

Unruptured intracranial aneurysms: Current perspectives with consideration of small lesions

Christopher S. Ogilvy, M.D.

Director, Endovascular and Operative Neurovascular
Surgery

BIDMC Brain Aneurysm Institute

Professor of Neurosurgery, Harvard Medical School
Boston, Massachusetts

Disclosures

- None relative to this talk
- Medtronic DSMB Embolize trial
- Consultant- CereVasc
- Performed ‘open’ neurovascular surgery until 2008 – Did a fellowship at Univeristy of Buffalo

FORMATION OF INTRACRANIAL ANEURYSMS

- Usually occur at the bifurcation of vessels
- There is most likely a predisposition for aneurysm formation (20-25% familial)
- Local hemodynamics contribute to formation
- Other factors (smoking, hypertension, connective tissue disorders) seem additive to formation of aneurysms

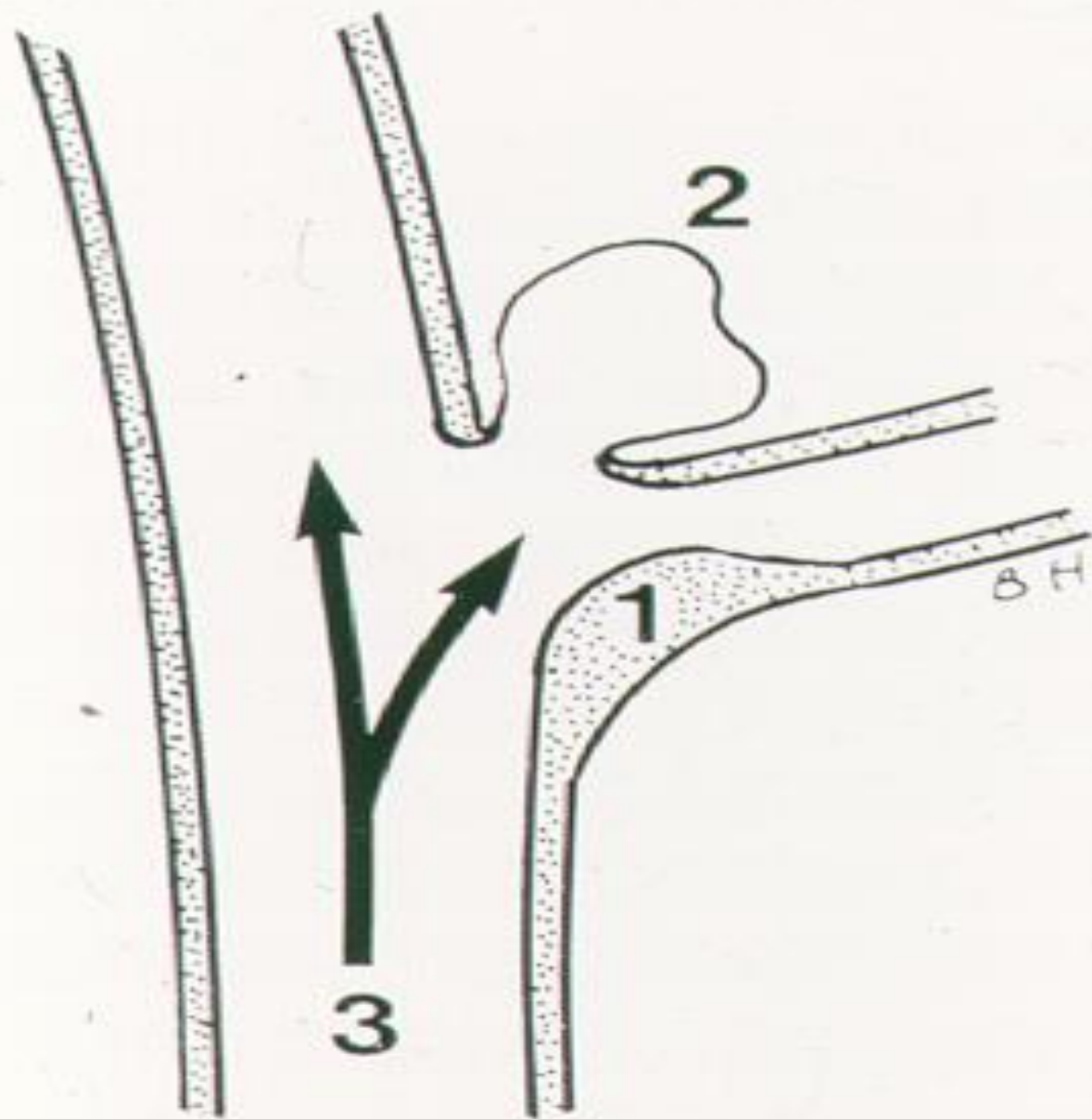
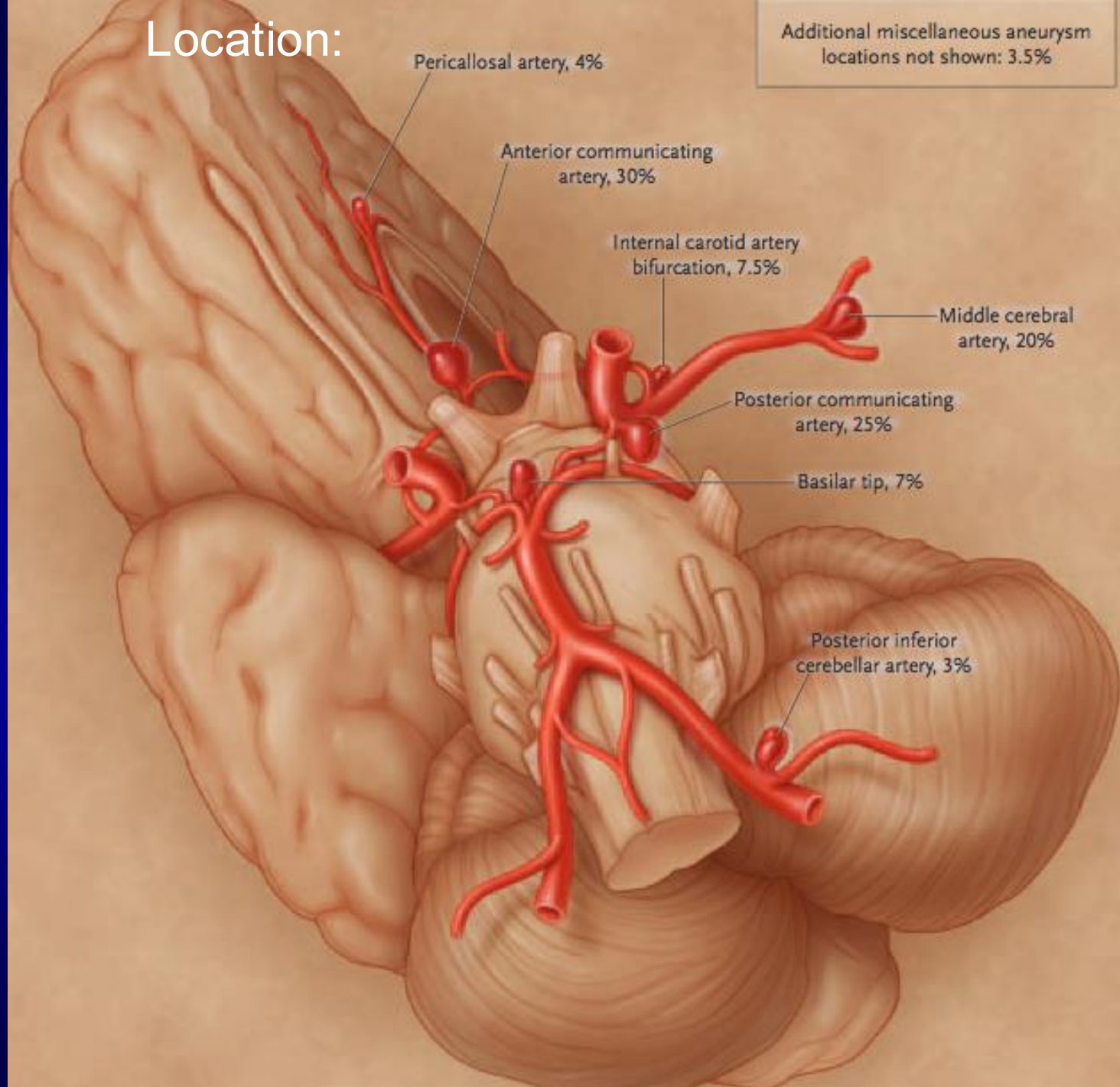


FIGURE 30-1. Pathogenesis of berry aneurysm. 1. Intimal cushion; 2. aneurysm; 3. direction of blood flow.

CIRCLE OF WILLIS

Location:

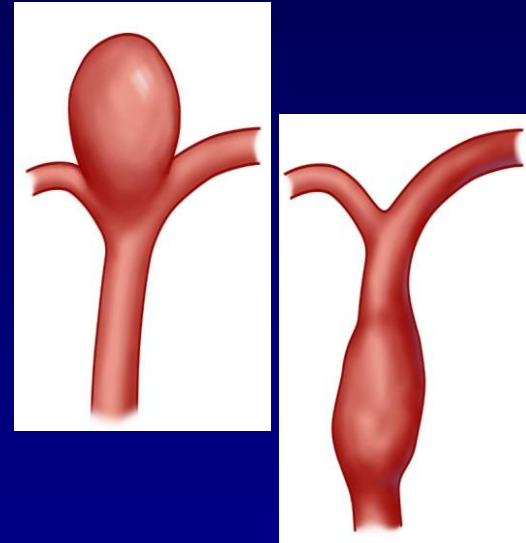
Additional miscellaneous aneurysm locations not shown: 3.5%





Classification

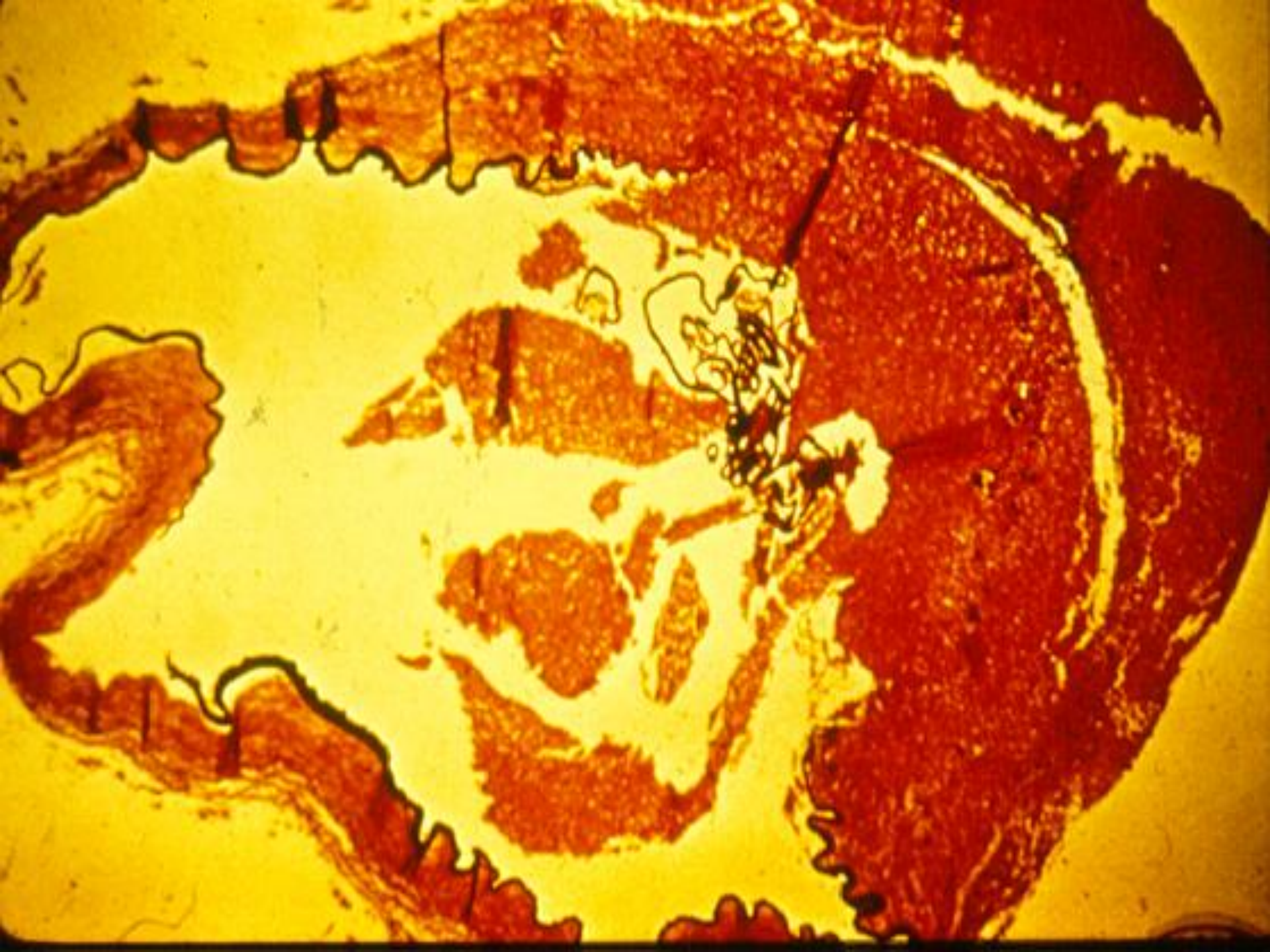
- **Saccular (Berry)**
- **Fusiform/Dissecting**
- **Mycotic**
- **Traumatic**



Saccular aneurysms are sporadic and acquired (not congenital)

SUBARACHNOID HEMORRHAGE





How common are
unruptured aneurysms?

INTRACRANIAL ANEURYSMS

- Prevalence at autopsy: 2-5%
- 2-5 million Americans have unruptured cerebral aneurysm

With advances in neuroimaging, more unruptured aneurysms are being detected

- For mild or moderate head injury
- For cranial scanning in tumor patients
- Headaches (all types)
- Virtually any neurologic symptom or sign

Trends in asymptomatic unruptured intracranial aneurysm detection

2024 Feb 1;94(2):297-306



OPEN

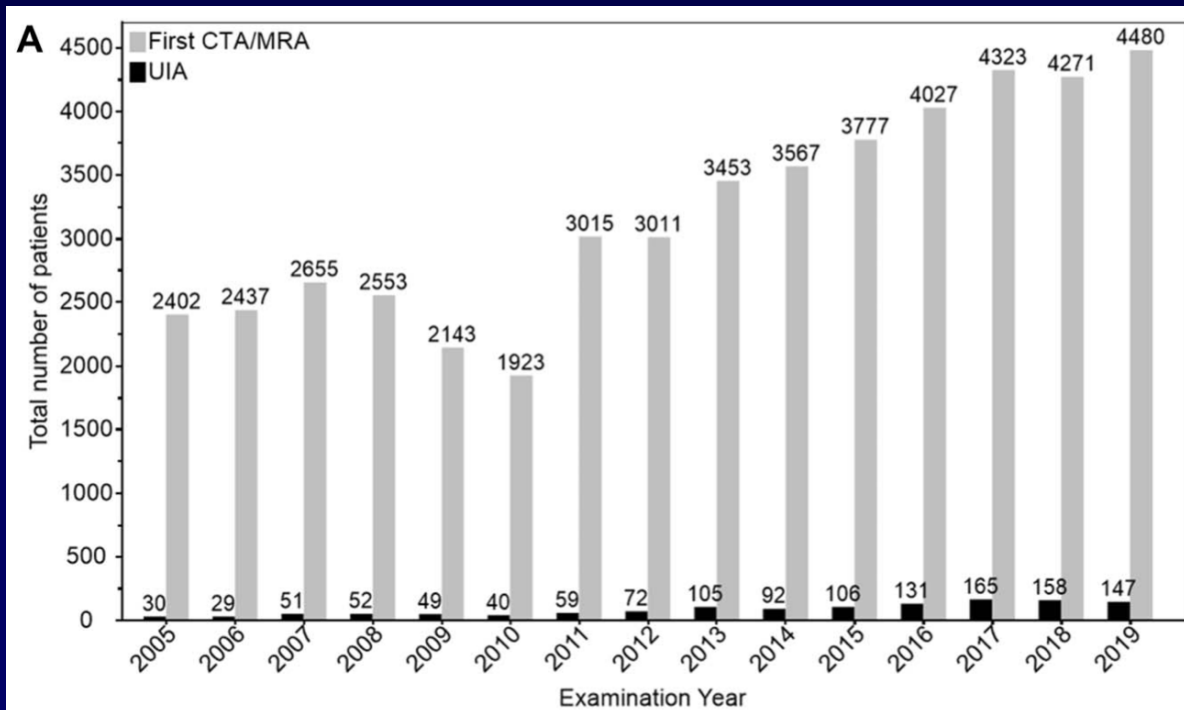
Detection Rates and Trends of Asymptomatic Unruptured Intracranial Aneurysms From 2005 to 2019

Dan Laukka, MD, PhD ^{*,†}, Juri Kivelev, MD, PhD ^{*,†}, Melissa Rahi, MD, PhD ^{*,†}, Tero Vahlberg, MSc ^{‡,§}, Jooa Paturi, MD ^{*,†},
Jaakko Rinne, MD, PhD ^{*,†}, Jussi Hirvonen, MD, PhD ^{||¶}

^{*}Department of Neurosurgery, Neurocenter, Turku University Hospital, Turku, Finland; [†]Clinical Neurosciences, University of Turku, Turku, Finland; [‡]Department of Clinical Medicine, Biostatistics, University of Turku, Turku, Finland; ^{||}Department of Radiology, Turku University Hospital and University of Turku, Turku, Finland; [¶]Department of Radiology, University of Tampere, Tampere, Finland; [§]Department of Biostatistics, University of Turku and Turku University Hospital, Turku, Finland

