Interrater Agreement in the Radiologic Characterization of Ruptured Intracranial Aneurysms Based on Computed Tomography Angiography

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OBJECTIVE: **To determine interrater agreement in the initial radiologic characterization of ruptured intracranial aneurysms based on computed tomography angiography (CTA) with special emphasis on the rater's level of experience.**

METHODS: **One junior and one senior rater of 5 high-volume neurovascular tertiary centers evaluated anonymized CTA images of 30 consecutive patients with aneurysmal subarachnoid hemorrhage. Each rater described location, side, size, and morphology in a standardized manner. Interrater variability was analyzed using intraclass correlation and Fleiss' kappa analysis.**

RESULTS: **There was a high level of agreement for location (κ = 0.76, 95% confidence interval [CI] 0.74–0.79), side (κ = 0.95, CI 0.91–0.99), maximum diameter (intraclass correlation coefficient [ICC] 0.81, CI 0.70–0.90), and dome (ICC 0.78, CI 0.66–0.88) of intracranial aneurysms. In contrast, a lower level of agreement was observed for aneurysms' neck diameter (ICC 0.39, CI 0.28–0.58), the presence of multiple aneurysms (κ = 0.35, CI 0.30–0.40), and aneurysm morphology (blister κ = 0.11, CI −0.05 to 0.07; fusiform κ = 0.54, CI 0.48–0.60; multilobular, κ = 0.39 CI 0.33–0.45). The interrater agreement in the senior rater group was greater than in the junior rater group.**

CONCLUSIONS: **Interrater agreement confirms the benefit of CTA as initial diagnostic imaging in ruptured intracranial aneurysms but not for aneurysm morphology and presence of multiple aneurysms. A trend towards greater interrater agreement between more experienced raters was noticed.**

INTRODUCTION

Computed tomography angiography (CTA) for the initial workup of aneurysmal subarachnoid hemorrhage (aSAH) has proven itself as a reliable and accurate diagnostic tool with a sensitivity for aneurysm detection of >90%.[1] Because CTA is a noninvasive, low-risk procedure that provides information not only about the aneurysms but also about the adjacent brain parenchyma and the extent of the SAH, it is used widely as the primary diagnostic and preoperative planning tool in most patients with SAH.[2,3]

Although digital subtraction angiography (DSA) usually is considered the gold standard to determine intracranial aneurysm (IA) morphology, some authors have stated the additional value of CTA over DSA in demonstrating IA morphology and the relationship to the surrounding vessels.[4-6] However, the radiologic assessment of IA is rater dependent and therefore interrater

Key words
- Aneurysm morphology
- Computed tomography angiography
- Interrater agreement
- Interrater reliability
- Neurovascular imaging
- Subarachnoid hemorrhage

Abbreviations and Acronyms
3D: 3-Dimensional
aSAH: Aneurysmal subarachnoid hemorrhage
CTA: Computed tomography angiography
DICOM: Digital Imaging and Communications in Medicine
DSA: Digital subtraction angiography
IA: Intracranial aneurysm
ICA: Internal carotid artery
PCom: Posterior communicating artery
PGY: Postgraduate year
Swiss SOS: Swiss study on aneurysmal subarachnoid hemorrhage

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differences can occur.[7] Although there is evidence concerning the interrater agreement when characterizing IAs with DSA, information regarding interrater agreement when characterizing ruptured IA based on CTA is scarce.[8-12] This information is important to obtain data homogeneity, especially in multicenter trials, where data collection is conducted in a decentralized fashion.

In daily clinical practice, interrater agreement for interpretation of CTA imaging is equally important. In case of an aSAH, a neurosurgical resident usually sees both the patient and the CTA first and then reports his or her interpretation to the attending. Characterizing a ruptured IA as uniformly as possible is therefore an important goal in the training of young neurosurgeons as well as among practitioners in different centers. No study has so far assessed the degree of agreement between residents and board-certified neurosurgeons when evaluating ruptured IA based on CTA.

