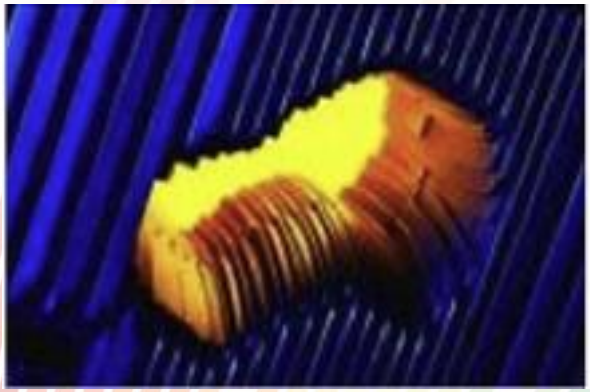
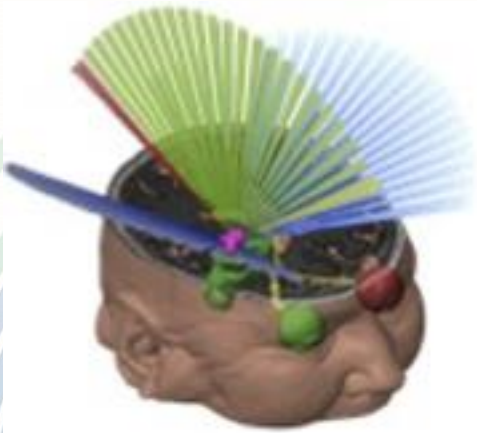
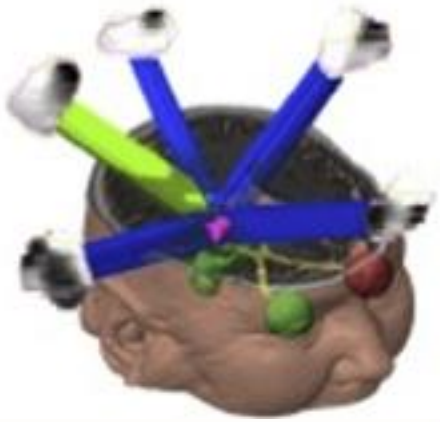
Refresher Course ACRO ALATRO Endorsed by ASTRO
1-2 septiembre 2023
Bogotá-Colombia

1.er Simposio ACRO-ALATRO de Radioterapia Estereotáctica y Radiocirugía







Radiocirugia LINAC en Malformaciones Arteriovenosas

Ricardo Sánchez F.
Oncólogo Radioterapico
Hospital Universitario San Ignacio / Hospital Militar Central

Conflicto de intereses

- No tengo conflicto de intereses

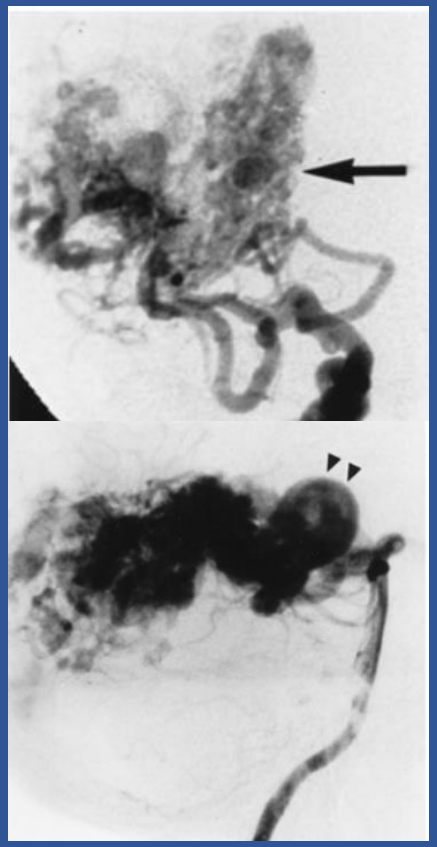
Introducción

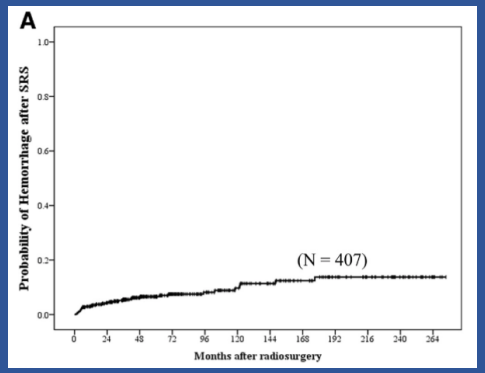
- Patologias vasculares poco frecuentes.
- Menores de 40 años.
- Tasa de hemorragia 2% - 4%.
- Tasa de resangrado 6% - 18%.
- Mortalidad / hemorragia: 12% - 66%.
- Déficit neurológico: 20% - 40%.

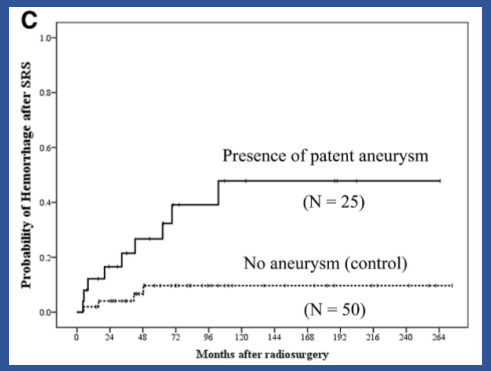
Laakso,A et al. Neurosurgery 2008; 63 (2): 244 – 53.
Imagen:Endovascular Embolisation of Brain Arteriovenous Malformation (AVM). NHS The walton center NHS Foundation trust.