Trends in aUIA detection

- number of first CTA/MRA examinations increased significantly over time
- UIA detection rates increased significantly over time
- Increase in UIA detection rates over time was most profound in older patients: 60–69 years (RR, **1.29**; 95% CI, 1.01-1.63), 70–79 years (RR, **1.71**; 95% CI, 1.30-2.25), and >79 years (RR, **2.33**; 95% CI, 1.56-3.47) btw. 2010–2014 to 2015–2019



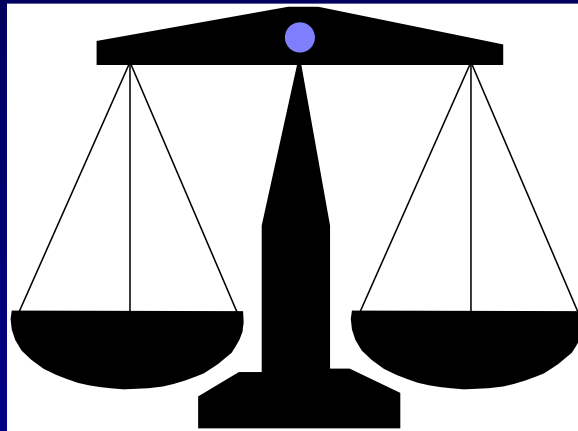
More small aUIAs are being detected over time

TABLE 3. Characteristics of Saccular UIA From First CTA or MRA in Different Periods: RR (95% CI) in 2015–2019 Compared With That in 2010–2014

Characteristics	Total	Period, y			RR (95% CI) 2015–2019 vs 2010–2014	P-value
		2005–2009	2010–2014	2015–2019		
Largest UIA—No.	1286	211	368	707	—	<.001
Size of the largest aneurysm—mean, mm (SD)	4.6 (3.3)	5.7 (4.4)	4.8 (3.5)	4.2 (2.7)	—	<.001
Distribution of the largest aneurysm—No. (%)						
1–2 mm	342 (26.6)	45 (21.3)	94 (25.5)	203 (28.7)	1.29 (0.97–1.74)	.08 ^b
3–4 mm	469 (36.5)	63 (29.9)	129 (35.1)	277 (39.2)	1.10 (0.85–1.43)	.47 ^b
5–6 mm	242 (18.8)	46 (21.8)	80 (21.7)	116 (16.4)	0.68 (0.49–0.94)	.02^b
7–9 mm	154 (12.0)	29 (13.7)	36 (9.8)	89 (12.6)	1.17 (0.79–1.77)	.42 ^b
≥10 mm	79 (6.1)	28 (13.3)	29 (7.9)	22 (3.1)	0.32 (0.18–0.58)	<.001^b
Proportion of <5 mm aneurysms—No. (%)	811 (63.1)	108 (51.2)	223 (60.6)	480 (67.9)	1.55 (1.18–2.03)	.002^b
Proportion of <7 mm aneurysms—No. (%)	233 (18.1)	57 (27.0)	65 (17.7)	111 (15.7)	1.30 (0.92–1.83)	.13 ^b
Multiple aneurysms—No. of patients (%)	239/1286 (18.5)	54/211 (16.9)	71/368 (19.5)	109/707 (15.6)	0.92 (0.66–1.27)	.61

Once an aneurysm is detected, the question for the neurovascular surgeon is whether to recommend treatment or observation of the aneurysm

Decision Making in Unruptured Aneurysm Treatment?



- Rupture Risk
- ISUIA Data
- UCAS
- Metanalysis
- PHASES score

- Treatment risk
- Endovascular
- Surgical

International Study of Unruptured Intracranial Aneurysms (I.S.U.I.A.)

N Engl J Med 1998;339:1725-33

ISUIA 2003 Retrospective Component

GROUP 1 (n = 1077)

**No history of SAH
from another aneurysm**

GROUP 2 (n = 615)

**History of SAH
from a different aneurysm
repaired successfully**

5-year Cumulative Rupture Rate

	<7 mm		7-12 mm	13-24 mm	≥25 mm
	Group 1	Group 2			
AC/MC/IC	0	1.5%	2.6%	14.5%	40%
Post-P comm	2.5%	3.4%	14.5%	18.4%	50%

- Predictors of rupture:
 - Size: 7-12 mm, RR 3.3;
 - Location (Tip of basilar, RR 2.3; P-comm, RR 2.1)

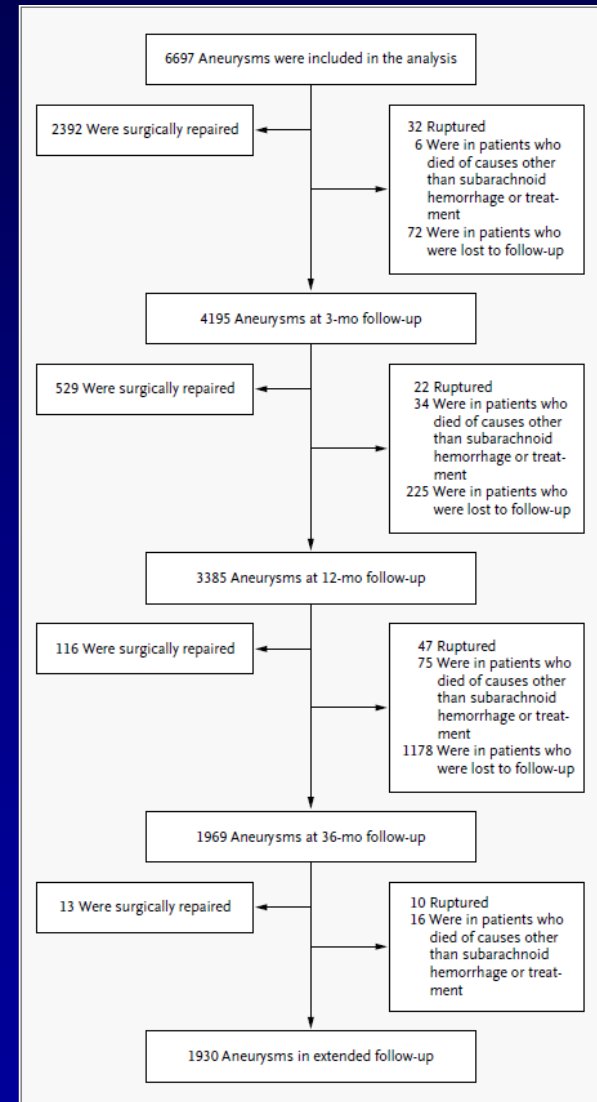
Unruptured Cerebral
Aneurysms in a
Japanese Cohort
(UCAS)- NEJM, 2012

The Unruptured Cerebral Aneurysm Study of Japan*

Hypothesis: Unruptured cerebral aneurysms of 5mm or more rupture at an annual rate of more than 0.5%

Methods:

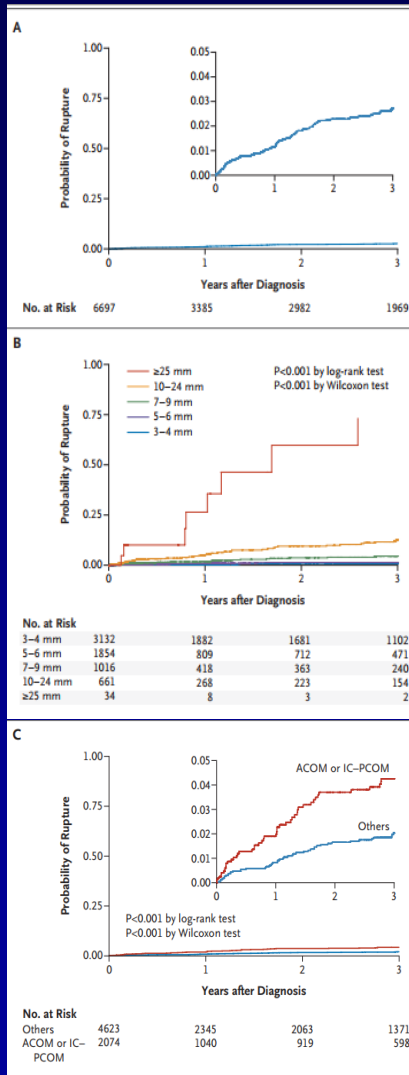
- 6413 patients >20 years of age with unruptured cerebral aneurysms >3mm identified; 5720 patients with 6697 aneurysms met eligibility criteria (fusiform and dissecting aneurysms were excluded)
- Follow-up data collected at 3, 12, and 36 months and at 5 and 8 years with clinical status assessed by mRS
- Data collection ended when the patient died or aneurysm ruptured (or the patient could no longer be followed)



*The UCAS Japan Investigators. NEJM 336(26):2474-2482, 2012.

The Unruptured Cerebral Aneurysm Study of Japan*

Probability of rupture:



Overall: 0.95% annual rate of rupture

Size

Location

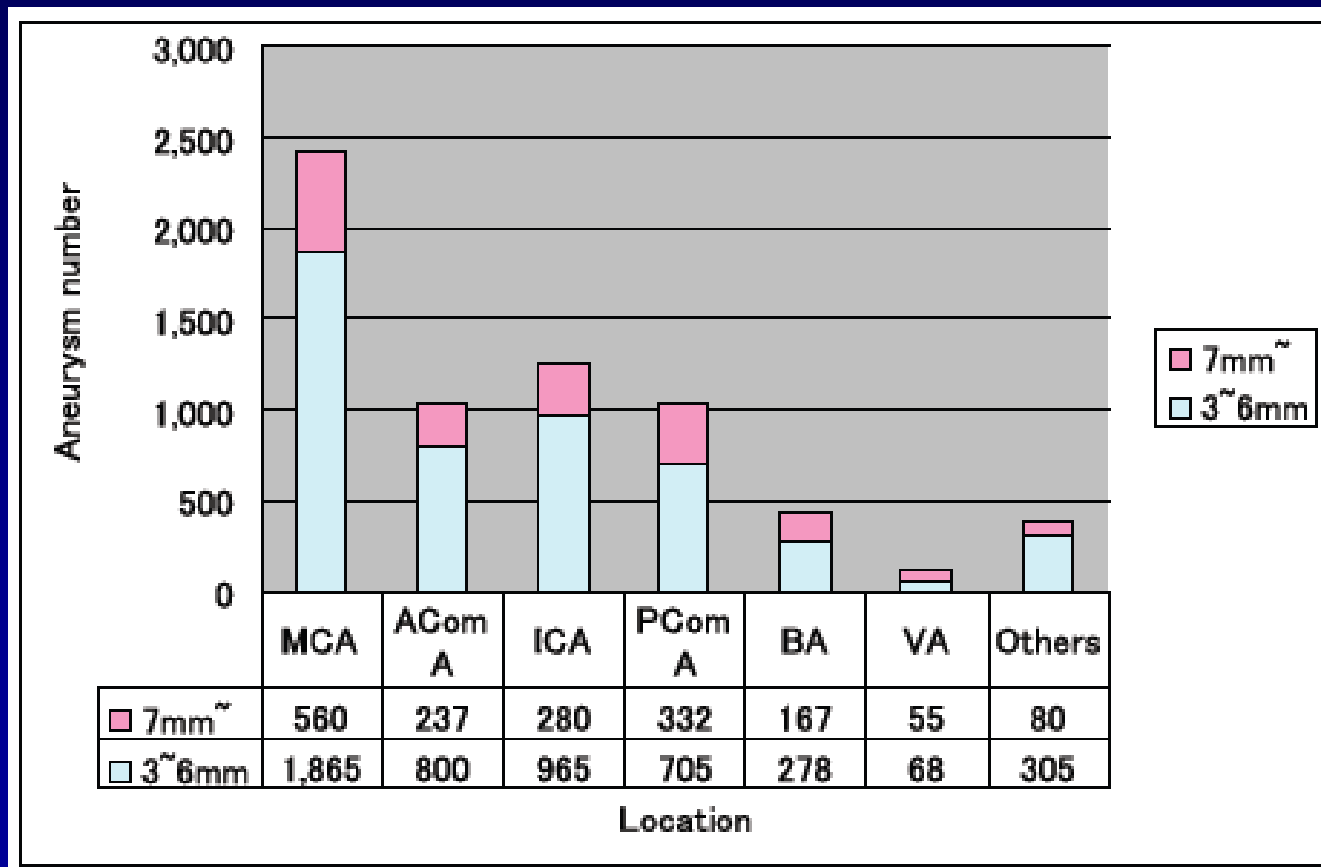
Table 3. Annual Rate of Rupture According to Size and Location of Aneurysm.

Location of Aneurysm	Rate of Rupture per Aneurysm per Year (95% CI)				
	3-4 mm	5-6 mm	7-9 mm	10-24 mm	≥25 mm
	<i>percent</i>				
Middle cerebral artery	0.23 (0.09-0.54)	0.31 (0.10-0.96)	1.56 (0.74-3.26)	4.11 (2.22-7.66)	16.87 (2.38-119.77)
Anterior communicating artery	0.90 (0.45-1.80)	0.75 (0.28-2.02)	1.97 (0.82-4.76)	5.24 (1.97-13.95)	39.77 (9.95-159.00)
Internal carotid artery	0.14 (0.04-0.57)	0	1.19 (0.30-4.77)	1.07 (0.27-4.28)	10.61 (1.49-75.3)
Internal carotid-posterior communicating artery	0.41 (0.15-1.10)	1.00 (0.37-2.66)	3.19 (1.66-6.12)	6.12 (1.66-6.13)	126.97 (40.95-393.68)
Basilar tip and basilar-superior cerebellar artery	0.23 (0.03-1.61)	0.46 (0.06-3.27)	0.97 (0.24-3.89)	6.94 (3.74-12.90)	117.82 (16.60-836.43)
Vertebral artery-posterior inferior cerebellar artery and vertebro-basilar junction	0	0	0	3.49 (0.87-13.94)	0
Other	0.78 (0.25-2.43)	1.37 (0.34-5.50)	0	2.81 (0.40-19.99)	0
Total	0.36 (0.23-0.54)	0.50 (0.29-0.84)	1.69 (1.13-5.93)	4.37 (3.22-5.93)	33.40 (16.60-66.79)

*The UCAS Japan Investigators. NEJM 336(26):2474-2482, 2012.

The Unruptured Cerebral Aneurysm Study of Japan*

Aneurysms:



*The UCAS Japan Investigators. NEJM 336(26):2474-2482, 2012.

The Unruptured Cerebral Aneurysm Study of Japan*

Patients/Results:

- Size, specific location, and presence of a daughter sac were independent risk factors affecting the risk of rupture
- All aneurysms >7mm were at a significantly increased risk of rupture
- Acomm and Pcomm but not posterior circulation aneurysms were at a significantly increased risk of rupture
- Women and patients with hypertension had an increased risk of rupture
- Prior SAH, smoking history, family history, and the presence of multiple aneurysms were not associated with risk of rupture

Table 2. Risk Factors Associated with Rupture of Cerebral Aneurysms.*

Risk Factor	Hazard Ratio (95% CI)	P Value
Female sex	1.54 (0.99–2.42)	0.05
Age ≥70 yr	1.21 (0.81–1.78)	0.34
Hypertension	1.41 (0.96–2.07)	0.08
Hyperlipidemia	0.54 (0.28–1.03)	0.06
Daughter sac	1.63 (1.08–2.48)	0.02
Largest dimension of aneurysm		
3–4 mm	Reference	
5–6 mm	1.13 (0.58–2.22)	0.71
7–9 mm	3.35 (1.87–6.00)	<0.001
10–24 mm	9.09 (5.25–15.74)	<0.001
≥25 mm	76.26 (32.76–177.54)	<0.001
Location of aneurysm		
Middle cerebral artery	Reference	
Anterior communicating artery	2.02 (1.13–3.58)	0.02
Internal carotid artery	0.43 (0.18–1.01)	0.05
Internal carotid–posterior communicating artery	1.90 (1.12–3.21)	0.02
Basilar tip and basilar–superior cerebellar artery	1.49 (0.78–2.83)	0.23
Vertebral artery–posterior inferior cerebellar artery and vertebrobasilar junction	0.68 (0.16–2.87)	0.60
Other	1.48 (0.61–3.60)	0.39

*The UCAS Japan Investigators. NEJM 336(26):2474-2482, 2012.