The purpose of our study was therefore to determine interrater agreement in the radiologic characterization of ruptured IA based on initial CTA imaging and to assess agreement depending on the interpreter's level of experience.

MATERIAL AND METHODS

CTA Imaging Series and Raters

The studied cases consist of a consecutive cohort of patients with aSAH admitted to the Department of Neurosurgery at the University Hospital Zurich between January 2012 and September 2012. No selection was performed based on the quality of the images. The only exclusion criterion was absence of in-house CTA before aneurysm treatment. The study was covered by the ethical committee approval for the Swiss study on aneurysmal subarachnoid hemorrhage (Swiss SOS) trial in each participating center (under the supervision of the Geneva institutional review board no. 11–233R, NAC 11–085R). Swiss SOS is a nationwide, multicenter clinical study on patients with aSAH.[13]

CTA imaging data of all cases was anonymized and saved on a USB memory stick containing an integrated Digital Imaging and Communications in Medicine (DICOM) viewer capable of conducting all required measurements (iQ-VIEW PRO version 2.7.0; www.image-systems.biz). The complete dataset for each study was provided, including source images, CTA axial, sagittal, and coronal reconstructions, and maximum intensity projection as well as 3-dimensional (3D) volume reconstructions if available. All raters used exclusively the provided DICOM viewer to eliminate software-related differences in image evaluation between raters. The memory stick was send to each participating center, and images were evaluated independently and in a blinded fashion by a junior resident (1–5 years of training in neurosurgery) as well as by a board-certified neurosurgeon (minimum of 8 years of neurosurgical experience including residency) in the following locations: 1) University Hospital Zurich, 2) Cantonal Hospital Aarau, 3) University Hospital of Basel, 4) University Hospital Geneva, and 5) University Hospital Lausanne. Imaging evaluation was performed between April and August 2016 following a standardized approach with use of the predefined protocol of the Swiss SOS data collection.[13]

Variables

For this study, all raters evaluated 10 different aneurysm-specific characteristics. Each rater described the location of the ruptured IA (anterior cerebral artery; anterior communicating artery; anterior inferior cerebellar artery; basilar artery; internal carotid artery [ICA]; middle cerebral artery; superior cerebellar artery; posterior cerebral artery; posterior communicating artery [PCom]; posterior inferior cerebellar artery; vertebral artery), the side on which aneurysm was located (left/right/middle), and the presence of multiple aneurysms (yes/no). In case of multiple aneurysms, the rater selected one aneurysm that he or she assumed had been ruptured.

In addition, each rater measured the maximum diameter of the IA, dome, and neck in millimeter using the DICOM viewers integrated measuring tools. Because we aimed to analyze interrater agreement in IA morphology relevant for the Swiss SOS registry, only variables included in the SOS study protocol were recorded: blister (yes/no), fusiform (yes/no) or mycotic (yes/no) aneurysm type as opposed to saccular, as well as multilobular shape (yes/no). We deliberately did not give any instructions or definitions on how to analyze IA morphology and size measurement because we wanted to simulate a realistic clinical situation in which the neurosurgeon had to decide according to his/her best knowledge. For this subanalysis of interrater agreement in IA morphology and size measurements, we had to exclude all cases in which at least one rater evidently evaluated a wrong aneurysm based on his/her specifications on IA location and presence of additional aneurysms (Supplementary Figure 1). This was the case in 7 patients (70/230 ratings).

Statistical Analysis

To determine interrater agreement in diameter measurements, we calculated the intraclass correlation coefficient in a 2-way random effect model set for absolute agreement. For aneurysms location, side, numbers of aneurysms, and aneurysm morphology interrater agreement was described with the Fleiss' kappa analysis. All kappa values were interpreted dependent on the criteria of Landis and Koch[14]: a value of 0.99–0.81 indicates almost-perfect agreement; 0.61–0.80, substantial agreement; 0.41–0.60, moderate agreement; 0.21–0.40, fair agreement; and 0–0.20, slight agreement. All statistical analysis was performed with SPSS software, Version 23.0.0.0 (IBM Corp., Armonk, New York, USA).