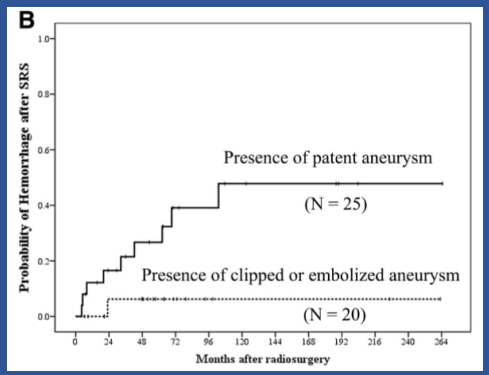
Factores de riesgo de hemorragia

- Tamaño pequeño del nido
- Presencia de aneurisma + AVM 2,7% al 16,7%
- Drenaje venoso profundo exclusivo
- Localización profunda o en fosa posterior
- Ectacia venosa



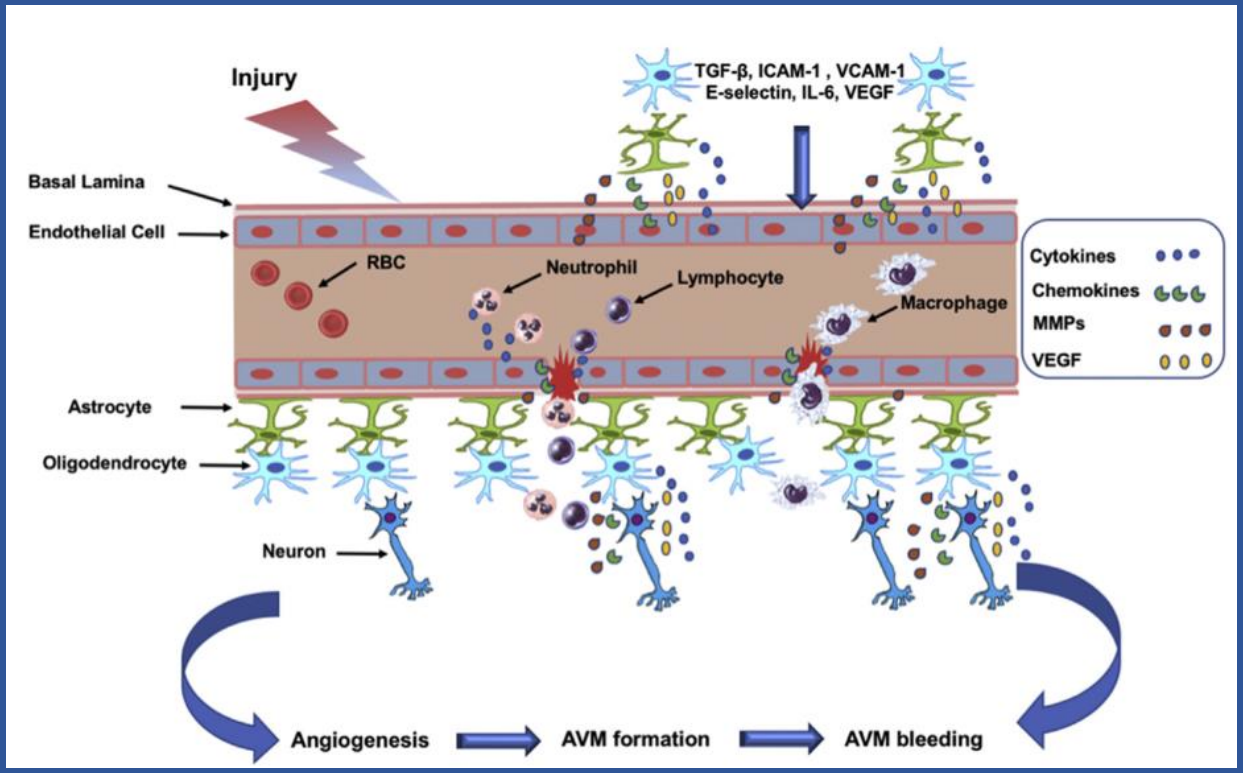






Kano et al . SRS for Hemorrhagic AVMs. Stroke, November 2015.

- Lesiones congénitas
- Factores genéticos
  - Osler – Weber – Rendu
  - Sturge – Weber
  - Wyburn – Mason
- Mecanismo inflamatorio



World Neurosurgery. 159: 314-326, March2022

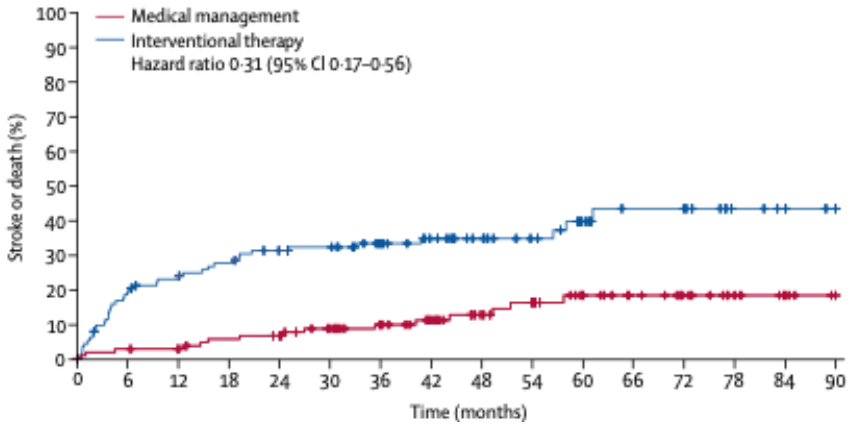
CUANDO INTERVENIR AVM?

Cuando intervenir una AVM?