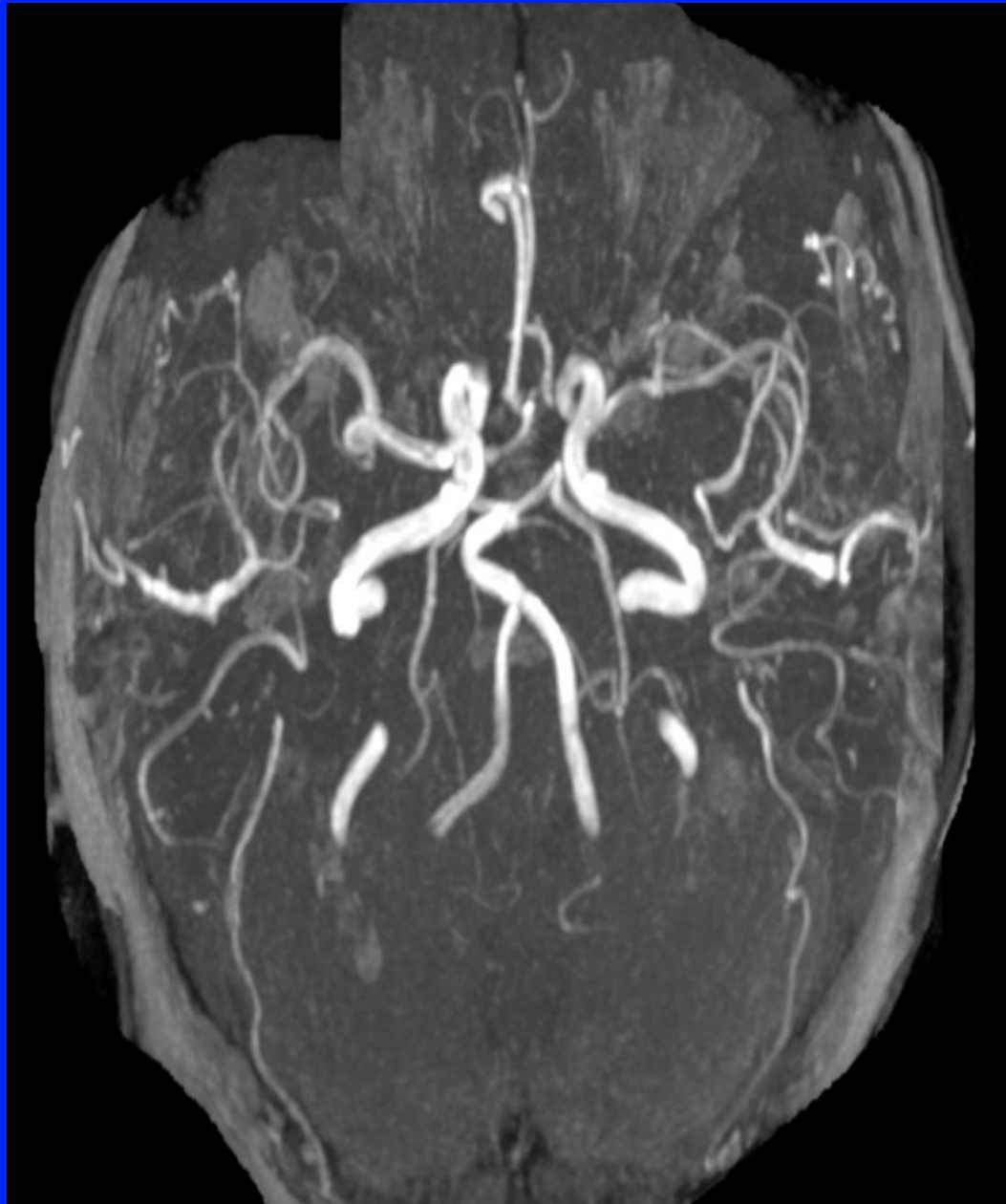
UCAS-We are starting to
see data of rupture in
unruptured aneurysms
stratified by size, site,
irregular shape

SIZE OF ANEURYSM- JUST
ONE FACTOR- shape also
important

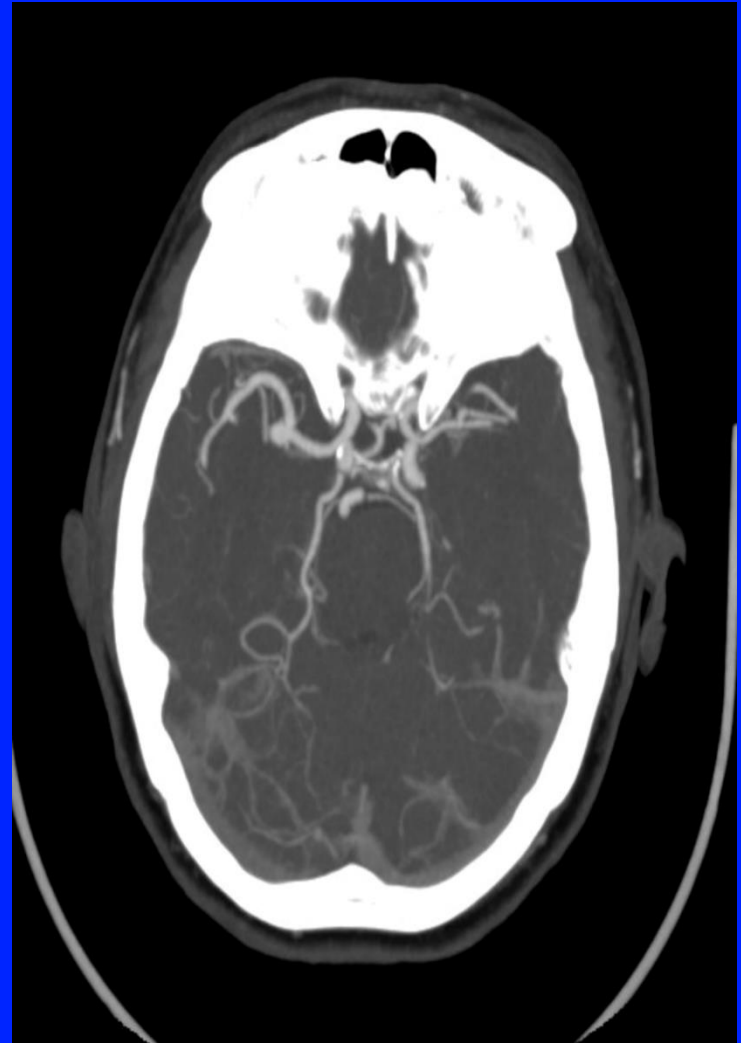
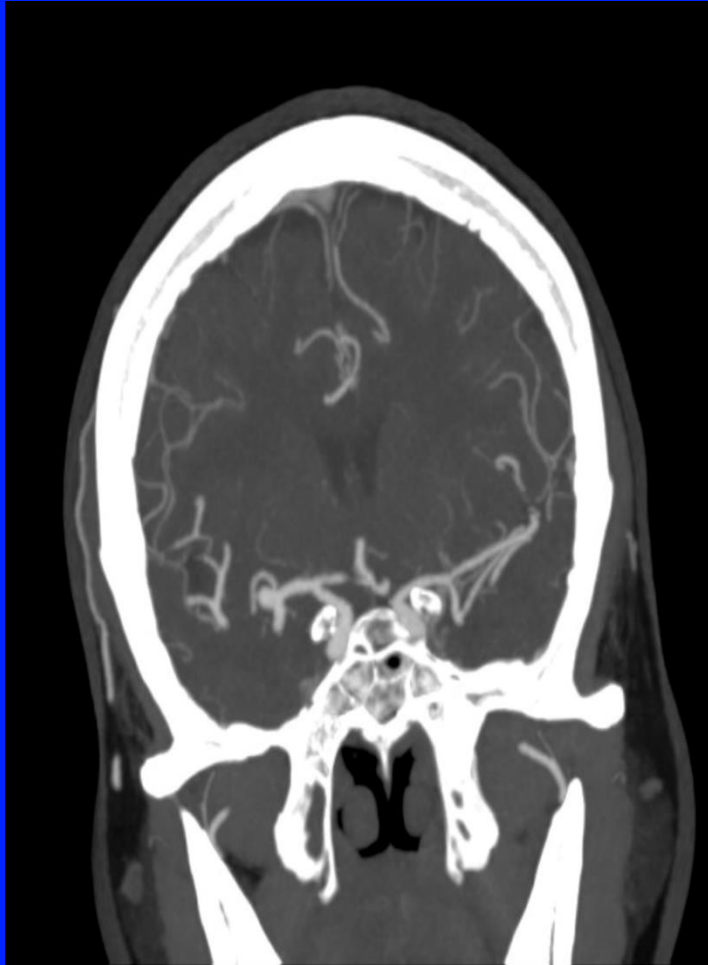
RECENT PATIENT

- 45 Y.O. woman with headaches
- MRI shows 5 mm MCA aneurysm

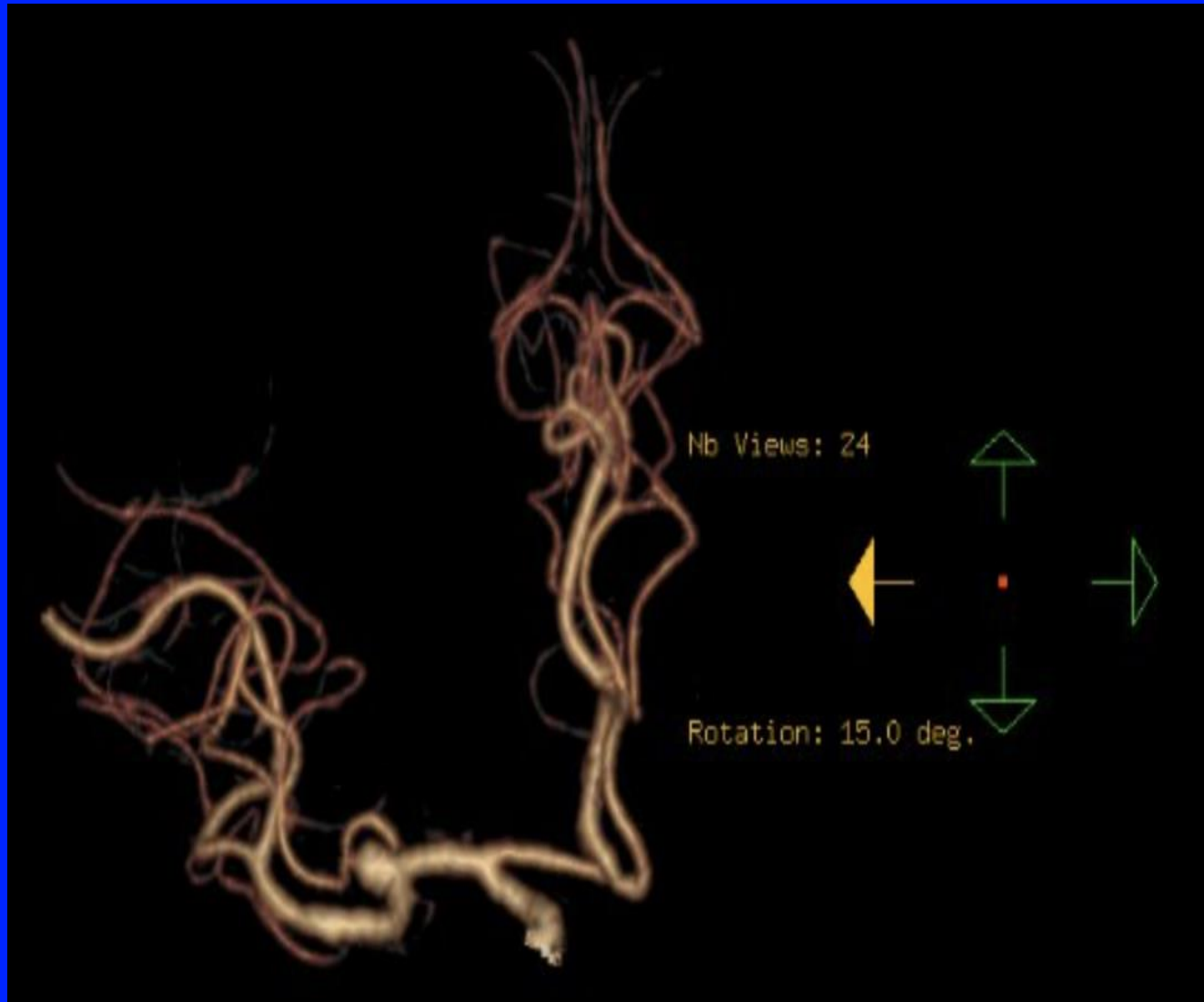
Unruptured MCA Aneurysm: MRA



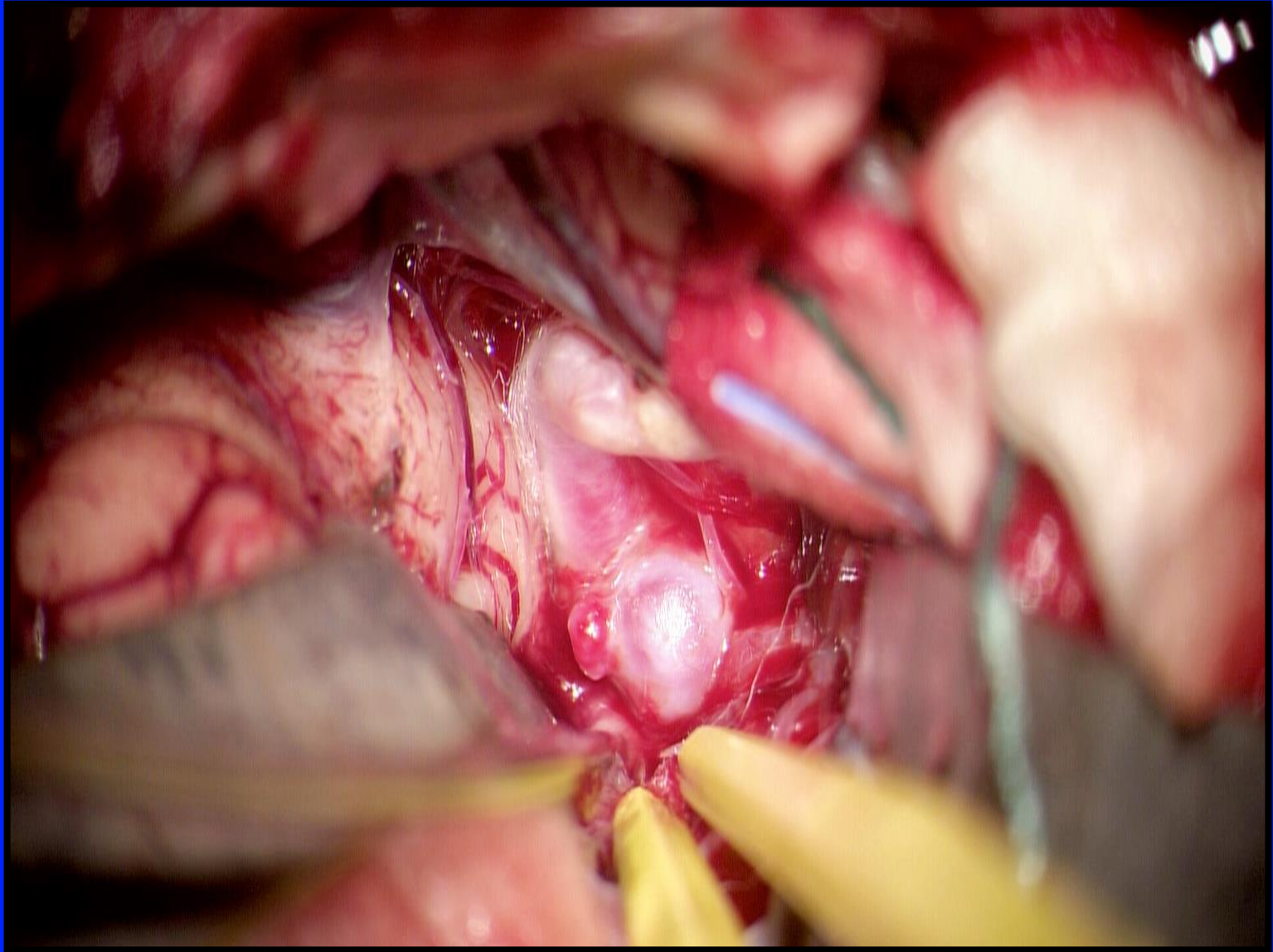
Unruptured MCA Aneurysm: Pre-op CTA



Unruptured MCA Aneurysm: Pre-op CTA



Unruptured MCA Aneurysm



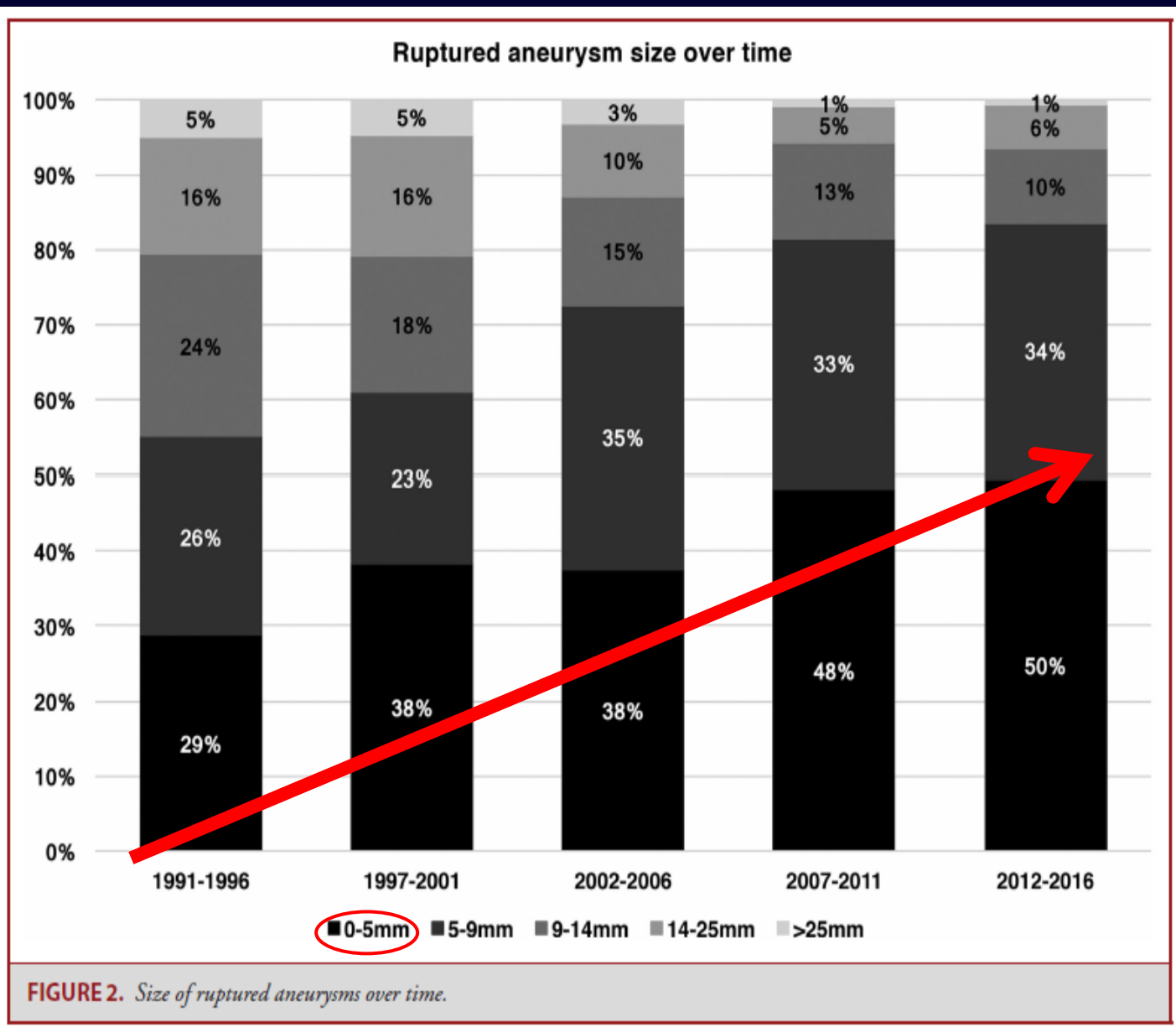
Bleb on base of Aneurysm

Regarding size

- A glaring fact left unanswered- When patients present with aneurysmal SAH, 80% have lesions less than 10 mm (50% < 5 mm)
- Therefore- when unruptured lesions are small, they are less likely to bleed yet when aneurysms bleed, they are likely to be small!

