputed data)

		mRS >2 in six months		mRS >2 in one year		mRS >2 in two years		mRS >2 in five years	
		OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
Primary treatment	**Clipping**		Reference		Reference		Reference		Reference
	Coiling	**0.41**	**0.10–1.61**	**0.35**	**0.08–1.50**	**0.33**	**0.09–1.26**	**0.29**	**0.08–1.06**
Age		**1.05**	**1.00–1.09**	1.03	0.98–1.07	1.04	1.00–1.08	**1.06**	**1.01–1.10**
Smoking	**No**		Reference		Reference		Reference		Reference
	Yes	1.65	0.48–5.70	1.72	0.45–6.55	1.97	0.57–6.88	1.21	0.38–3.83
Hypertension	**No**		Reference		Reference		Reference		Reference
	Yes	0.83	0.23–3.04	0.90	0.22–3.64	1.40	0.37–5.30	0.78	0.22–2.81
WFNS grade	**I**		Reference		Reference		Reference		Reference
	II	1.88	0.45–7.86	1.68	0.37–7.55	1.54	0.35–6.68	1.81	0.41–7.98
	III	3.42	0.683–17.15	**7.53**	**1.47–38.59**	**2.80**	**0.55–14.22**	**2.74**	**0.53–14.30**
	IV	0.87	0.09–8.29	1.05	0.11–10.08	0.81	0.08–7.92	1.95	0.32–11.98
	V	4.73	0.78–28.80	3.20	0.47–21.71	**10.18**	**1.75–59.21**	10.16	1.72–60.22
Aneurysm location	**ACOM**		Reference		Reference		Reference		Reference
	PCOM	1.08	0.28–4.15	1.01	0.24–4.22	0.68	0.15–3.03	0.63	0.14–2.78
	ACM	0.81	0.20–3.28	0.61	0.14–2.78	1.03	0.26–4.00	1.06	0.28–3.98
Aneurysm largest diameter		0.99	0.89–1.11	1.01	0.90–1.12	1.02	0.92–1.13	1.01	0.91–1.12

OR, odds ratio; CI, confidence interval; mRS, Modified Rankin Scale; WFNS, World Federation of Neurosurgical Societies; ACM, Middle Cerebral Artery; ACOM, Anterior Communicating Artery; PCOM, Posterior Communicating Artery.