	Medical management (n=110)	Interventional therapy (n=116)
Age, years	44·3 (12·2)	44·5 (12·5)
Sex		
Female	44 (40%)	50 (43%)
Male	66 (60%)	66 (57%)
White ethnicity	88 (80%)	100 (86%)
Right-handed	101 (92%)	109 (94%)
Clinical presentation*		
Seizure	45 (41%)	52 (45%)
Headaches	60 (55%)	56 (48%)
Focal deficit	10 (9%)	21 (18%)
Other	8 (7%)	3 (3%)
Asymptomatic	49 (45%)	45 (39%)
Modified Rankin Scale score		
0	51 (46%)	57 (49%)
1	59 (54%)	59 (51%)
Spetzler-Martin grade†		
I (%)	33 (30%)	32 (28%)
II (%)	27 (25%)	45 (39%)
III (%)	35 (32%)	29 (25%)
IV (%)	15 (14%)	8 (7%)
Concurrent arterial intracranial aneurysms		
Associated aneurysm‡	21 (19%)	15 (13%)
Unrelated aneurysm (%)	7 (6%)	4 (3%)
Venous drainage pattern†		
Superficial only	69 (63%)	79 (69%)
Any deep	41 (37%)	35 (31%)
AVM nidus morphology		
Maximum diameter, mm	27·6 (11·1)	24·8 (12·1)
Maximum diameter <3 cm	61 (55%)	79 (68%)
Left-sided	51 (46%)	50 (43%)
Any lobar location	100 (91%)	105 (91%)
Infratentorial location	5 (5%)	8 (7%)
Eloquent location§	52 (47%)	55 (47%)

Medical management with interventional therapy versus medical management alone for unruptured brain arteriovenous malformations (ARUBA): final follow-up of a multicentre, non-blinded, randomised controlled trial

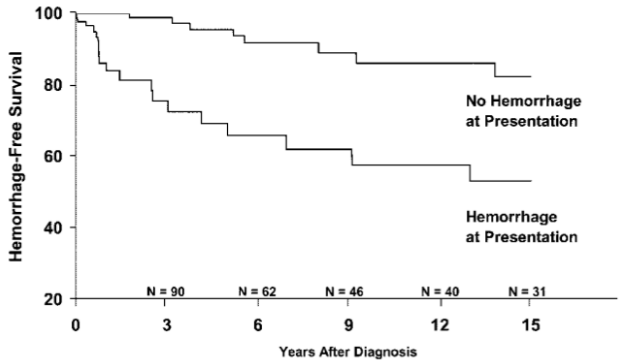
Jay P Mohr, Jessica R Overbey, Andreas Hartmann, Rüdiger von Kummer, Rustam Al-Shahi Salman, Helen Kim, H Bart van der Worp, Michael K Parides, Marco A Stefani, Emmanuel Houdart, Richard Libman, John Pile-Spellman, Kirsty Harkness, Charlotte Cordonnier, Ellen Moquete, Alessandra Biondi, Catharina J M Klijn, Christian Stapf, Alan J Moskowitz, for the ARUBA co-investigators

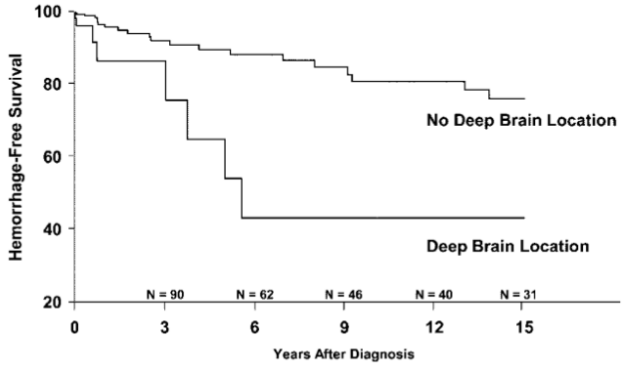


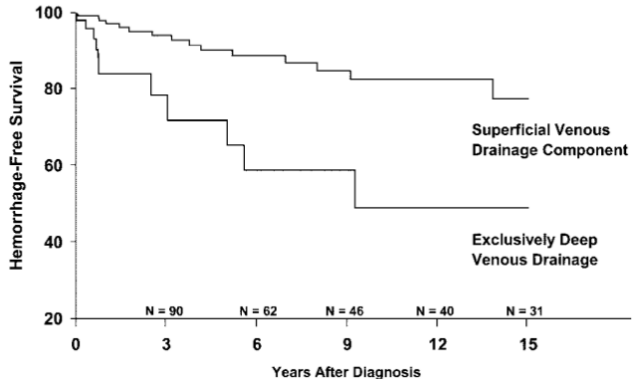
- 32% solo embolización.
- No análsis por intervención de tratamiento.
- Periodo corto de seguimiento (5 años).

Lancet Neurol 2020; 19: 573–81

Cuando intervenir una AVM?