TABLE 3. Literature Review, Proportion of Ruptured Aneurysms < 5 mm

Author	Publication year	Location	Patients	Enrollment start	Enrollment finish	<5 mm (%)
Lee ⁴⁴	2015	Korea	200	2012	2014	47
Froelich ²⁷	2016	Australia	131	2010	2015	49
Dolati ²⁸	2015	Canada	123	2008	2012	37
Zhao ²⁹	2014	China	766	2006	2013	51
Kashiwazaki ¹⁶	2013	Japan	851	2003	2011	28
Tahir ¹⁷	2009	Pakistan	55	2004	2007	24
Nahed ¹⁹	2005	USA	152	2001	2004	33
Taylor ²⁰	2004	USA	127	1998	1999	33
Forget ²¹	2001	USA	245	1996	2000	35
Shiue ²²	2011	Australia	432	1995	1998	22
ISAT ²⁵	2002	Intl	2143	1994	1997	52
Horiuchi ²³	2006	Japan	2577	1988	2002	39
Osawa ²⁴	2001	Japan	2055	1988	1998	38
Ohashi ¹⁸	2004	Japan	280	1984	2001	26
Inagawa ⁴⁵	2010	Japan	285	1980	1998	24
Kassell ¹²	1983	Intl	676	1980	1987	13
Rosenorn ¹³	1993	Denmark	908	1978	1983	18
Sundt ¹⁴	1982	USA	644	1969	1981	23
Mccormick ¹⁵	1970	USA	54	1970	1970	4

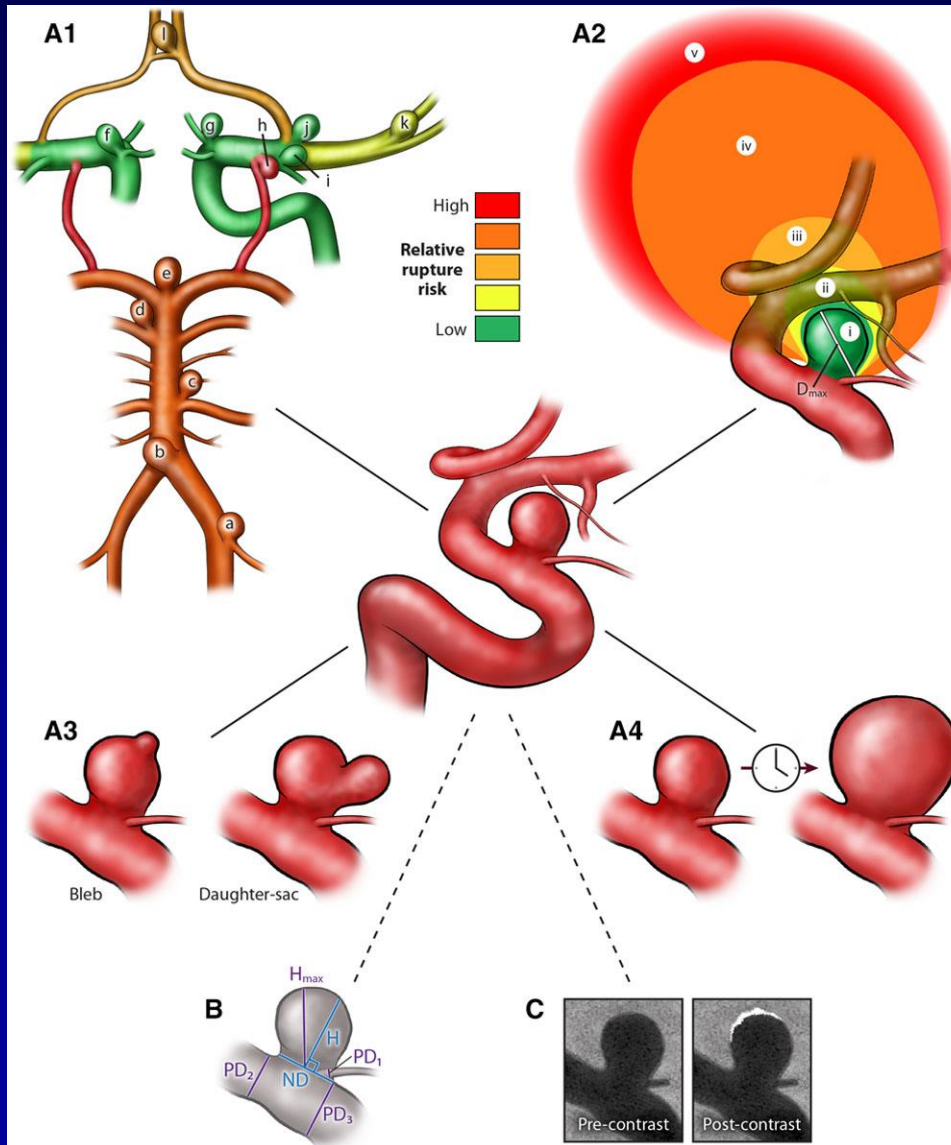


*Bender et al. Neurosurgery 0(0):1-8, 2017.

REMEMBER!

- 80% of all ruptured aneurysms that present for treatment are smaller than 10mm
- *DARN IT!, THE OFFICE VISIT FOR THE 5 MM UNRUPTURED ANEURYSM HAS JUST BECOME AN HOUR!*

Stratification for rupture risk of unruptured intracranial aneurysm



PHASES score

Development of the PHASES score for prediction of risk of rupture of intracranial aneurysms: a pooled analysis of six prospective cohort studies

Jacoba P Greving, Marieke J H Wermer, Robert D Brown Jr, Akio Morita, Seppo Juvela, Masahiro Yonekura, Toshihiro Ishibashi, James C Torner, Takeo Nakayama, Gabriel J E Rinkel, Ale Algra

Lancet Neurol 2014; 13: 59–66

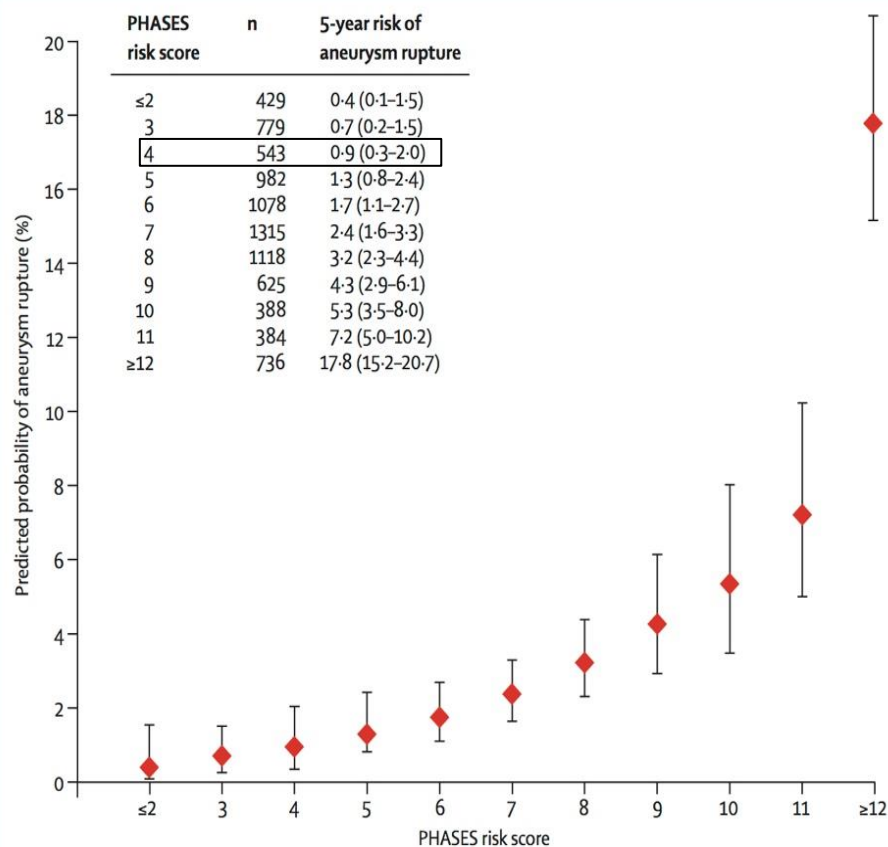
Published Online

November 27, 2013

[http://dx.doi.org/10.1016/](http://dx.doi.org/10.1016/S1474-4422(13)70263-1)

S1474-4422(13)70263-1

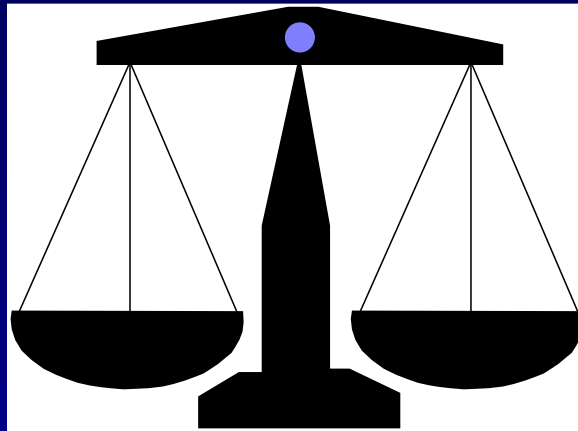
PHASES aneurysm risk score	Points
(P) Population	
North American, European (other than Finnish)	0
Japanese	3
Finnish	5
(H) Hypertension	
No	0
Yes	1
(A) Age	
<70 years	0
≥70 years	1
(S) Size of aneurysm	
<7.0 mm	0
7.0–9.9 mm	3
10.0–19.9 mm	6
≥20 mm	10
(E) Earlier SAH from another aneurysm	
No	0
Yes	1
(S) Site of aneurysm	
ICA	0
MCA	2
ACA/Pcom/posterior	4



Decision-making for unruptured aneurysms: natural history vs treatment risks

- Natural History-patient and lesion specific factors
 - Size, Location of lesion, Age of patient (life horizon), Risk factors (smoking, ethnicity), Female, ?Multiple lesions
- Risk of treatment-patient and lesion specific factors
 - Age , Size, Comorbidities
 - Decreasing risk with improved technology and techniques
 - Use open surgery or endovascular techniques to select lowest risk treatment

Decision Making in Unruptured Aneurysm Treatment?



- **Rupture Risk**

- ISUIA Data
- UCAS
- Metanalysis
- PHASES score

- **Treatment risk**

- Endovascular
- Surgical

TREATMENT RELATED
RISKS FOR
UNRUPTURED
INTRACRANIAL
ANEURYSMS

ISUIA- Prospective results

- Prospective evaluation of surgical and endovascular results
- Morbidity and mortality higher than prior reports

ISUIA 2003

Prospective Results - Surgery

	N (%)	Overall morbidity and mortality	
		1 month	1 year
Surgery			
Group 1	1591	13.7%	12.6%
Group 2	326	11.0%	10.1%

Risk factors for poor surgical outcome

- Age (≥ 50 yrs RR 2.4)
- Diameter > 12 mm (RR 2.6)
- Posterior circulation location (RR 1.6)

Stratification of outcome for surgically treated unruptured intracranial aneurysms.

Neurosurgery 2003;52:82-8 (Ogilvy,Carter)

- 604 Aneurysms
- 481 Patients
- No. of Aneurysms:
 - 5: one patient
 - 4: 8 patients
 - 3: 17 patients
 - 2: 61 patients
 - 1: 394 patients

STRATIFICATION OF OUTCOME FOR SURGICALLY TREATED UNRUPTURED INTRACRANIAL ANEURYSMS

Christopher S. Ogilvy, M.D.

Cerebrovascular Surgery,
Neurosurgical Service,
Massachusetts General Hospital,
Harvard Medical School, Boston,
Massachusetts

Bob S. Carter, M.D.

Cerebrovascular Surgery,
Neurosurgical Service,
Massachusetts General Hospital,
Harvard Medical School, Boston,
Massachusetts

Reprint requests:

Christopher S. Ogilvy, M.D.,
Director, Cerebrovascular Surgery,
Neurosurgical Service,
Massachusetts General Hospital,
Harvard Medical School, 55 Fruit
Street, VBK710, Boston, MA
01114.

Email: cogilvy@partners.org

Received, May 10, 2002.

Accepted, August 13, 2002.

OBJECT: The combination of low anticipated rupture rates for many unruptured aneurysms, better delineation of treatment risks, and the availability of alternative modalities of treatment have led to heightened scrutiny of the surgical management of unruptured intracranial aneurysms. Most reports to date have provided aggregate data concerning surgical treatment risks. This study was performed to better delineate risk estimates for the surgical treatment of patients with unruptured intracranial aneurysms according to a patient's risk profile with regard to age, aneurysm location, and aneurysm size.

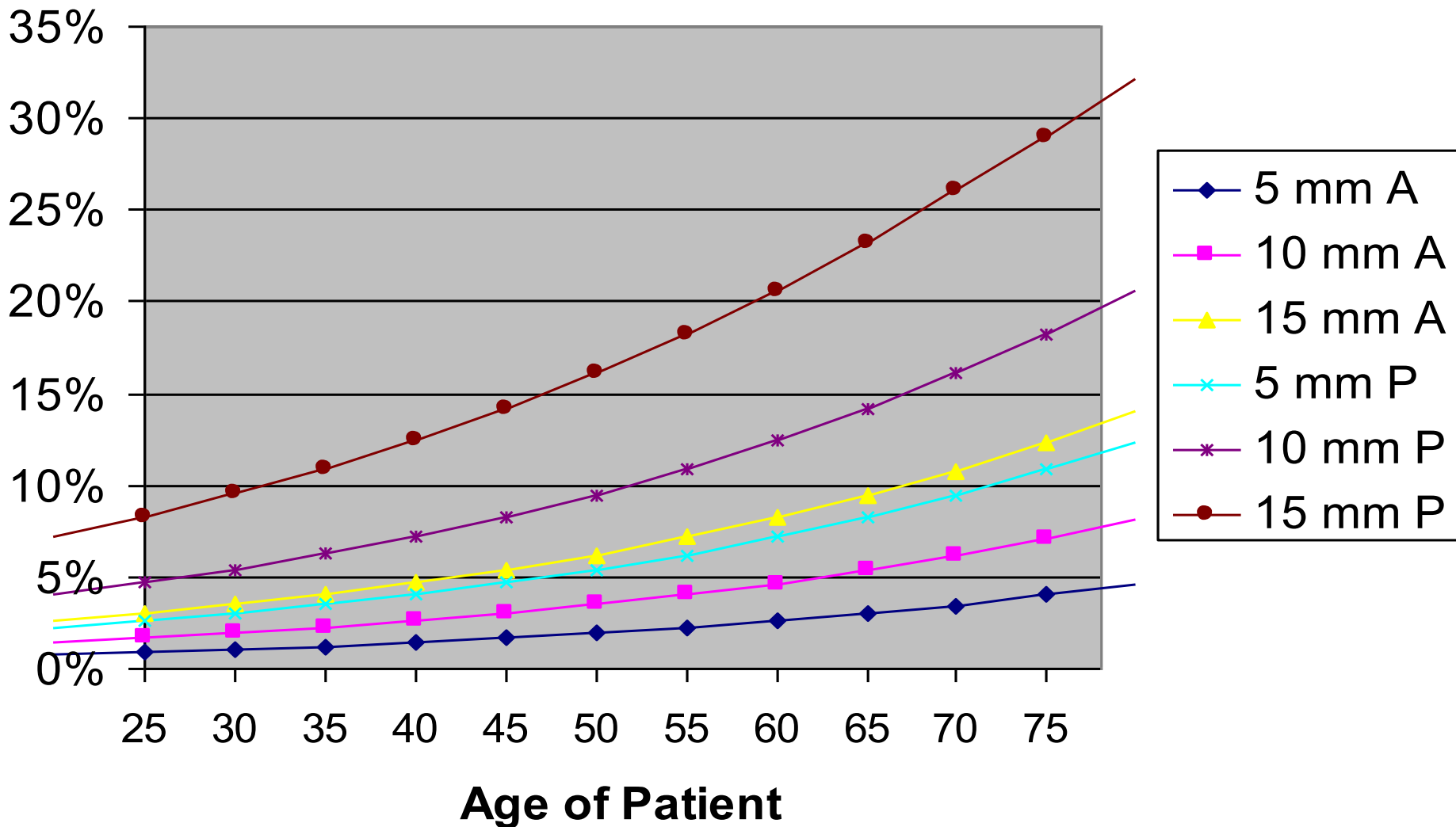
METHODS: We studied 493 patients who were treated with surgical clipping of 604 unruptured saccular aneurysms. Information regarding aneurysm size, location, patient age, and 6-month or greater outcome were gathered prospectively from 1992 to 1999. Multivariate analysis was performed to identify independent risk factors for outcome. On the basis of the model, risk stratification curves were generated.