RESULTS

Patient characteristics for the 30 cases are provided in Table 1. They represent a typical cohort of patients with aSAH, with a mean age of 55 years, a predominance of female sex, and aneurysms in the anterior circulation.[15] In total, 10 raters from 5 neurosurgical departments in Switzerland participated in the study. The junior rater group included neurosurgical residents with a median neurosurgical experience of 3.5 years (range postgraduate year [PGY] 1–5), and the senior rater group included board-certified neurosurgeons with a median neurosurgical experience of 12 years (range 8–20 years).

Interrater agreement on aneurysm location, aneurysm side, numbers of aneurysms, and aneurysm morphology including blister, fusiform and mycotic aneurysm type, and multilobular

Table 1. Patient Characteristics

Mean age, years	55
Sex, male/female	7/23
Aneurysm location	
ACom	8
PCom	8
MCA	6
ICA	4
PCA	1
SCA	1
BA	1
VA	1
ACA	0
AICA	0
PICA	0
Circulation	
Anterior	26
Posterior	4

ACom, anterior communicating artery; PCom, posterior communicating artery; MCA, middle cerebral artery; ICA, internal carotid artery; PCA, posterior cerebral artery; SCA, superior cerebellar artery; BA, basilar artery; VA, vertebral artery; ACA, anterior cerebral artery; AICA, anterior inferior cerebellar artery; PICA, posterior inferior cerebellar artery.

Table 2. Interrater Agreement Between All Raters

		Agreement	95% Confidence Interval	*P* Value
Fleiss' Kappa				
Aneurysm location	0.76	Substantial	0.736–0.786	<0.05
Multiple aneurysms	0.35	Fair	0.301–0.399	<0.05
Aneurysm side*	0.95	Near complete	0.907–0.993	<0.05
ICC				
Aneurysm size*				
Maximum diameter	0.81	Near complete	0.695–0.900	<0.05
Dome size	0.78	Substantial	0.660–0.880	<0.05
Neck size	0.39	Fair	0.247–0.588	<0.05
Fleiss' Kappa				
Aneurym morphology*				
Blister	0.11	Slight	−0.050 to 0.072	0.71
Fusiform	0.54	Moderate	0.479–0.601	<0.05
Multilobular	0.39	Fair	0.330–0.451	<0.05
Mycotic	No variation			

ICC, intraclass correlation coefficient.
*In 23 of 30 aneurysms; 7 cases were excluded in the analysis because at least one rater evaluated the wrong aneurysm.

shape are provided in Table 2. We found a substantial to almost-perfect agreement for aneurysm location and aneurysm side. In contrast, only slight-to-moderate agreement was observed for numbers of aneurysms and aneurysm morphology. Table 2 also shows the results for the interrater agreement in size measurements, including maximum diameter, dome, and neck size. Although there was substantial to almost-perfect agreement in maximum diameter and dome size, there was only moderate agreement in neck size between the raters. No aneurysm was found in only 2 of 300 ratings (<1%).

Table 3 provides the interrater agreement divided into groups of junior and senior raters. Although there was a generally greater agreement between the senior raters compared with the junior raters, the confidence intervals ($\alpha = 0.05$) of reliabilities for the 3 groups were overlapping, indicating that they do not significantly differ from each other (Figures 1 and 2).

DISCUSSION

This study reveals that agreement between neurosurgeons in the radiologic characterization of ruptured IAs varies between parameters and between the experience of the raters. Although we observed an overall substantial to near-complete agreement in aneurysm location, side, maximum diameter, and dome diameter, there was a distinctive lower level of agreement concerning other characteristics, such as the size of aneurysm neck, the presence of additional unruptured aneurysms, as well as aneurysm morphology, such as blister or fusiform subtype and multilobular morphology. This trend was reinforced by our subanalysis, in which we evaluated senior and junior raters separately.