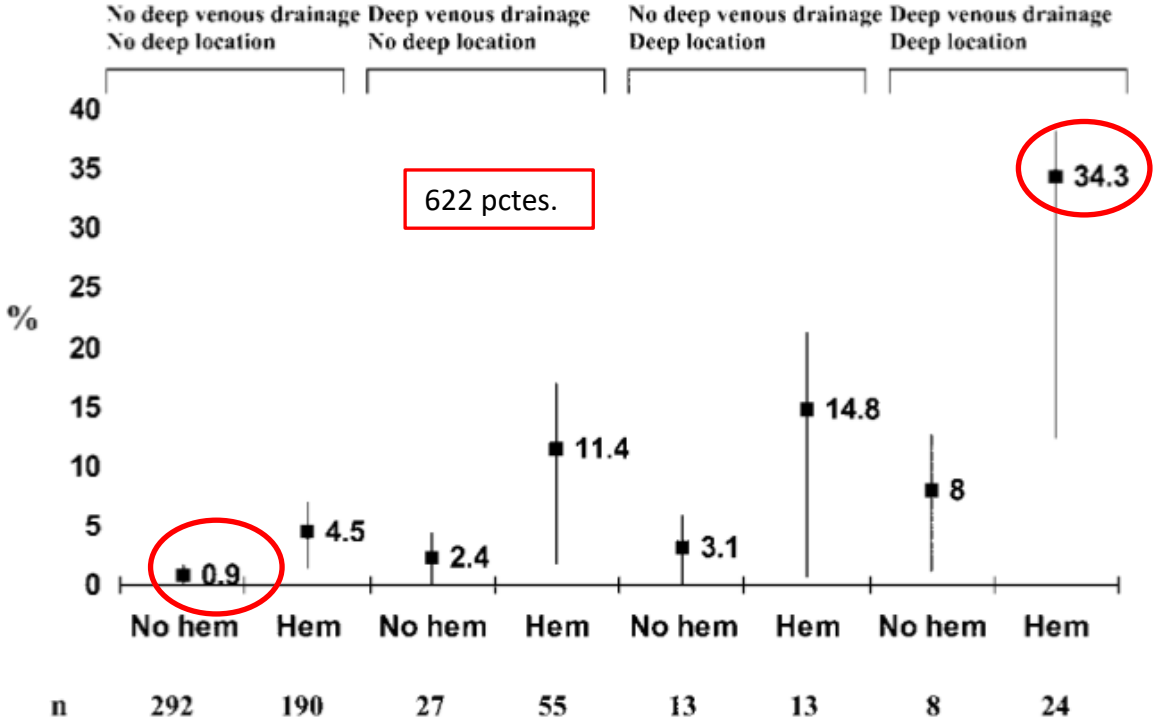






Predictors of hemorrhage in patients with untreated brain arteriovenous malformation

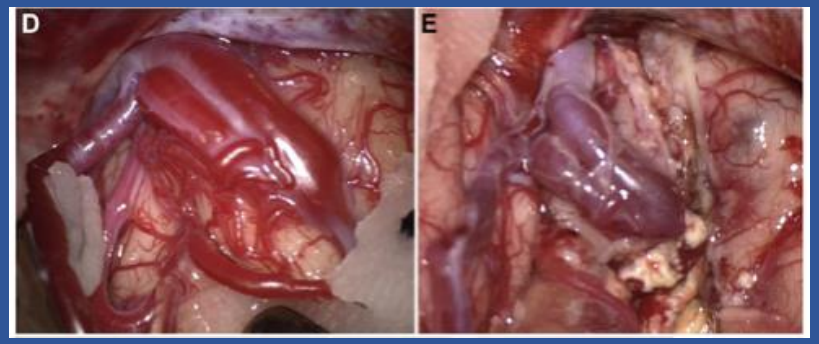
C. Stapf, MD; H. Mast, MD; R.R. Sciacca, EngScD; J.H. Choi, MD; A.V. Khaw, MD; E.S. Connolly, MD; J. Pile-Spellman, MD; and J.P. Mohr, MD



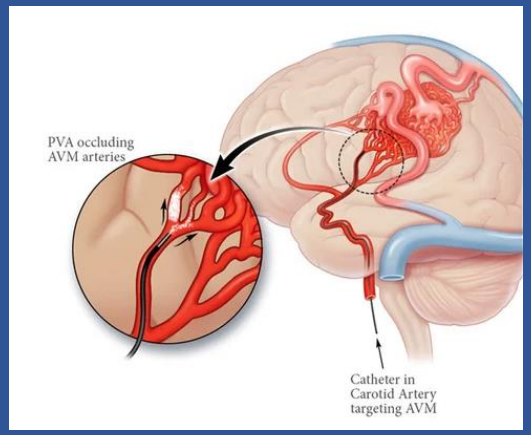
Neurology.2006;66:1350–1355

Intervenciones en AVM

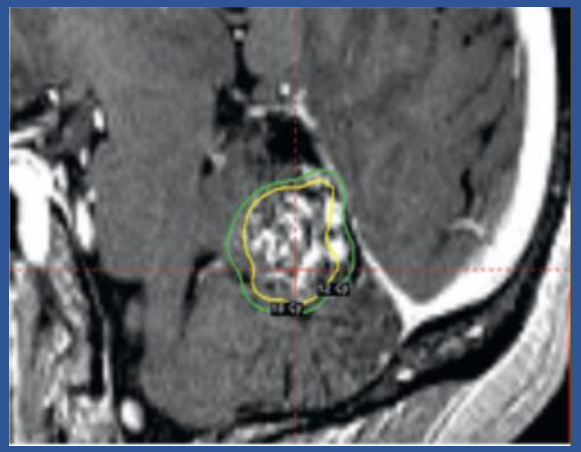
- TTO definitivo pero con riesgo.



- Complemento a la Cx y SRS.
- Oclusión completa 15% (<3cm, no elocuentes, poco pedículo arterial).



- Radiocirugía



World Neurosurgery. 159: 314-326, March2022
Principles of Neurological Surgery. January 1, 2018. Pag 727 – 735. e2.