RESULTS: In our series, the mean patient age was 53 years, and the mean lesion size was 8.8 mm. Lesion locations included the internal carotid artery ($n = 259$, 43%), the middle cerebral artery ($n = 174$, 28%), the anterior cerebral artery ($n = 99$, 17%), and the vertebrobasilar artery ($n = 67$, 11%). Multivariate analysis revealed that aneurysm size ($\beta = 0.122$, $P < 0.001$), patient age ($\beta = 0.0308$, $P < 0.05$), and vertebrobasilar location ($\beta = 1.37$, $P = 0.0080$) were independently associated with high risk of poor outcome or death.

CONCLUSION: Small aneurysms in the anterior circulation in young patients carry a very low treatment risk (approximately 1%), and treatment in elderly individuals (ages 70 years and older) with large lesions (greater than 10 mm), carries a significant risk of poor outcome (5% in the anterior circulation, 15% in the posterior circulation). The nomograms generated by this study should be particularly useful in discussing with patients the risks and benefits of surgical treatment of unruptured aneurysms.

KEY WORDS: Risk stratification, Unruptured aneurysm

Risk of Poor Outcome after Unruptured Aneurysm Surgery



TREATMENT RISKS

- Patient specific factors:
 - Age
 - Medical comorbidities
- Lesion specific factors:
 - Size
 - Location
 - Calcification
 - Local anatomy details (parent vessel, perforators)

Treatment Risk

Changing the risk landscape...

- As with natural history, ***THERE IS STRATIFICATION OF TREATMENT RELATED RISKS***
- Highly specific treatment selection of surgical or endovascular therapy can be used based on patient and aneurysm characteristics.
- Treatment risk is not static, but changes as specialty progresses...

Treatment Risk

Christopher S. Ogilvy, M.D.

Cerebrovascular Surgery,
Neurosurgical Service,
Massachusetts General Hospital,
Harvard Medical School, Boston,
Massachusetts

Bob S. Carter, M.D.

Cerebrovascular Surgery,
Neurosurgical Service,
Massachusetts General Hospital,
Harvard Medical School, Boston,
Massachusetts

CLINICAL STUDIES

STRATIFICATION OF OUTCOME FOR SURGICALLY TREATED UNRUPTURED INTRACRANIAL ANEURYSMS

CONCLUSION: Small aneurysms in the anterior circulation in young patients carry a very low treatment risk (approximately 1%), and treatment in elderly individuals (ages 70 years and older) with large lesions (greater than 10 mm), carries a significant risk of poor outcome (5% in the anterior circulation, 15% in the posterior circulation). The

Neurosurgery 52:82-88, 2003

REVIEW

Safety and effectiveness of microsurgical clipping, endovascular coiling, and stent assisted coiling for unruptured anterior communicating artery aneurysms: a systematic analysis of observational studies

Anthea H O'Neill,^{1,2} Ronil V Chandra,^{1,2,3} Leon T Lai^{2,4,5}

O'Neill AH, et al. *J NeuroIntervent Surg* 2016;0:1-5. doi:10.1136/neurintsurg-2016-012629

BMJ

SNIS

1

RESEARCH—HUMAN—CLINICAL STUDIES

Michaël Bruneau, MD, PhD*

Sepideh Amin-Hanjani, MD‡

Päivi Koroknay-Pal, MD, PhD§

Philippe Bijlenga, MD, PhD¶

Behnam Reza Jahromi, MBS

Surgical Clipping of Very Small Unruptured Intracranial Aneurysms: A Multicenter International Study

CONCLUSION: VSUIA clipping is highly effective and is associated with a low morbidity rate. For VSUIAs selected for treatment, our data support surgical clipping as the modality of choice.

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In each unruptured aneurysm patient encountered, an analysis can be done incorporating lesion and patient specific factors

SYNERGISTIC treatment of
unruptured aneurysms in all
locations

Previous studies of treatment related risks for unruptured aneurysms

- Most reports are of surgical or endovascular outcomes
- Often couched in terms of ‘clip vs coil’ or surgery vs endovascular
- True combined modality management outcomes are scarce

SYNERGY

- The interaction or cooperation of two or more organizations, substances, or other agents to produce a combined effect greater than the sum of their separate effects
- Look at synergistic treatment outcomes of unruptured intracranial aneurysms using endovascular and surgical techniques

Patient population

- 658 aneurysms in 553 patients treated between 2014-2017 at BIDMC
- Techniques used
 - Open surgical techniques (mostly direct clipping)
 - Endovascular techniques
 - Direct coiling
 - Stent assisted coiling
 - Balloon assisted coiling
 - Flow diversion

Treatment modality

- Chosen based on predicted risk for that patient (aneurysm specific and patient specific risks) for endovascular or surgical obliteration
- ‘Selection bias’- During this interval of treatment 960 patients were evaluated with unruptured lesions and were not treated based on aneurysm size, patient comorbidity or age

Surgical and Endovascular Comprehensive Treatment Outcomes of Unruptured Intracranial Aneurysms: Reduction of Treatment Bias

Christopher S. Ogilvy, Noah J. Jordan, Luis C. Ascanio, Alejandro A. Enriquez-Marulanda, Mohamed M. Salem, Justin M. Moore, Ajith J. Thomas

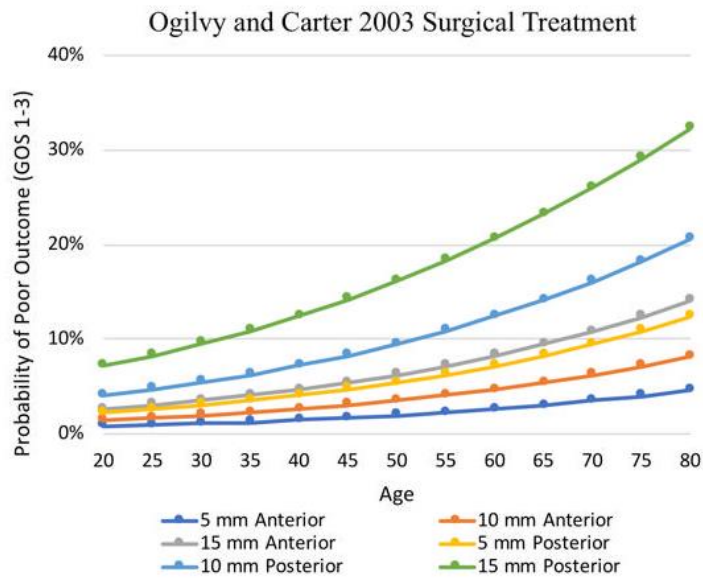
COMPLICATIONS

- No permanent morbidity from the 4.2% of procedures with non neurologic complications
- Of the 38 (5.7%) of procedures with neurologic complications, only 7 (1%) resulted in permanent, severe neurologic deficits

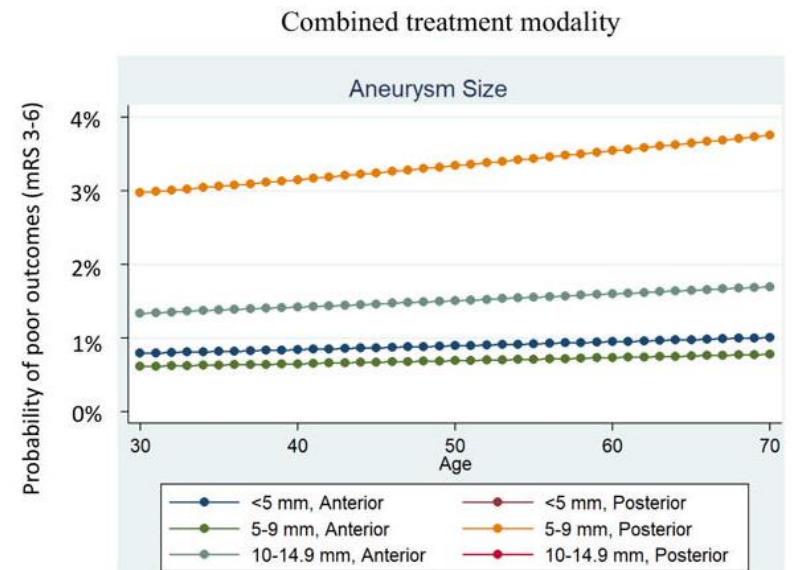
Comparison to similar previous analysis of surgical results

- Ogilvy and Carter, Neurosurgery 52:82-88, 2003
- 604 aneurysms in 493 patients
- Similar distributions of age and aneurysm sizes
- Results reported as GOS, current study results reported as mRS

2003



2018



Multicenter study of outcomes using surgical and endovascular treatments in synergy

- BIDMC/Harvard
- University of Florida
- University of Calgary
- University of Utah
- University of California Irvine

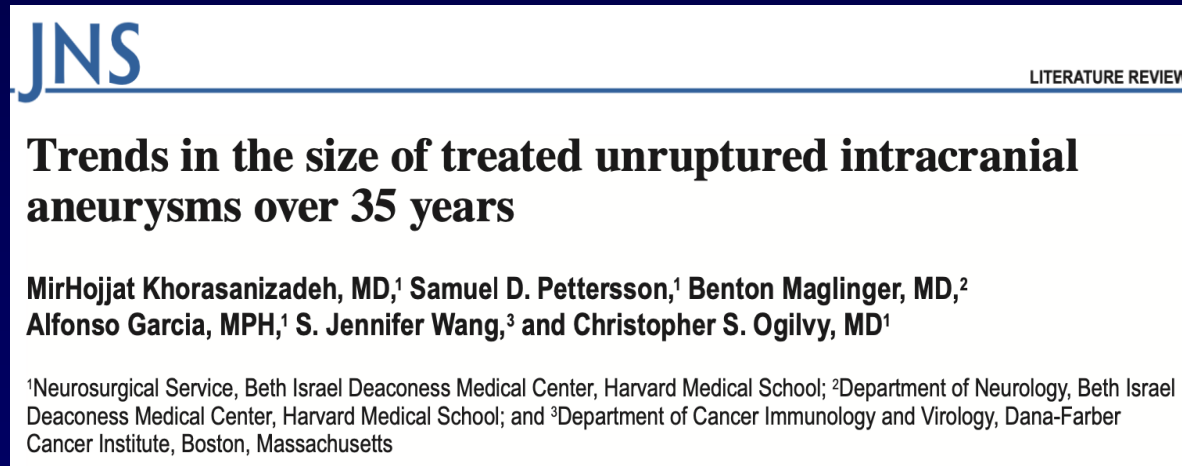
Overall treatment risks of unruptured aneurysms is lower over time

- Increased use of endovascular techniques
- Better surgical results
- Is there a changing criteria for treatment
 - Flow diversion for ICA lesions – more lesions being treated?, smaller lesions?
 - Smaller lesions being treated?
 - Older patients being offered treatment?

Are smaller aneurysms
being treated?

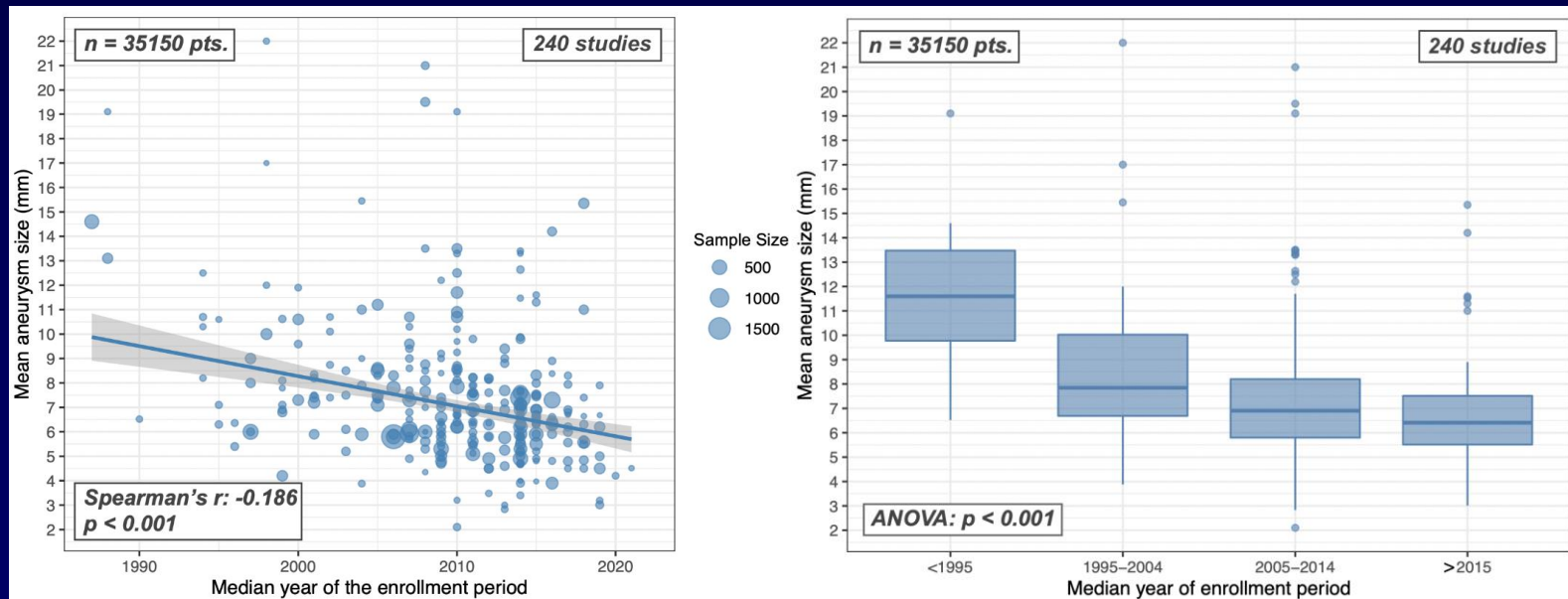
Reported size of aneurysms treated over time- literature search 2023

- Main finding: Over past 35 years, the literature suggests that the annual mean treated UIA dome size in the literature surpassed below 7mm in 2012



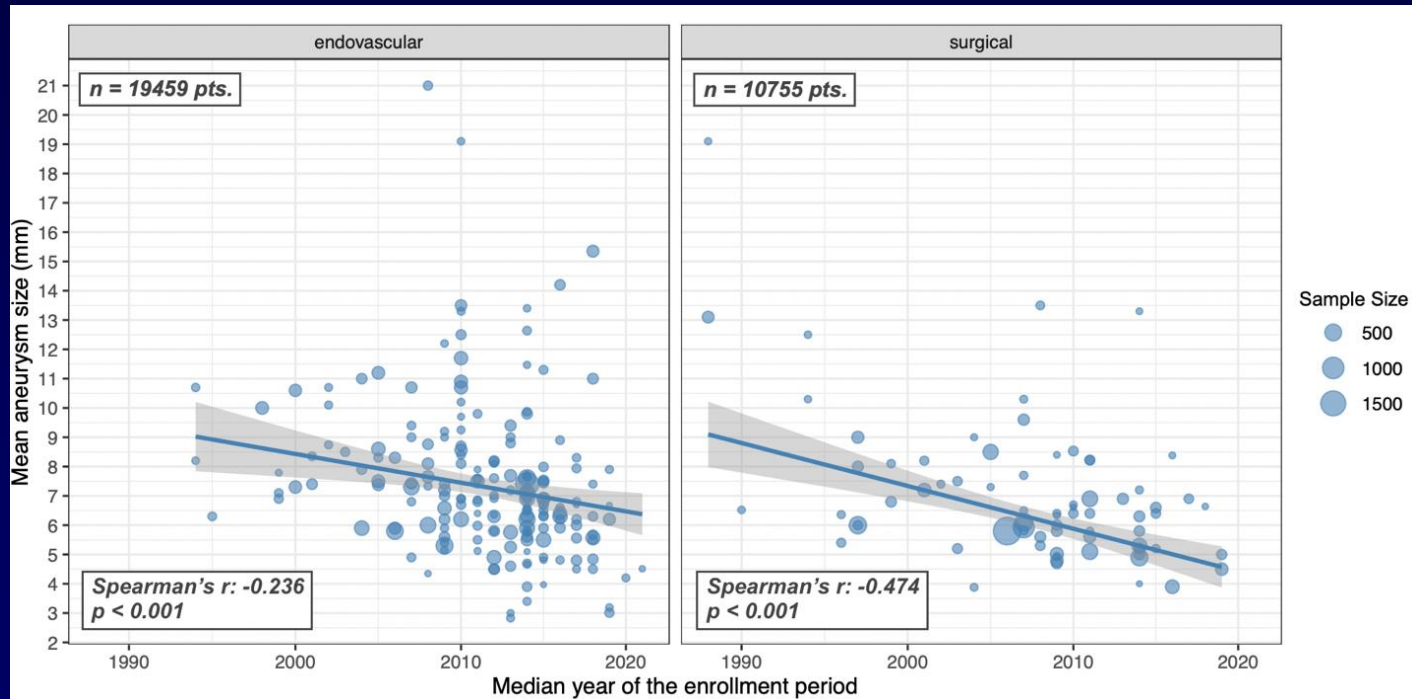
Reported size of aneurysms treated over time- literature search

- Weighted regression analysis suggests that the annual mean treated UIA dome size in the literature surpassed below 7mm in 2012