Analyzing the overall substantial interrater variability for aneurysm location in detail, we observed the greatest level of disagreement in PCom aneurysms. Because most deviating evaluations in these cases stated an ICA origin instead of PCom, this phenomenon might be explained partly by different perceptions of the parent vessel in aneurysms arising from the junction area of the 2 vessels. Particularly high disagreement concerning aneurysm location was observed in one case (Figure 3). In this rare case of a complex basilar trunk aneurysm that incorporated the basilar–anterior inferior cerebellar artery junction, CTA might be inferior to DSA because of a lower spatial resolution.[3] Another explanation could be that the automatic dual-energy bone-removal technique that was used in most of our cases is known to restrict 3D visualization by overprojecting bones in the area of the skull base.[2,16,17] Therefore, by analyzing only maximum intensity projection and volume-rendering techniques, images derived from the automatic bone-removal technique instead of the source images could lead to misinterpretation, especially of the vessel anatomy in the cavernous/paraclinoid segments of the ICA and the posterior fossa close to the skull base, leading to false-positive findings.

For the purpose of simulating a realistic emergency situation in clinical routine, we elected not to provide the rater with any

Table 3. Interrater Agreement for Junior and Senior Raters

	Junior Rater			Senior Rater		
		95% CI	*P* Value		95% CI	*P* Value
Fleiss' Kappa						
Aneurysm location	0.713	0.661—0.765	<0.05	0.774	0.721—0.826	<0.05
Numbers of aneurysms	0.356	0.249—0.464	<0.05	0.263	0.160—0.366	<0.05
Aneurysm side*	0.949	0.856—1.039	<0.05	0.947	0.855—1.039	<0.05
ICC						
Aneurysm size*						
Maximum diameter	0.752	0.573—0.876	<0.05	0.841	0.719—0.922	<0.05
Dome size	0.762	0.625—0.874	<0.05	0.773	0.617—0.884	<0.05
Neck size	0.248	0.079—0.479	<0.05	0.498	0.311—0.697	<0.05
Fleiss' Kappa						
Aneurym morphology*						
Blister	−0.043	−0.17 to 0.083	0.501	−0.009	−0.138 to 0.120	0.89
Fusiform	0.459	0.333—0.586	<0.05	0.610	0.480—0.739	<0.05
Multilobular	0.348	0.219—0.478	<0.05	0.402	0.273—0.532	<0.05
Mycotic	No variation			No variation		

CI, confidence interval; ICC, intraclass correlation coefficient.
*In 23 of 30 aneurysms; 7 cases were excluded in the analysis because at least one rater evaluated the wrong aneurysm.

advanced imaging tools. It is conceivable that the use of advanced software tools, giving the possibility of creating one's own 3D volume-rendering techniques, could have resulted in greater interrater agreement. Moreover, although the raters were free to use different images, planes, and viewing angles, this freedom could have led to divergent size measurements. This is especially true in the measurement of neck size, which is known to be highly dependent on the viewing angle and could explain the lower degree in interrater agreement compared with maximum aneurysms size and dome size.[8] Larrabide et al.[18] published an automated process of isolating and quantifying IA based on 3D rotational angiography that is able to reduce the inherent intra- and interobserver variability of manual analysis. Although this method is promising, it is yet limited to simple saccular aneurysms and is not widely available.

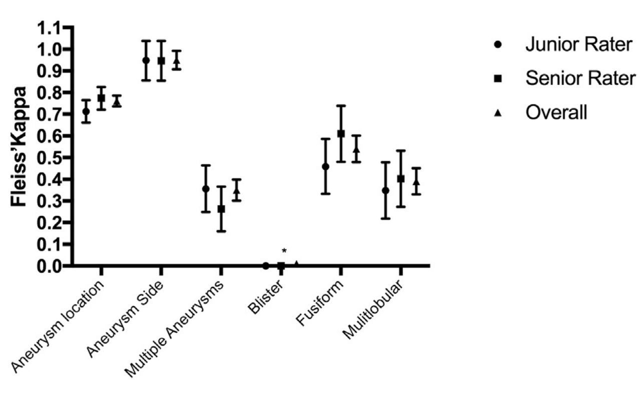

Figure 1. Comparison of interrater reliability. Fleiss' kappa values and corresponding confidence intervals at $\alpha = 0.05$ (confidence interval, represented as *error bars*) for the junior rater group, senior rater group and overall agreement ($P < 0.05$). *Not significant.