Radiocirugía en AVM

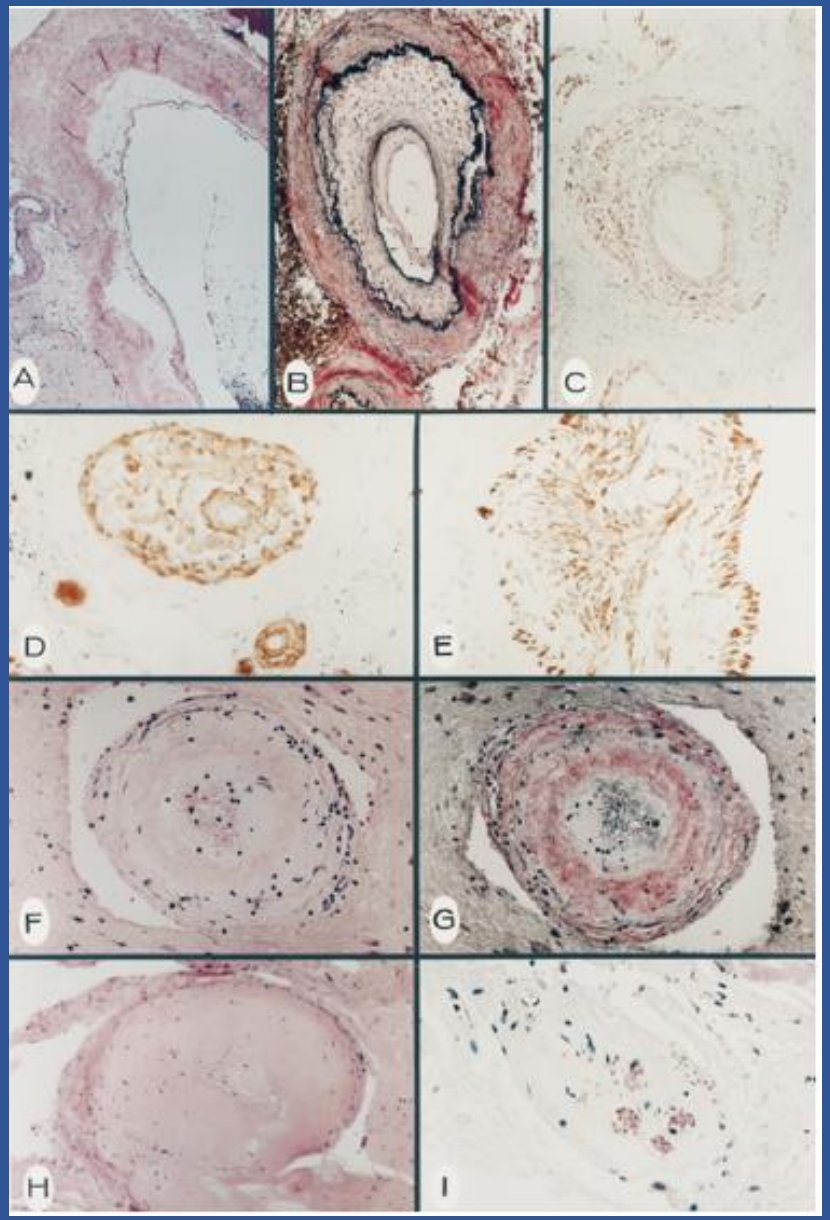
- Objetivo primario: Oclusión completa del nido

- En angiografía: tiempo normal de circulación sin evidencia de vasos patológicos en el nido y desaparición o normalización de la vena de drenaje.

- Oclusión entre 1-5 años.

Int J Radiat Oncol Biol Phys 49:1045-1051. 2001.

Cambios histopatológicos en AVM post SRS



- Daño endotelial y subendotelial.
- Proliferación de células de músculo liso intimal.

- SMA + y factor VIII -.

- Degeneración celular progresiva e incremento de la densidad de la matriz.
- Depósito de colágeno fibrilar denso.

- Hialinización celular y oclusión total del vaso.

J. Neurosurg. / Volume 87 / September, 1997

La Radiocirugía representa la única terapia biológica en el manejo de las AVM.

Neurosurgery. Focus. Vol 26. May 2009

Sistemas de graduación en AVM

Grading Scale	Points
Spetzler-Martin grading scale[19]	
Size	
<3 cm	1
3–6 cm	2
>6 cm	3
Venous drainage	
Superficial	0
Deep	1
Location	
Noneloquent	0
Eloquent*	1
Postoperative neurologic complications	
Grade I	1 (0%)
Grade II	2 (5%)
Grade III	3 (16%)
Grade IV	4 (27%)
Grade V	5 (31%)
Buffalo score[22]	
Arterial pedicles (*n*)	
1 or 2	1
3 or 4	2
≥5	3
Diameter of arterial pedicles	
Most >1 mm	0
Most ≤1 mm	1
Nidus location	
Noneloquent	0
Eloquent*	1
Perioperative complication†	
Grade 1	1 (0%)
Grade 2	2 (0%)
Grade 3	3 (14%)
Grade 4	4 (50%)
Grade 5	5 (75%)
Virginia radiosurgery AVM scale[23]	
AVM volume	
<2 cm^3	0
2–4 cm^3	1
>4 cm^3	2

Continues

Suplementary Grading

Age
<20
20-40
>40
Bleeding
Yes
No
Compactness
Yes
No

- SM más usado.
  - Validado morbilidad POP.
  - Tamaño más no volumen.
- Buffalo en embolización.
  - Isquemia y hemorragia.
- Virginia (Gammaknife / Linac).
  - Volumen (dosis marginal óptima)

Grading Scale	Points
Location	
Noneloquent	0
Eloquent*	1
History of hemorrhage	
No	0
Yes	1
Favorable outcome‡	
0 points	83%
1 point	79%
2 points	70%
3 points	48%
4 points	39%

World Neurosurgery. 159: 338-347, March 2022

Sistemas de graduación en AVM

Pollock-Flickinger Formula (RBAS)

AVM score = 0.1 * volume + 0.02 * age + 0.5 * location

Parameter info

- volume: in mL /cc
- age: in years
- location:
  - superficial (hemispheric/corpus callosum/cerebellar) = 0;
  - deep (basal ganglia/thalamus/ brainstem) = 1

Chance (in %) of AVM obliteration (with 95% CI)

- AVM score ≤1.00: 89 (79-94)
- AVM score 1.01 - 1.50: 70 (59-79)
- AVM score 1.51 - 2.00: 64 (51-75)
- AVM score >2.00: 46 (33-60)

Chance (in %) of Modified Rankin Scale decline (with 95% CI)

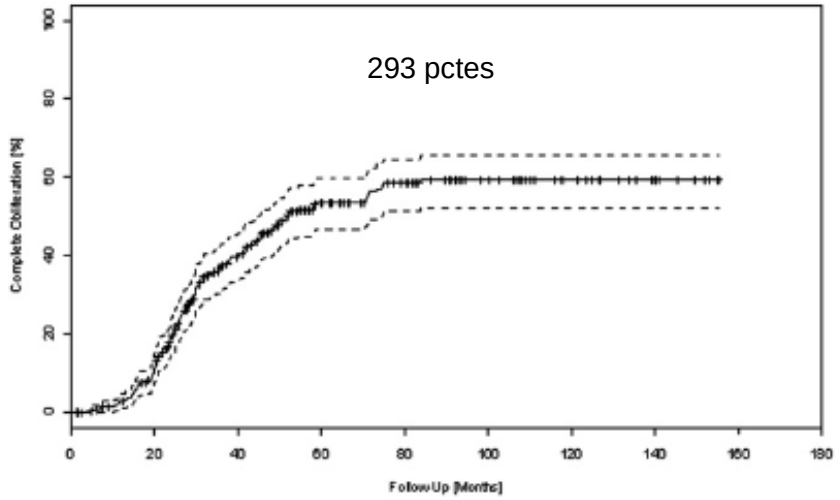
- AVM score ≤1.00: 0 (0-8)
- AVM score 1.01 - 1.50: 13 (7-22)
- AVM score 1.51 - 2.00: 20 (12-32)
- AVM score >2.00: 36 (24-50)