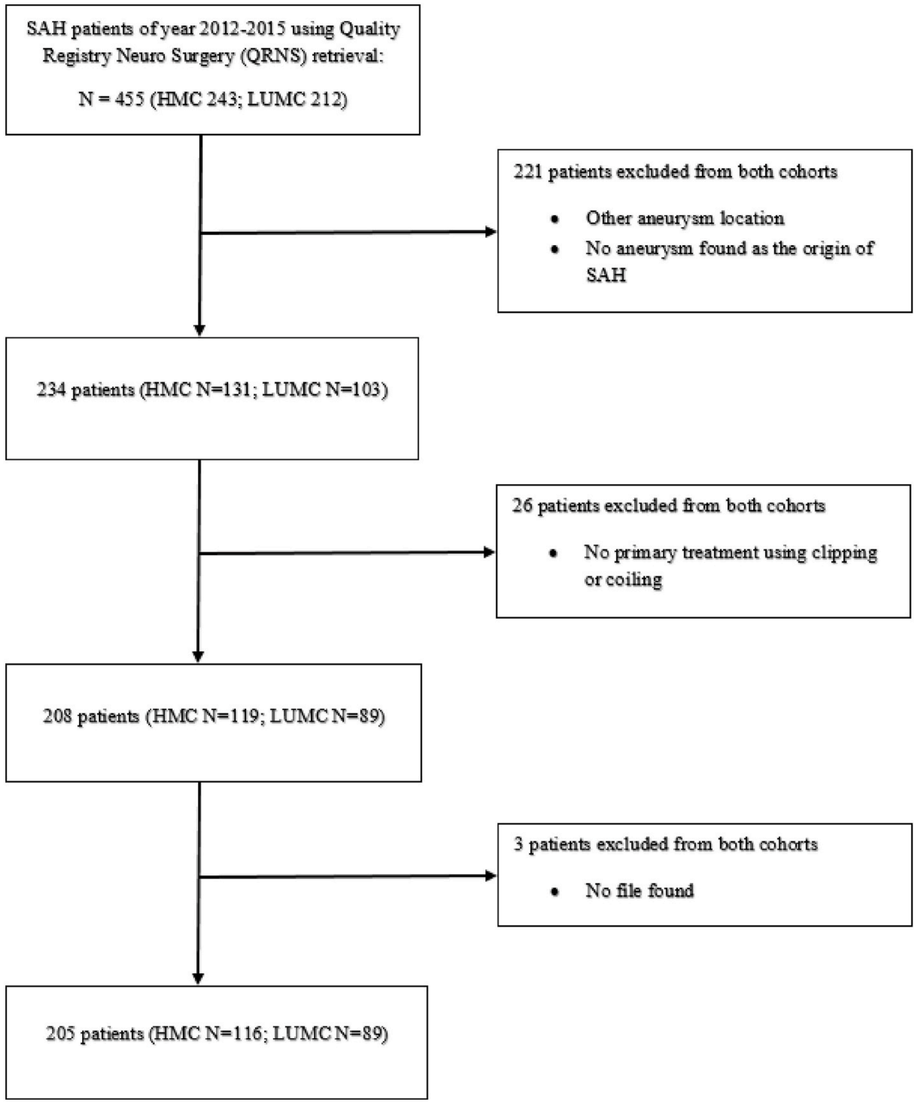

Fig. A.1. Flow diagram of exclusions.

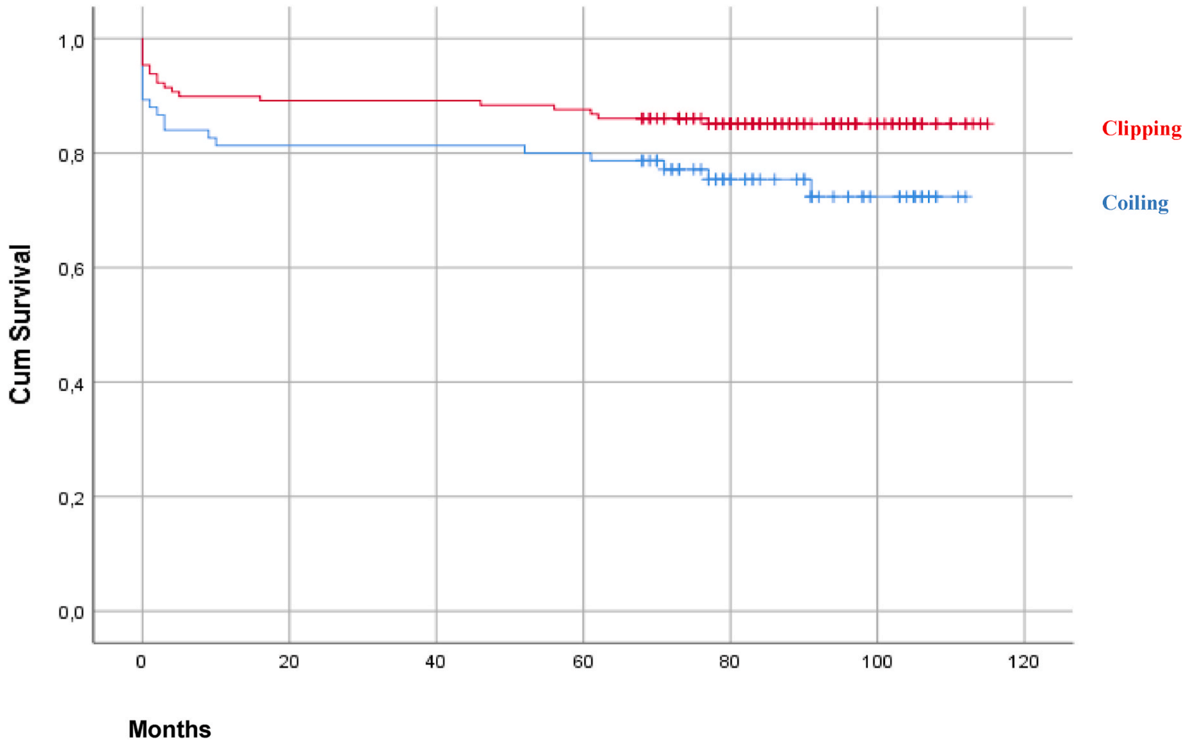

Fig. A.2. Survival analysis.

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