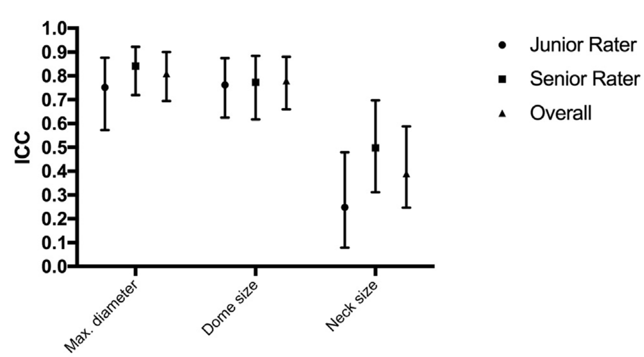

Figure 2. Comparison of interrater reliability. Intraclass correlation coefficients (ICCs) and corresponding confidence intervals at $\alpha = 0.05$ (confidence interval, represented as *error bars*) for the junior rater group, senior rater group and overall agreement ($P < 0.05$).

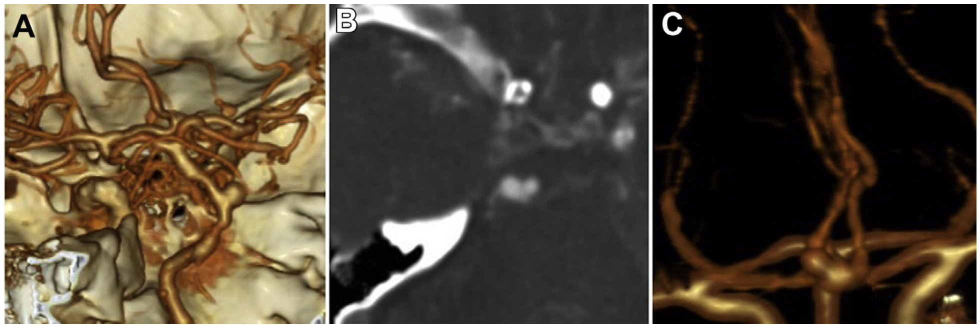

Figure 3. (**A**) Computed tomography angiogram (CTA) volume-rendering technique (VRT) reconstruction and (**B**) CTA axial plane images obtained in a case with high interrater disagreement over a complex broad-based aneurysm on the junction of basilar (BA) and anterior inferior cerebellar artery incorporating the 2 vessels. In addition, stenosis of right internal carotid artery (ICA) and right proximal right BA with brain perfusion supplied over the left ICA and BA. (**C**) VRT reconstruction image showing an anterior communicating artery with perfect agreement over the location of the aneurysm.

Although the variable "multilobular" had a comparatively high prevalence in our cohort, it showed only a fair agreement between raters. In contrast, when interpreting the interrater agreement for the variable "fusiform," one has to bear in mind that Fleiss' kappa is limited and sensitive to extreme distribution.[19] Although for the variable "fusiform," overall kappa ($\kappa = 0.54$) showed moderate agreement, only 15 of 230 (6.5%) of all ratings deviated from the consensus. Because kappa calculates the agreement beyond chance, if the prevalence of a feature like fusiform is low, there is a lower heterogeneity between cases, and the possible agreement beyond chance becomes high in advance. For methodologic reasons, small disagreement between raters can therefore produce low kappa values and oblige us to interpret kappa values with caution.

In the subanalysis evaluating interrater agreement for junior or senior raters separately, we found a slightly greater agreement in the senior rater group as expected. Although this difference was not statistically significant and may have occurred by chance, it could, however, have clinical relevance. This observation is most likely explained by the mean difference of 8.5 years in clinical experience in interpreting CTA images between the 2 groups. Pedersen et al.[20] described an increase in sensitivity from 88% to 94% for the detection of aneurysms after 1 year experience in a cohort of 162 patients.