Neurosurgery 2008. 63:239-243

Proposal for a New Prognostic Score for Linac-Based Radiosurgery in Cerebral Arteriovenous Malformations

Stefanie Milker-Zabel, M.D.,* Annette Kopp-Schneider, Ph.D.,† Hannah Wiesbauer,* Wolfgang Schlegel, Ph.D.,‡ Peter Huber, M.D., Ph.D.,§ Jürgen Debus, M.D., Ph.D,* and Angelika Zabel-du Bois, M.D.*,§

**Department of Radio-oncology and Radiotherapy, University of Heidelberg, Heidelberg, Germany; †Department of Biostatistics, German Cancer Research Center, Heidelberg, Germany; ‡Department of Medical Physics, German Cancer Research Center, Heidelberg, Germany; and §Department of Radiotherapy, German Cancer Research Center, Heidelberg, Germany*



Heidelberg score	edad	diámetro	puntuación
Edad y diámetro	<= 50 años	<3cm	1
Edad o diámetro	> 50 años	>= 3cm	2
Edad y diámetro	> 50 años	>= 3 cm	3

- Factor 0,447.

Int J Radiation Oncol Biol Phys, Vol. 83, No. 2, pp. 525e532, 2012

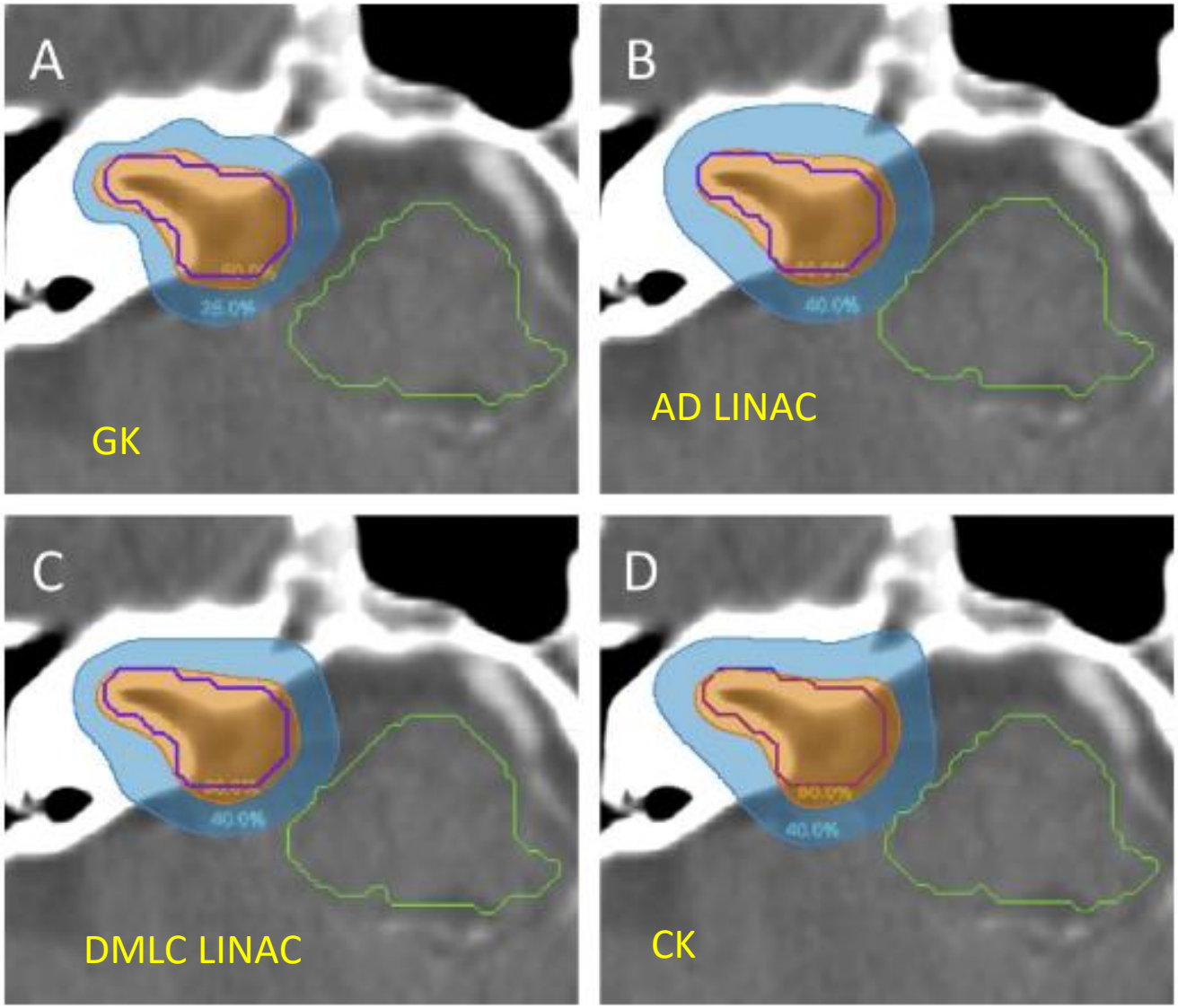
Comparación GK /LINAC

	Gammaknife	Linac
Experiencia Clinica	>	<
Precisión	Submilimetrica	Submilimetrica
QA	<	>
Uso de maquina	Dedicada SRS	No exclusiva SRS
Precio	Alto Cambio de fuentes 5 – 7 años	Menos costosa
Localización tumor	Difícil lesiones perisféricas	Fácil lesiones perisféricas
Tratamientos fraccionados	Menos experiencia	Mayor experiencia
Tiempo de tratamiento	>	<