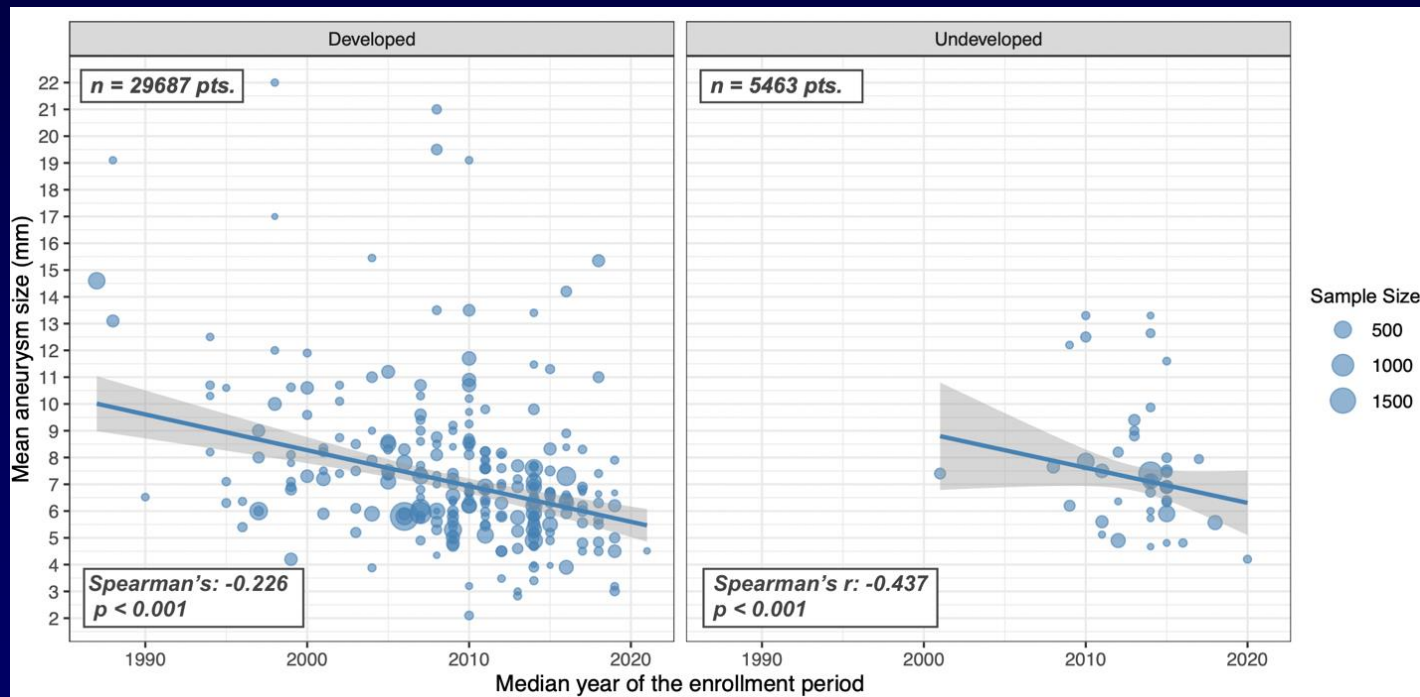
Endovascular and Surgical Treatment

- The rate of decrease in average size of the treated UIAs was 0.65 mm per every 5-year in the surgical group compared to 0.51 mm in the endovascular group



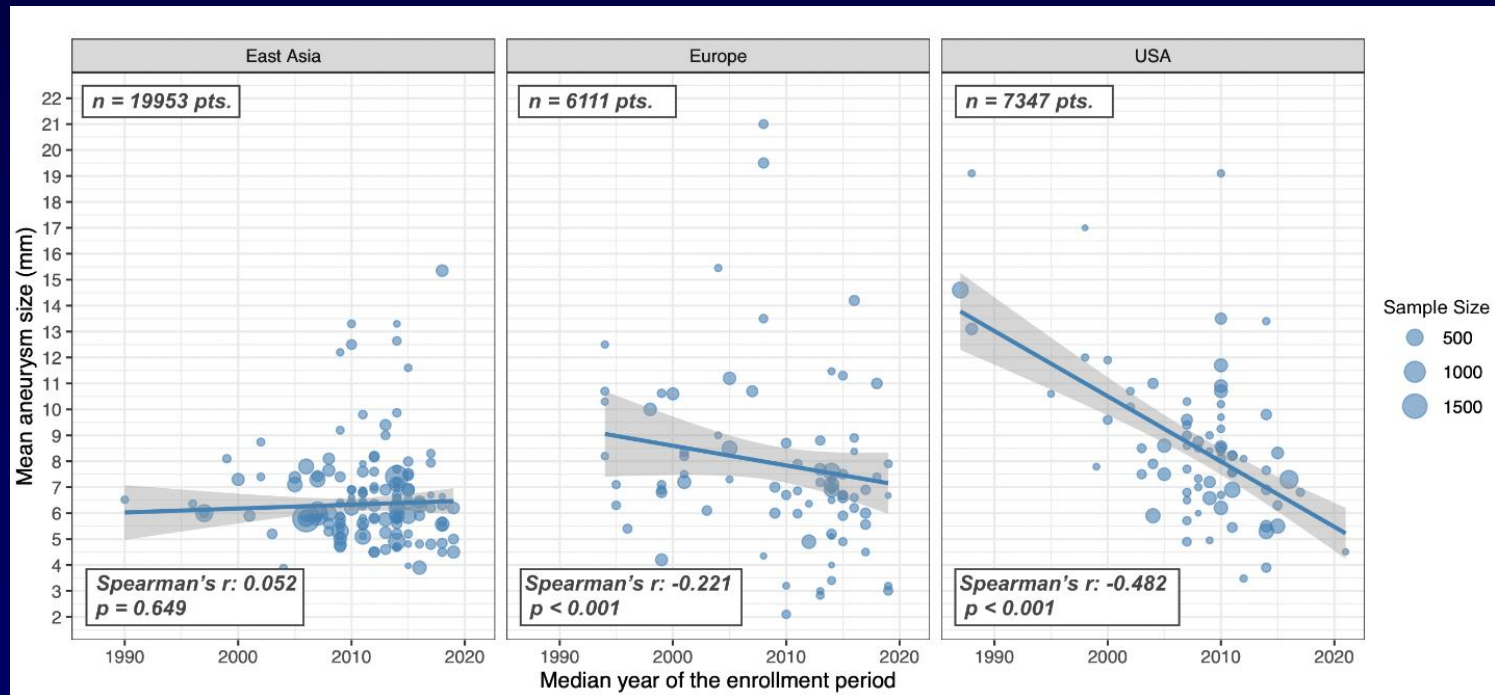
Developed and Non-Developed Countries

- The rate of decrease in average size of the treated UIAs was 0.35 mm per every 5-year in the developed group compared to 0.71 mm in the developing group
- Categorized according to the 2022 International Monetary Fund List of Advanced Economies



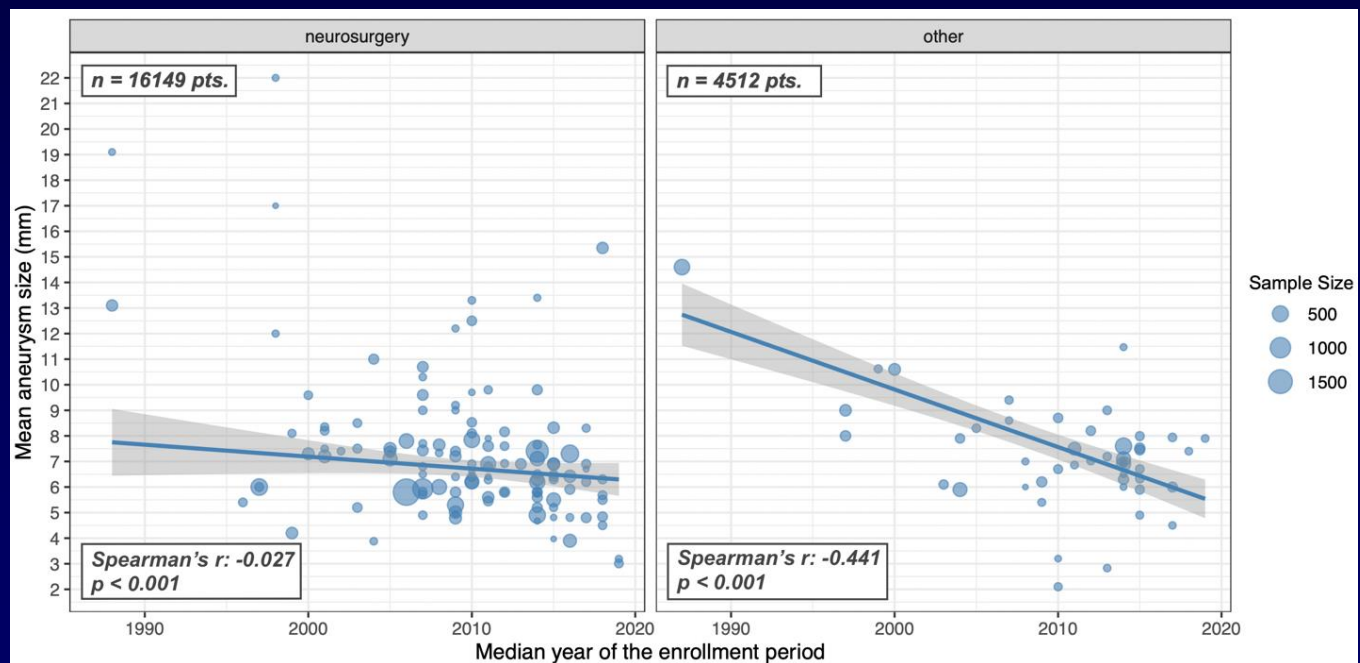
Trends among Eastern Asia, Europe, and the U.S.

- The rate of decrease in average size of the treated UIAs was 1.25 mm per every 5-year in the U.S. and 0.41 mm per every 5-year in Europe
- Reasons for these observations are unclear and warrant further studies



Neurosurgery and All Other Departments

- The rate of decrease in average size of the treated UIAs was 0.26 mm per every 5-year in neurosurgical studies compared to 1.01 mm in non-neurosurgical studies



Reported age of patients treated over time – literature review

- Main finding: The rate of increase in the average age of the patients treated is from 1990-2020 is roughly 0.2 years per annum

LITERATURE REVIEW

 Check for updates

Trends in the Age of Patients Treated for Unruptured Intracranial Aneurysms from 1990 to 2020

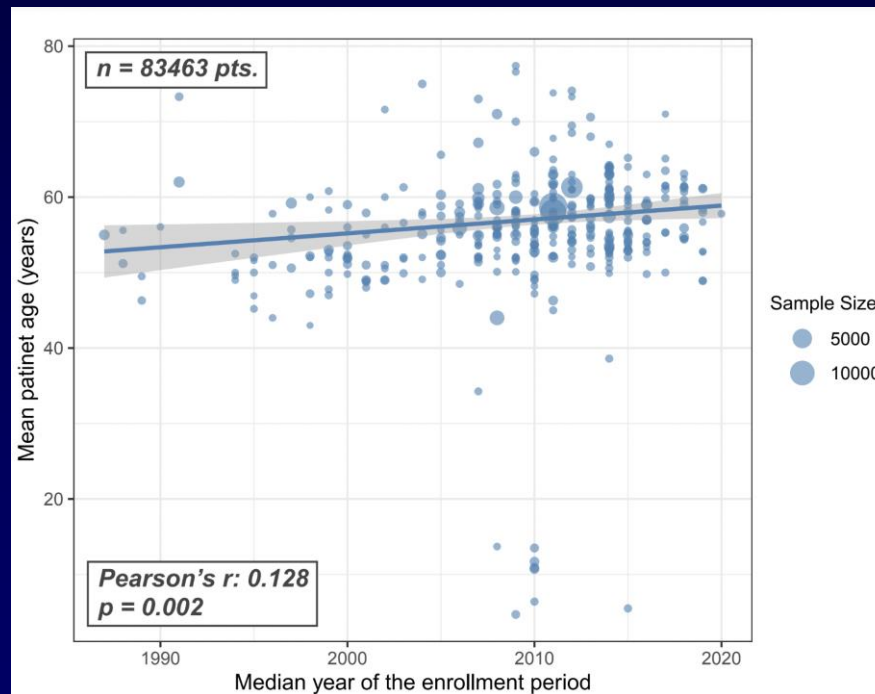
Samuel D. Pettersson¹, MirHojjat Khorasanizadeh¹, Benton Maglinger², Alfonso Garcia¹, S. Jennifer Wang³, Philipp Taussky¹, Christopher S. Ogilvy¹

WORLD
NEUROSURGERY



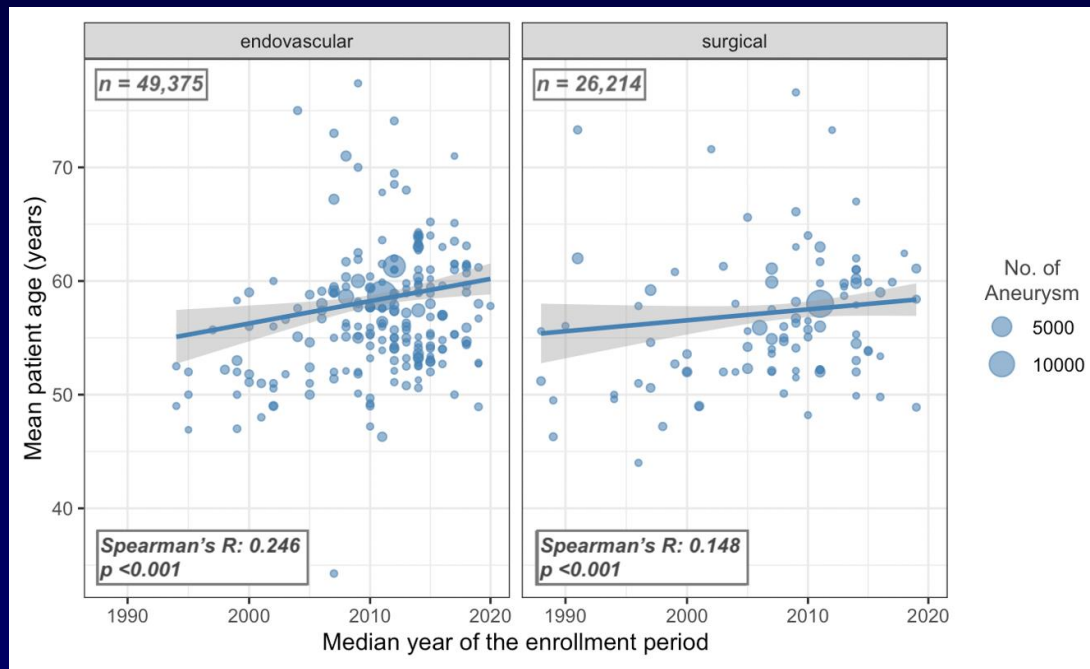
Reported age of patients treated over time

- The rate of increase in the average age of the patients treated is roughly 0.2 years per annum



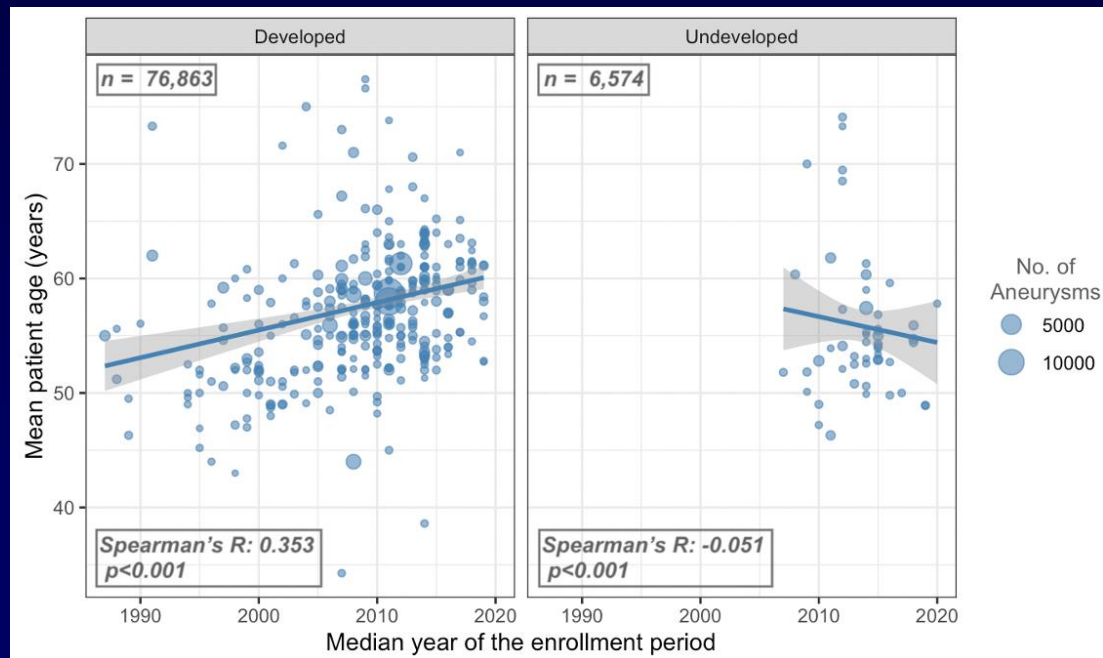
Endovascular and Surgical Treatment

- The rate of increase in average age was 0.56 years in age per every 5-year in the surgical group compared to 1.03 years in age in the endovascular group.