It is conceivable that there is a learning curve and an increasing uniformity not only in the detection but also in the characterization of IA along training. The range of experience among our junior raters were relatively wide. Two of five junior raters had experience ranging between PGY 1 and 2, whereas the others showed more than 3.5 years of experience in neurosurgery. To ensure a representative number of raters within each group, we did not further subdivide residents based on their PGY. However, we feel that the PGY distribution within our junior rater group corresponds well with daily clinical practice in which young residents report their interpretation of an emergency CTA to the attending and also may be involved in data collection in the setting of multicenter trials.

Interestingly, despite including neurosurgeons at the beginning of their residency in the analysis, we could show a relatively high interrater agreement on basic radiologic characteristics. White et al.[21] showed that neuroradiologists had better sensitivity and agreement in the detection of aneurysms based on different imaging techniques when compared with other observers. However, this difference did not reach statistical significance, and the number of raters was limited to only one participating neurosurgeon. Although only one of our raters (D.Z.) had a formal training in imaging analysis, the question remains whether the inclusion of neuroradiologists would have shown different results.

The following limitations of our study must be mentioned. First, we analyzed a limited number of morphologic variables and did not consider other important variables, such as the presence of a daughter sac, intra-aneurysmal thrombosis, and intra- or peri-aneurysmal calcification. Furthermore, for reasons of feasibility, we limited our study to a number of 30 cases. Although one could criticize the rather small sample size, it proved to be sufficient, with 10 different raters to find robust and significant effects for all variables that are not infrequent. By including only cases with a known ruptured IA, we were not able to make any assumptions on a rater's sensitivity in the detection of IA based on CTA. However, this question has already been discussed extensively in previous publications.[1,22,23] Imaging quality was not evaluated or controlled for, and advanced software tools were not provided to the raters. Because image quality was rather low in some of the emergency cases, the level of agreement could have been potentially greater for nonurgent situations, such as the evaluation of unruptured IA. Finally, we did not analyze intrarater variability for aneurysms characterization in a test—retest scenario.

However, to the best of our knowledge, this is the first study to systematically assess interrater agreement in the radiologic description of ruptured IAs between a rather large number of neurosurgeons with different levels of experience and educational backgrounds. In doing so, we intended to identify potential sources of error when collecting data in multicenter trials and data repositories like the Swiss SOS, Subarachnoid Hemorrhage International Trialists, and others.[13,24] Moreover, high interrater agreement is crucial in longitudinal studies evaluating IA over time.[25] We were able to show that there is a high level of agreement concerning aneurysms location, aneurysm size, and dome size, when data collection is based on CTA. However, we identified a relatively high degree in rater dependence for aneurysms neck size, multiple aneurysms, and aneurysm morphology, with slightly greater agreement in the senior rater group. Radiologic data incorporated in the Swiss SOS database are drawn from the whole set of available imaging modalities, including DSA, magnetic resonance angiography, and CTA. These images are evaluated by at least 2 neuroradiologists, as well as the responsible junior and senior neurosurgeons participating at each site. The present data cannot give an estimate of the data quality found in the Swiss SOS. Considering the relatively high interrater disagreement identified for the more complex characteristics, especially aneurysm morphology, standardized methods to find consensus between conflicting statements seem important. In addition, uniform techniques and definitions on IA characteristics are likely to improve consistency in multicenter trials.

CONCLUSIONS

Basic radiologic characteristics including aneurysm location, side, and size had a high interrater agreement between neurosurgeons, confirming the benefit of CTA as initial diagnostic imaging in ruptured IAs. There was lower interrater agreement on more detailed characteristics, which are difficult to access with CTA only, including aneurysm morphology and the presence of multiple aneurysms. A trend towards greater interrater agreement between more experienced raters was present.

REFERENCES

1. Chappell ET, Moure FC, Good MC. Comparison of computed tomographic angiography with digital subtraction angiography in the diagnosis of cerebral aneurysms: a meta-analysis. *Neurosurgery*. 2003;52:624-631 [discussion: 630-631].