Clinical Radiation Oncology. Gunderson & Tepper. 2012

Dosimetric comparison of different treatment modalities for stereotactic radiosurgery of arteriovenous malformations and acoustic neuromas

Thierry Gevaert [a,b,*], Marc Levivier [c], Thomas Lacornerie [d], Dirk Verellen [a,b], Benedikt Engels [a,b], Nick Reynaert [d], Koen Tournel [a,b], Michael Duchateau [a,b], Truus Reynders [a,b], Tom Depuydt [a,b], Christine Collen [a,b], Eric Lartigau [d], Mark De Ridder [a,b]

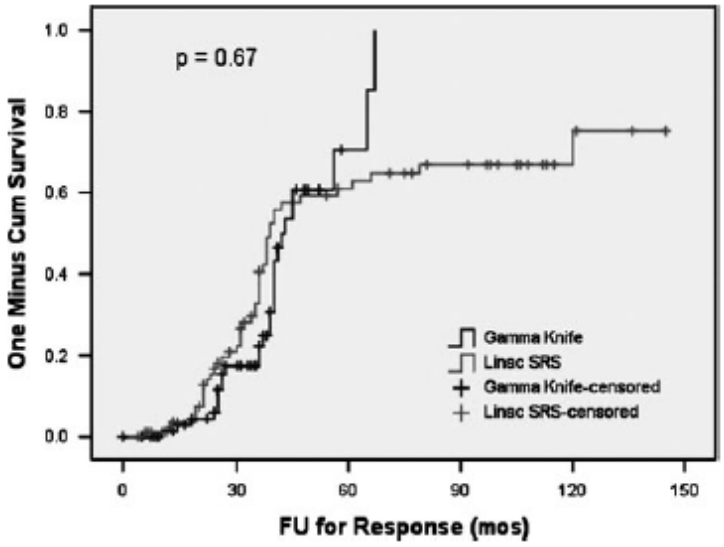


- IC: GK y CK
- IG: GK
- IH: LINAC

Treatment of arteriovenous malformations with linear accelerator–based radiosurgery compared with Gamma Knife surgery

Peter Orio, D.O., Keith J. Stelzer, M.D., Ph.D., Robert Goodkin, M.D., and James G. Douglas, M.D., M.S.

Departments of Radiation Oncology and Neurological Surgery, The University of Washington Gamma Knife Facility at Harborview Medical Center, Seattle, Washington; and Department of Radiation Oncology, Ceilo Cancer Center, The Dalles, Oregon



	Gammaknife (2000 – 2003)	LINAC (1992 – 2000)
No pacientes	91	96
Dosis media	20Gy	16Gy
Isodosis	50%	70%
Toxicidad crónica	8%	8%

J Neurosurg (Suppl) 105:58–63, 2006

Linear accelerator radiosurgery for arteriovenous malformations: Updated literature review

S. Yahya [a], G. Heyes [a], P. Nightingale [b], S. Lamin [c], S. Chavda [c], I. Geh [a], D. Spooner [a], G. Cruickshank [d], P. Sanghera [a,*]

[a] Hall-Edwards Radiotherapy Research Group, Queen Elizabeth Hospital, Birmingham, United Kingdom
[b] Wolfson Computer Laboratory, University Hospitals Birmingham, NHS Foundation Trust, United Kingdom
[c] Department of Neuroradiology, University Hospitals Birmingham, NHS Foundation Trust, United Kingdom
[d] Department of Neurosurgery, University Hospitals Birmingham, NHS foundation Trust, United Kingdom

Study	No	Obliteration rate	Dose (Median)	Treatment volume	Radio-surgery system	Reported Toxicity	Follow up (median) years
Current (2016)	47	74.5%	19.8 Gy	1.97	Linac based	6.4% (Hge = 4/47)	4.4
Zebel Du Bois et al. [8]	50	76%	18 Gy	4 cc	Linac based	12%	3.1
Bollet et al. [9]	118	54%	24.5 Gy/max	7.4 cc	Arc Rs therapy	3.9%	3.8
Gobin et al. [10]	125	65%	25 Gy(60–70% isodose)	6.2 cc	Linac based	3%	3.3
Miyawaki et al. [11]	73	50%	25.18 Gy/max	8.4 cc	Linac based	Hge = 5.1% necrosis = 22%	5.9
Schlienger et al. [12]	169	64%	25 Gy/60–70% isodose	2.46 cc	Linac based	2.3%	4.8
Barker et al. [13]	1250		10.5 Gy	33.7 cm^3	Proton SRS	4.9%	6.5
Kano et al. [14]	474	48% at 3 years	20 Gy	3.8 ml	GK	6.4%	7.4
Bowden et al. [15]	40	53% at 3 years	21 Gy	3.85 cm^3	GK	6%	6
Colombo et al. [16]	102	81.2%	26.25 Gy	21.05 ml	Cyber knife	2.9%	3
Maruyama et al. [17]	50	66%	20 Gy	1.5 cm^3	GK	1.7%	3.27
Touboul et al. [18]	100	51%	20 Gy	968 mm^3	GK	10%	3
Lunsford et al. [19]	227	80% (37/46)	21.2 Gy	–	GK	4%	1.1
Douglas et al. [20]	95	71.4%	20	3.8 cm^3	GK	13.8%	3.1
Flickinger et al. [21]	264	73%	20 Gy	5.7 cm^3	GK	–	7
Gawish et al.	68	68%	19,8 Gy	10,6 cc	Linac based	20%	2.1

Pediatric Intracranial Arteriovenous Malformation: Long-Term Outcomes with Linear Accelerator (LINAC)-Based Radiosurgery