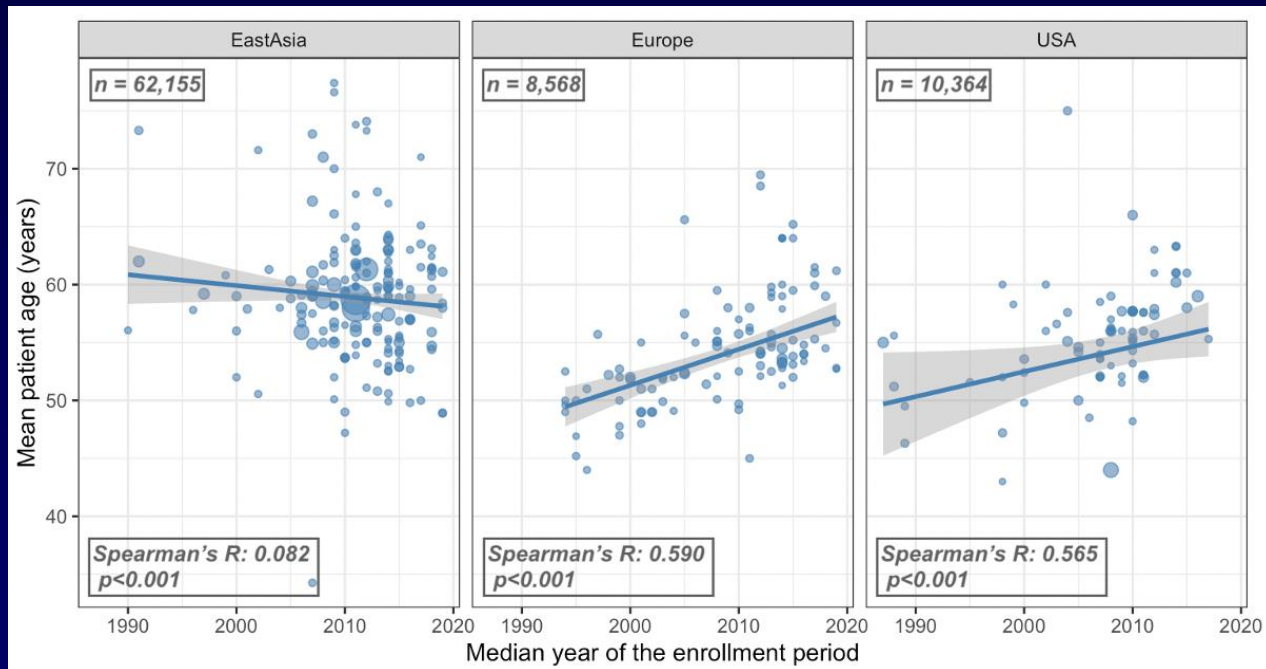
Developed and Non-Developed Countries

- The rate of increase in the trend in the average age of the treated patients was 1.25 years in age per every 5-year in the developed group compared to a decrease in 1.23 years of age per every 5-year in the developing group.
 - Categorized according to the 2022 International Monetary Fund List of Advanced Economies



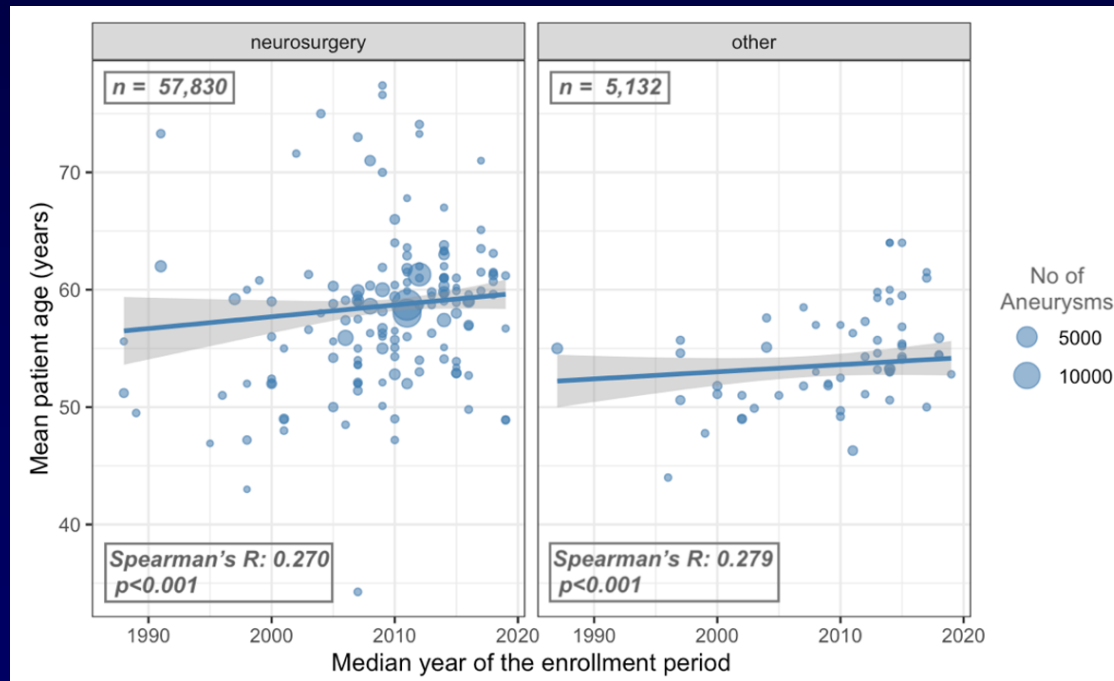
Trends among Eastern Asia, Europe, and the U.S.

- The rate of change in the trend in the average age of the treated patients was 1.21 years of age per every 5-year in the U.S., 1.64 years of age per every 5-year in Europe, and -0.08 years of age per every 5-year in Eastern Asia.
 - Reasons for these observations are unclear and warrant further studies



Neurosurgery and All Other Departments

- The rate of increase in average age of treated patients was 0.54 years of age per every 5-year in neurosurgical studies compared to 0.38 years of age in non-neurosurgical studies.



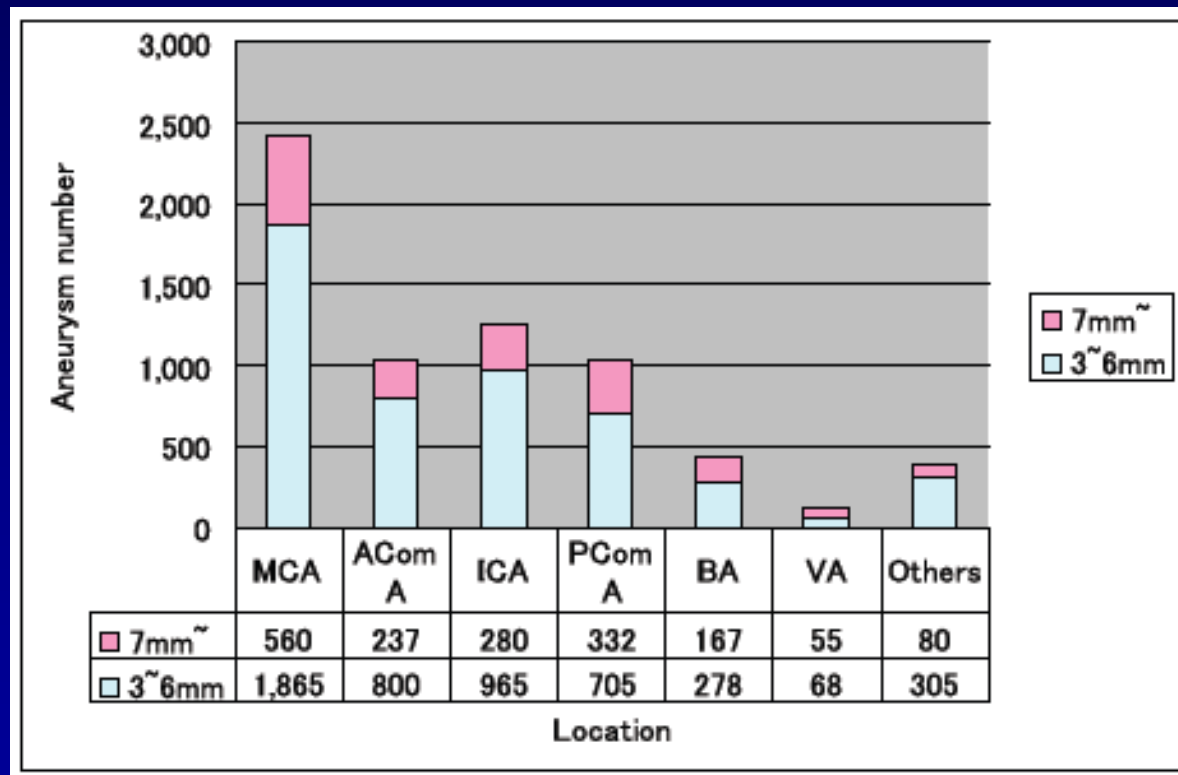
HOW ABOUT SMALL (<7MM) UNRUPTURED ANEURYSMS- BEYOND ISUIA

Size AND other modifiers of natural
history

Unruptured Cerebral
Aneurysms in a
Japanese Cohort
(UCAS)- NEJM,
2012

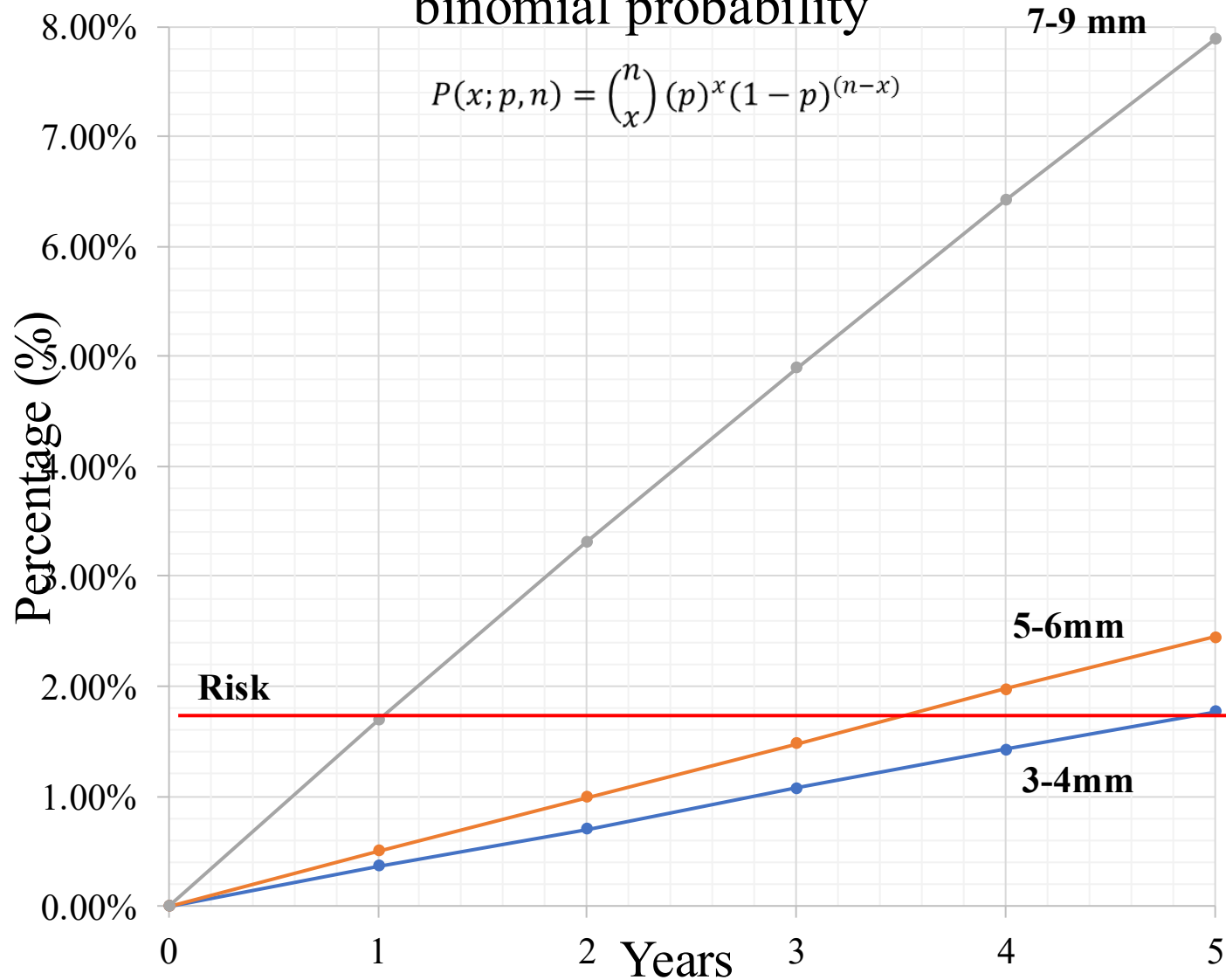
The Unruptured Cerebral Aneurysm Study of Japan*

Aneurysms:



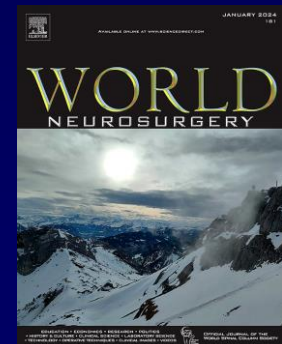
*The UCAS Japan Investigators. NEJM 336(26):2474-2482, 2012.

UCAS Probability of aneurysm rupture by binomial probability



Small (<7mm) IA rupture risk factors – meta-analysis

- Not all predictor variables for rupture are equally shared among small and larger IAs
- Meta-analysis of 4739 small IAs confirms IA morphology and hemodynamic variables are significantly superior to traditional size alone variables for predicting rupture



Morphology and flow predictors outperforming traditional predictors

- Aspect ratio (MD 0.16; $p < 0.00001$)
- Size ratio (MD 0.40; $p < 0.00001$)
- Irregularity (OR 2.95; $p < 0.00001$)
- Dome-neck ratio (MD 0.17; $p = 0.0009$)
- Height-width ratio (MD 0.07; $p = 0.007$)
- Pressure loss coefficient (MD 0.32; $p = 0.002$)
- Wall shear stress (Pa) (MD -0.16; $p = 0.01$)

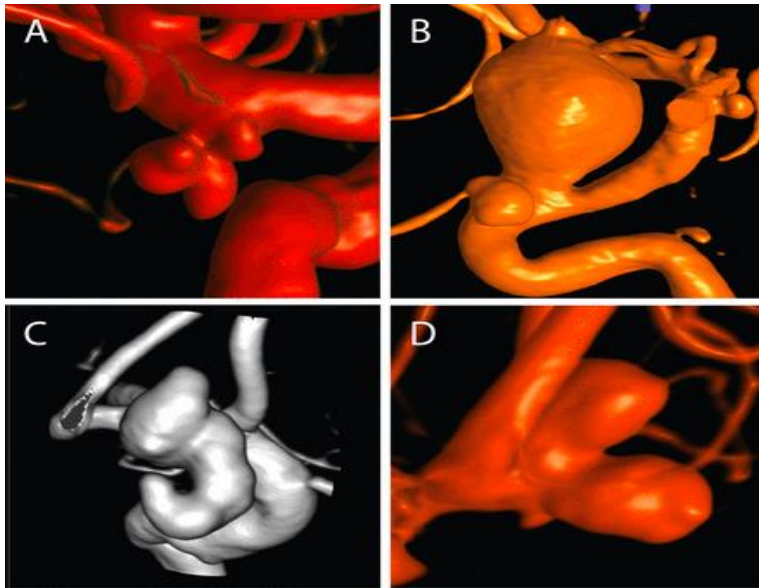
Limitations with morphology and hemodynamics

- IA morphological parameters require significant time to obtain compared to traditional predictors, and software for obtaining flow dynamics is still in the experimental phase (harder to use in office or at bedside).
- The implementation of artificial intelligence will play a crucial role in the upcoming years to allow for retrieval and utilization of these critical predictor variables at the bedside.

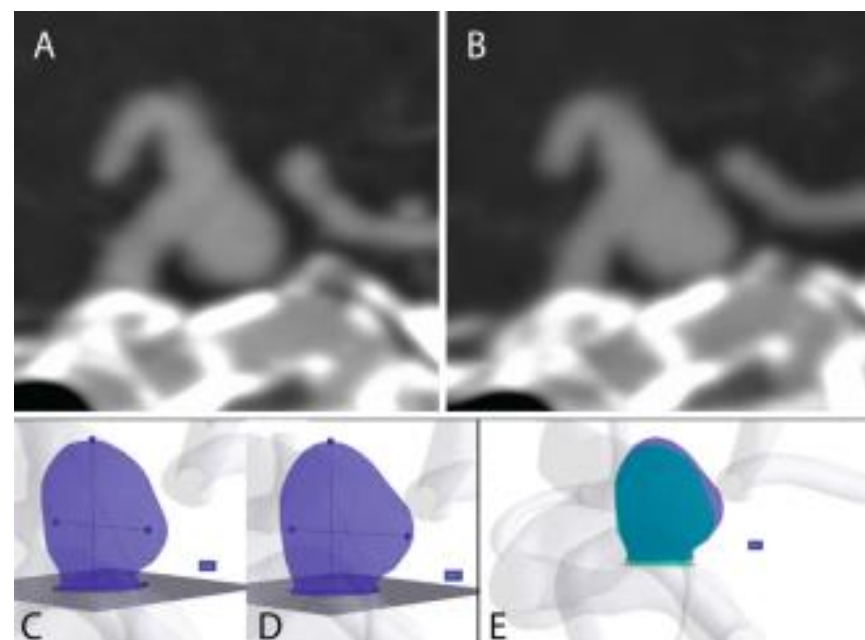
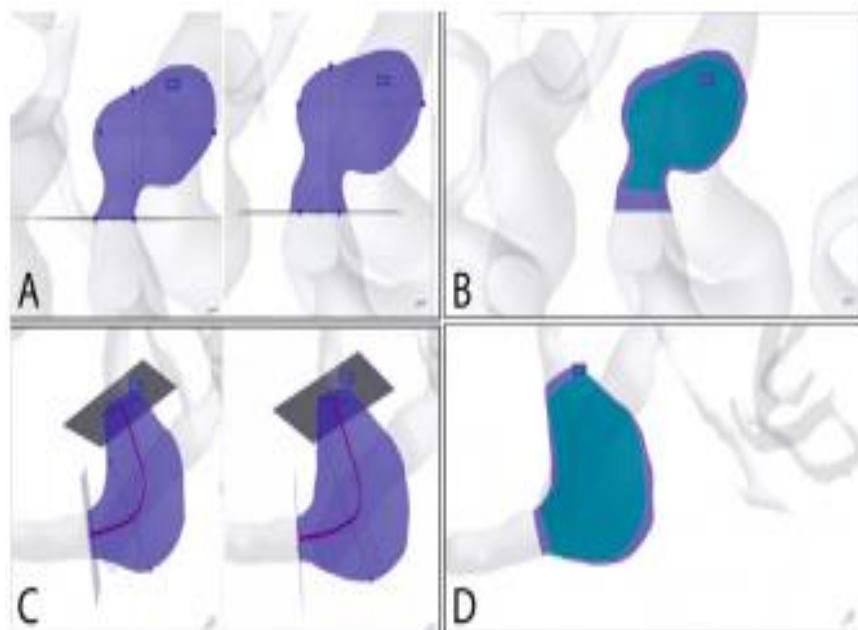
Original research