2. Dehdashti AR, Rufenacht DA, Delavelle J, Reverdin A, de Tribolet N. Therapeutic decision and management of aneurysmal subarachnoid haemorrhage based on computed tomographic angiography. *Br J Neurosurg*. 2003;17:46-53.

3. Hoh BL, Cheung AC, Rabinov JD, Pryor JC, Carter BS, Ogilvy CS. Results of a prospective protocol of computed tomographic angiography in place of catheter angiography as the only diagnostic and pretreatment planning study for cerebral aneurysms by a combined neurovascular team. *Neurosurgery*. 2004;54:1329-1342.

4. Villablanca JP, Hooshi P, Martin N, Jahan R, Duckwiler G, Lim S, et al. Three-dimensional helical computerized tomography angiography in the diagnosis, characterization, and management of middle cerebral artery aneurysms: comparison with conventional angiography and intraoperative findings. *J Neurosurg*. 2002;97:1322-1332.

5. Anderson GB, Findlay JM, Steinke DE, Ashforth R. Experience with computed tomographic angiography for the detection of intracranial aneurysms in the setting of acute subarachnoid hemorrhage. *Neurosurgery*. 1997;41:522-527 [discussion: 527-528].

6. Pedicelli A, Desiderio F, Esposito G, Rollo M, Albanese A, Verdolotti T, et al. Three-dimensional rotational angiography for craniotomy planning and postintervention evaluation of intracranial aneurysms. *Radiol Med*. 2013;118:415-430.

7. Wostrack M, Mielke D, Kato N, Guhl S, Schmidt NO, Maldaner N, et al. Interobserver variability in the characterization of giant intracranial aneurysms with special emphasis on aneurysm diameter and shape. *Acta Neurochir (Wien)*. 2015;157:1859-1865.

8. Kucukay F, Okten RS, Tekiner A, Dagli M, Gocek C, Bayar MA, et al. Three-dimensional volume rendering digital subtraction angiography in comparison with two-dimensional digital subtraction angiography and rotational angiography for detecting aneurysms and their morphological properties in patients with subarachnoid hemor. *Eur J Radiol*. 2012;81:2794-2800.

9. Wong SC, Nawawi O, Ramli N, Abd Kadir KA. Benefits of 3D rotational DSA compared with 2D DSA in the evaluation of intracranial aneurysm. *Acad Radiol*. 2012;19:701-707.

10. Rezek I, Lingineni RK, Sneade M, Molyneux AJ, Fox AJ, Kallmes DF. Differences in the angiographic evaluation of coiled cerebral aneurysms between a core laboratory reader and operators: results of the cerecyte coil trial. *Am J Neuroradiol*. 2014;35:124-127.

11. Forbes G, Fox AJ, Huston J 3rd, Wiebers DO, Torner J. Interobserver variability in angiographic measurement and morphologic characterization of intracranial aneurysms: a report from the International Study of Unruptured Intracranial Aneurysms. *AJNR Am J Neuroradiol*. 1996;17:1407-1415.

12. Suh SH, Cloft HJ, Huston J 3rd, Han KH, Kallmes DF. Interobserver variability of aneurysm morphology: discrimination of the daughter sac. *J Neurointerv Surg*. 2016;8:38-41.

13. Schatlo B, Fung C, Fathi AR, Sailer M, Winkler K, Daniel RT, et al. Introducing a nationwide registry: The Swiss study on aneurysmal subarachnoid haemorrhage (Swiss SOS). *Acta Neurochir (Wien)*. 2012;154:2173-2178.

14. Landis JR, Koch GG. The measurement of observer agreement for categorical data. *Biometrics*. 1977;33:159-174.

15. Hamdan A, Barnes J, Mitchell P. Subarachnoid hemorrhage and the female sex: analysis of risk factors, aneurysm characteristics, and outcomes. *J Neurosurg*. 2014;121:1367-1373.