Artificial intelligence aneurysm measurement tool finds growth in all aneurysms that ruptured during conservative management



Daniel H Sahlein,¹ Daniel Gibson,² John A Scott,¹ Andrew DeNardo,¹ Krishna Amuluru,¹ Troy Payner,³ David Rosenbaum-Halevi,¹ Charles Kulwin³



- Linear maximal measurements fail to completely characterize the size of the aneurysms and may fail to identify aneurysms with subtle growth.
- AI volumetric analysis increases the sensitivity for detecting interval growth

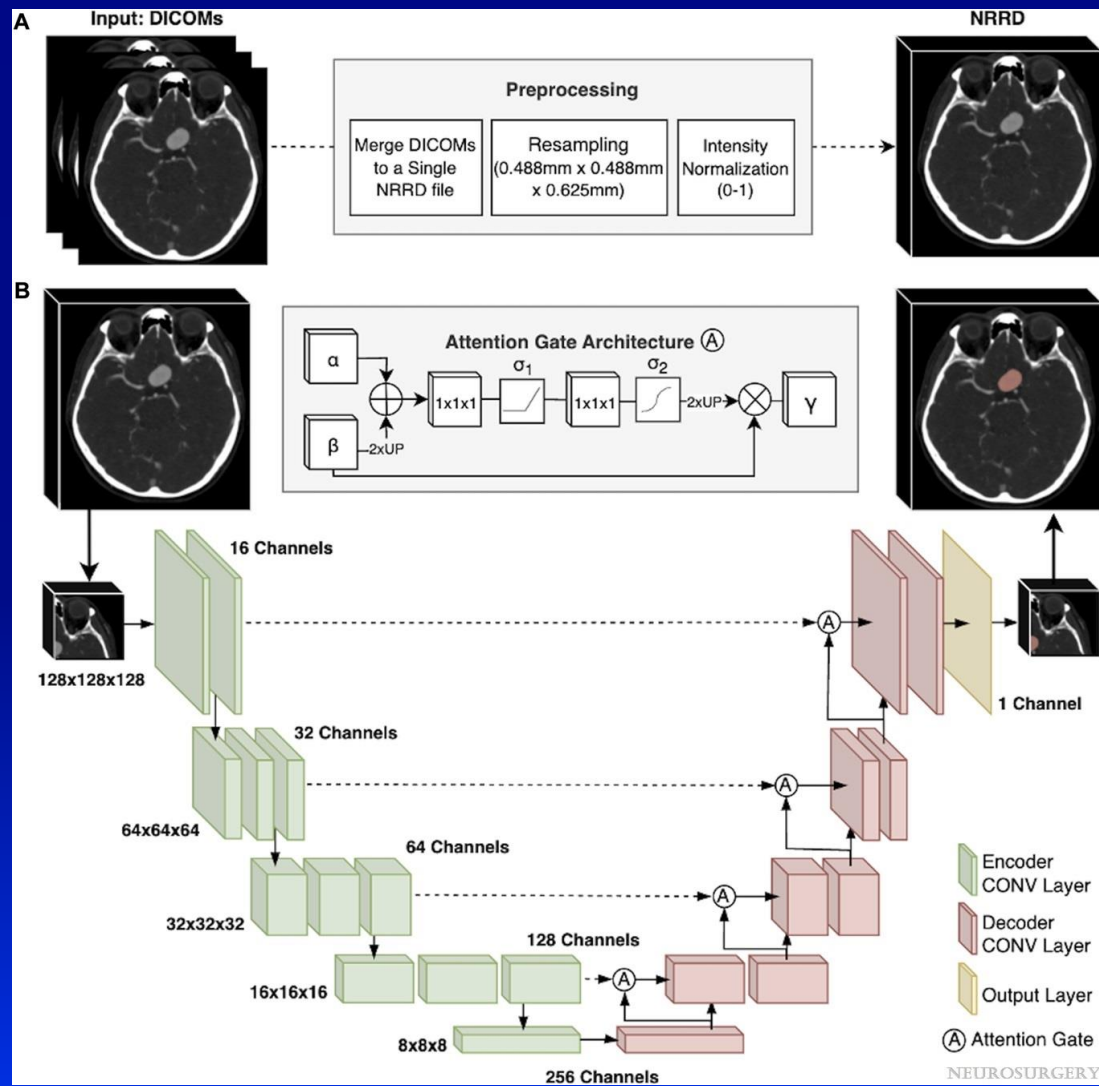


Addressing Limited Generalizability in Artificial Intelligence–Based Brain Aneurysm Detection for Computed Tomography Angiography: Development of an Externally Validated Artificial Intelligence Screening Platform

Pettersson, Samuel D.^{‡,§,*};  Filo, Jean BS^{‡,*}; Liaw, Peter MD^{||}; Skrzypkowska, Paulina MD[§]; Klepinowski, Tomasz MD, PhD^{||}; Szmuda, Tomasz MD, PhD[§]; Fodor, Thomas B. MD[‡]; Ramirez-Velandia, Felipe MD[‡]; Zieliński, Piotr MD, PhD[§]; Chang, Yu-Ming MD^{||}; Taussky, Philipp MD[‡];  Ogilvy, Christopher S. MD[‡]

[Author Information](#) 

Neurosurgery 97(6):p 1388-1396, December 2025. | DOI: 10.1227/neu.0000000000003549



WHAT ARE WE CURRENTLY DOING
WITH SMALL UNRUPTURED
ANEURYSMS?

Unruptured aneurysms 2014-2021 BIDMC: 1152 patients treated (all sizes) with 771 small- 1126 patients with lesions smaller than 7 mm managed conservatively (many < 4mm)

Total patients treated: 1152		
Small aneurysms (<7mm)	771	66.90%
Large aneurysms (>=7mm)	381	33.10%
Total	1152	100%

Treatment	Small aneurysms (<7mm)	Large aneurysms (>=7mm)	Total
Open surgery (clipping)	253 (32.8%)	65 (17.1%)	318 (27.6%)
Endovascular	518 (67.2%)	316 (82.9%)	834 (72.4%)
Total	771 (66.90%)	381 (33.10%)	1152 (100%)

Decision to treat smaller aneurysms

- Influenced by a number of patient specific and aneurysm specific factors

Aneurysm Rupture Risk Factors: SMALLSS Score (A Novel System for Decision Making)

- Size of Aneurysm - <3.9mm 0 point, 4-7mm 1 point
- Multiplicity of Aneurysms- 1 point
- Anatomic location- (anterior 0 point vs posterior 1 point)
- Lineage- Family History of aneurysm- 1 point
- Lifetime risk-Age - < 65- 1 point
- Smoking history- 1 point
- Shape-Irregularity of aneurysm (e.g. bleb)- 1 point



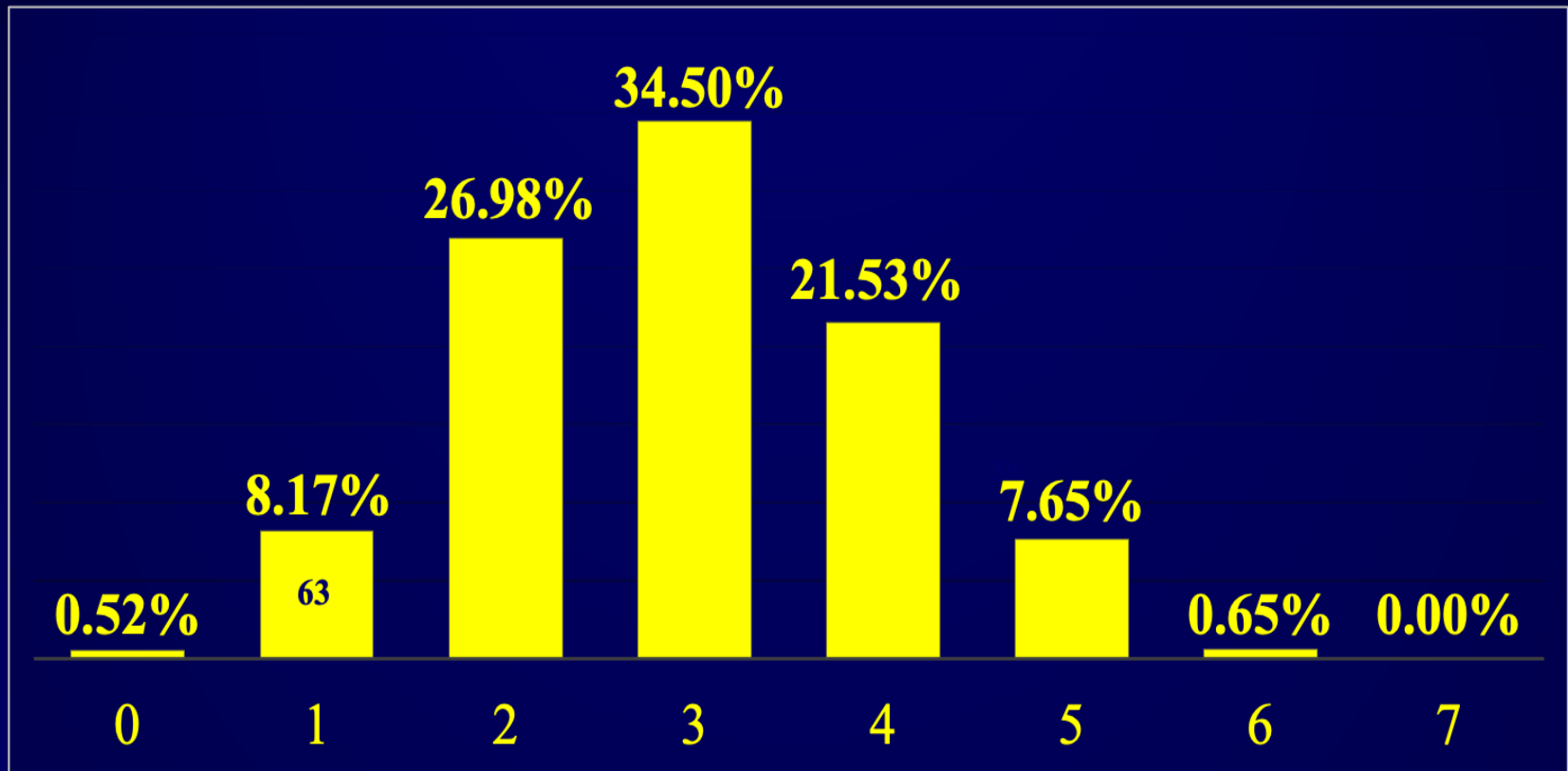
Treatment of small intracranial aneurysms using the SMALLSS scoring system: a novel system for decision making

Mira Salih¹ · Michael Young¹ · Thomas B Fodor¹ · Alexander Andreev¹ · Samuel D. Pettersson¹ · Joanna M. Roy² · Basel Musmar² · Max Shutran¹ · Phillip Taussky¹ · Christopher S. Ogilvy^{1,3} 

Received: 22 May 2024 / Accepted: 22 January 2025
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Lesions treated with
endovascular or surgical
techniques to minimize
risk and maximize efficacy

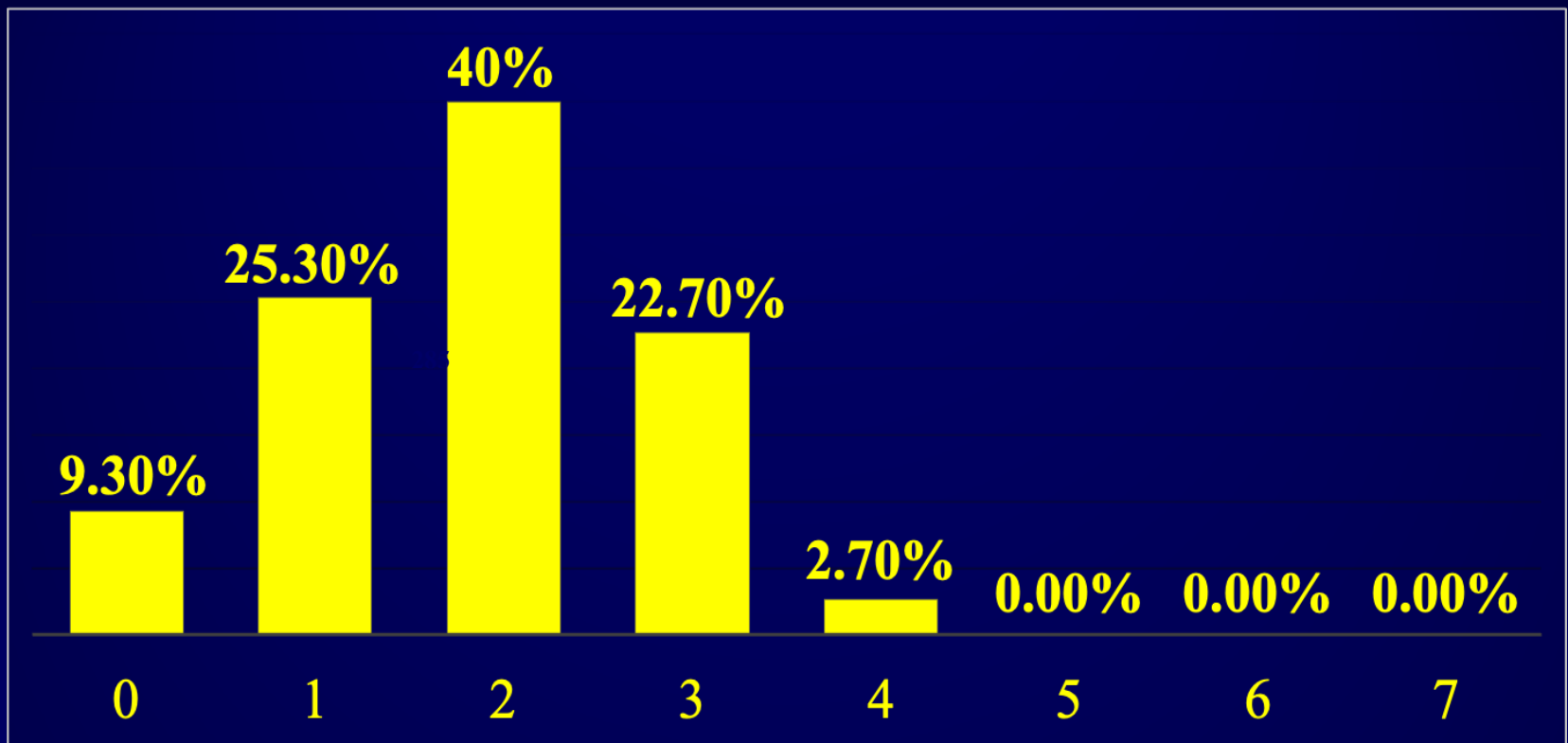
Percentage of TREATED cases per SMALLSS score (N= 771)



Conservatively managed (untreated) small aneurysms

- During this same interval (2014-2021), an estimated 1126 patients with aneurysms <7mm were evaluated and not offered treatment
- Conservative ‘observation’ based in aneurysm and patient specific factors

Percentage of UNTREATED cases per SMALLSS score (N= 1126)



For smaller aneurysms

- Many patients do NOT meet criteria for treatment
- However, when treatment is contemplated, endovascular and open surgical techniques should be considered
- Incorporation of ALL aneurysm specific factors and patient specific factors should be carefully weighed into the final recommendation for treatment balancing risks of treatment against the projected natural history of the lesion

Epidemiology

Epidemiology

- Prevalence: 0.5- 4.0%, **approximately 1 in 50**
- Typically spontaneous and single
 - multiple in ~10%
 - familial: 7- 20%
- Most symptomatic presentation between 4th and 6th decades
- Female preponderance

Associated Disorders

Increased risk of aneurysm formation

- **Autosomal dominant polycystic kidney disease (ADPKD)**
- **Fibromuscular dysplasia**
- **Coarctation of aorta**
- **Bicuspid aortic valve**
- **Type IV Ehlers-Danlos syndrome**
- **Marfan disease**
- **Primordial dwarfism**
- **Tuberous sclerosis**
- **Neurofibromatosis type 1**
- **Hereditary hemorrhagic telangiectasia**
- **Moyamoya**
- **Arteriovenous malformations**

Screening

Screening recommended (per AHA guidelines)

Class I

- **≥2 family members with aneurysm or SAH**
- h/o ADPKD, particularly with family history

Class IIA

- Reasonable to screen patients with aortic coarctation and primordial dwarfism

Note: Initial screening in young adulthood: age 25-30 y.o.

Should repeat screening at 7-10 year intervals

Thompson et al, Stroke,
2015;46:2368-2400

Screening

- Recent study showed incidence of aneurysms in women who smoke 19.1 % compared to 1.9% in women who do not smoke.
- Confirmed in multicenter study
- Cost effectiveness of screening published (2022)
- Consideration being given to add women who smoke to screening to the recommendations.

GENERAL thoughts at present

- Younger (<60 yrs) patients with aneurysms larger than 4-6 mm generally considered for treatment.
- The younger the patient, the stronger the consideration for treatment.
- Input from several physicians working together (Neurology, radiology, neurovascular neurosurgeon) is **EXTREMELY** helpful: Weekly conference.

For unruptured aneurysms

- At present, patients are evaluated on a case by case basis trying to incorporate true morbidity of treatment balanced against best estimates of the natural history for that individual. In addition, psychological and social factors are often important in the final decision of if and how to treat an unruptured aneurysm.

The future: Artificial Intelligence in aneurysm detection and decision making

- Detection/follow up
- Decision making incorporating
 - Aneurysm specific factors in natural history and treatment risks
 - Patient specific factors in natural history and treatment risk
 - Genetics

THANK YOU