16. Romijn M, Gratama van Andel HAF, van Walderveen MA, Sprengers ME, van Rijn JC, van Rooij WJ, et al. Diagnostic accuracy of CT angiography with matched mask bone elimination for detection of intracranial aneurysms: comparison with digital subtraction angiography and 3D rotational angiography. *AJNR Am J Neuroradiol*. 2008;29:134-139.

17. Hope JKA, Wilson JL, Thomson FJ. Three-dimensional CT angiography in the detection and characterization of intracranial berry aneurysms. *Am J Neuroradiol*. 1996;17:439-445.

18. Larrabide I, Cruz Villa-Uriol M, Cárdenes R, Pozo JM, Macho J, San Roman L, et al. Three-dimensional morphological analysis of intracranial aneurysms: a fully automated method for aneurysm sac isolation and quantification. *Med Phys*. 2011;38:2439-2449.

19. Tooth LR, Ottenbacher KJ. The kappa statistic in rehabilitation research: an examination. *Arch Phys Med Rehabil*. 2004;85:1371-1376.

20. Pedersen HK, Bakke SJ, Hald JK, Skalpe IO, Anke IM, Sagsveen R, et al. CTA in patients with acute subarachnoid haemorrhage. A comparative study with selective, digital angiography and blinded, independent review. *Acta Radiol*. 2001;42:43-49.

21. White PM, Wardlaw JM, Lindsay KW, Sloss S, Patel DKB, Teasdale EM. The non-invasive detection of intracranial aneurysms: are neuroradiologists any better than other observers? *Eur Radiol*. 2003;13:389-396.

22. Jayaraman MV, Mayo-Smith WW, Tung GA, Haas RA, Rogg JM, Mehta NR, et al. Detection of intracranial aneurysms: multi-detector row CT angiography compared with DSA. *Radiology*. 2004;230:510-518.

23. Van Gelder JM, Hoh BL, Ogilvy CS, Solomon RA, Batjer HH. Computed tomographic angiography for detecting cerebral aneurysms: implications of aneurysm size distribution for the sensitivity,

specificity, and likelihood ratios. *Neurosurgery*. 2003;53:597-606.

24. Macdonald RL, Jaja B, Cusimano MD, Etminan N, Hanggi D, Hasan D, et al. SAHIT Investigators—on the outcome of some subarachnoid hemorrhage clinical trials. *Transl Stroke Res*. 2013;4:286-296.

25. Juvela S, Poussa K, Lehto H, Porras M. Natural history of unruptured intracranial aneurysms: a long-term follow-up study. *Stroke*. 2013;44:2414-2421.

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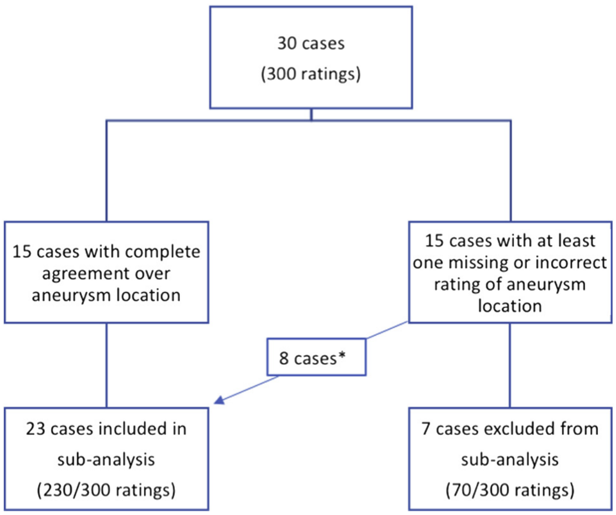
SUPPLEMENTARY DATA



Supplementary Figure 1. Flow chart of case inclusion in size and morphology subanalysis. *Reinclusion of cases if all deviating raters stated an aneurysm origin adjacent to the majority of votes (e.g., internal carotid artery and posterior communicating artery or anterior communicating artery and anterior cerebral artery origin) and no second aneurysm, indicating that all raters evaluated the same aneurysm and solely disagreed over the vessel of origin.