Ethan M. Glazener, MD,[a,*] Kenneth Lodin, MD,[a] Michael J. Miller, MD,[a] Matthew J. Frager, MD,[a] Javad Rahimian, PhD,[a] Joseph C.T. Chen, MD,[b] and Michael R. Girvigian, MD[a]

[a]*Department of Radiation Oncology, Kaiser Permanente, Los Angeles, California and* [b]*Neurorestoration Center, Keck School of Medicine, University of Southern California, Los Angeles, California*

Table 5 Comparison of LINAC-based pediatric AVM studies

Author Location	Year	No. of patients	Median age (y)	Median AVM volume (cc) (range)	Median follow-up (range)	Median prescription dose (Gy)	Obliteration rates	Hemorrhage
Nataf/France[28]	2003	49	12	3.5 (0.6-16)	34 (7-172)	25	61.2%	8.2%
Maity/USA[29]	2004	17	12	6.9 (0.7-25)	21 (9.4-63.1)	18	47%	0%
Zabel-Du Bois/ Germany[30]	2006	22	11.8	4.2 (0.4-26.5)	37.2 (20.4-87.6)	18	64%	23%
Reyns/France[31]	2006	100	12	1.7 (0.9-21.3)	26 (11-126)	23*	70%	1.7%
Buis/ Netherlands[32]	2008	22	13.8	1.8	24	19	68%	4.5%
Blamek/Poland[25]	2012	10	15.4	13.4 (0.56-36.81)	38.5 (13-120)	19	80%	0%
Galvan De la Cruz/Mexico[33]	2014	45	12.9*	3.67* (0.36-15.01)	37.7 (10-112)	17	66.7%	0%
Rajshekhar/ India[34]	2016	69	14	8.4* (0.6-41.8)	27.5*	15	63.8%	2.2%
Present study/USA	2019	34	14.4	2.9 (.23-27.31)	98 (36-200)	17	64.7%	5.9%

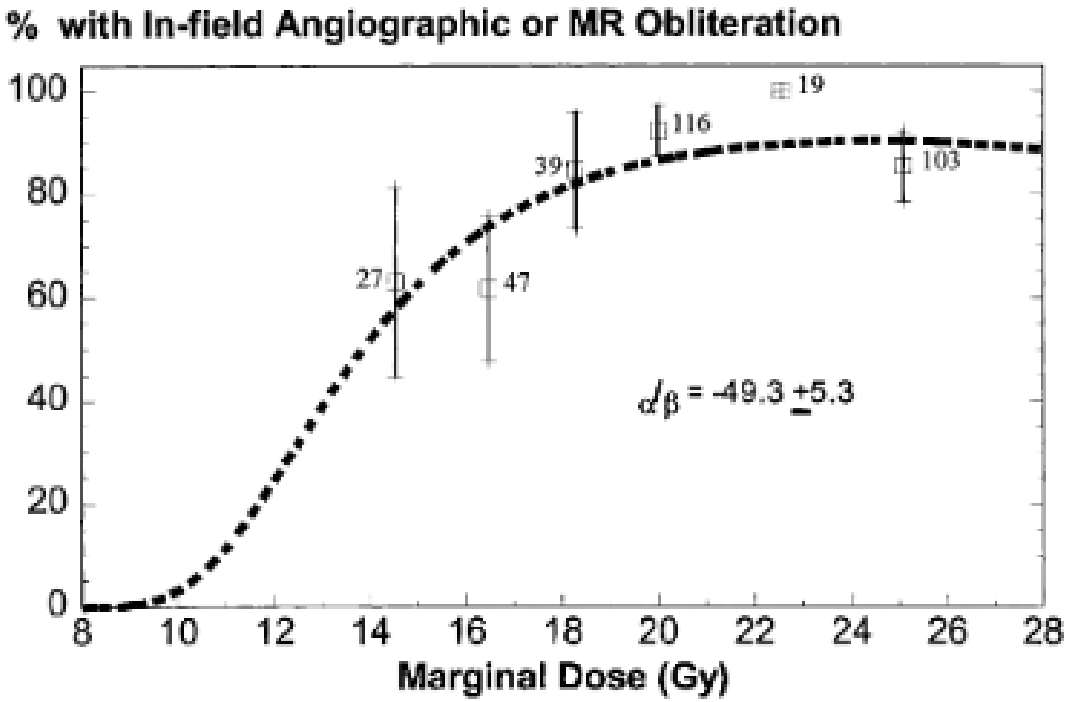
Table 3 Comparison of AVM characteristics and dose

AVM size (cc)	n (%)
<1.0	7 (20.6)
1.0–4.0	12 (35.3)
4.1–10.0	10 (29.4)
>10.0	5 (14.7)
AVM size (cc)	Median dose (cGy)
<1.0	1800
1.0–4.0	1800
4.1–10.0	1600
>10.0	1500
AVM location (n)	Median dose (cGy)
Eloquent (7)	1600
Noneloquent (27)	1760

- SRS LINAC en MAV intracraneanas en población pediátrica es segura y efectiva con un seguimiento a largo plazo.

Advances in Radiation Oncology (2020) 5, 850-855

Relación dosis respuesta en AVM



Dosis	Obliteración
26	88%
24	87%
22	85%
20	80%
18	73%
16	60%
14	44%
12	28%

Flickinger. Radioter Oncol 2002; 63: 347-354

Estrategias de Radiocirugía en AVM grandes

MAV
14 cc o 3cm

SRS dosis única / gran riesgo de toxicidad

- Volume-staged SRS
- Dose-staged SRS
  HSRT

Volume-staged versus dose-staged radiosurgery outcomes for large intracranial arteriovenous malformations

Shayan Moosa, B.A.,[1] Ching-Jen Chen, M.D.,[1] Dale Ding, M.D.,[1] Cheng-Chia Lee, M.D.,[2] Srinivas Chivukula, M.D.,[3] Robert M. Starke, M.D., M.Sc.,[1] Chun-Po Yen, M.D.,[1] Zhiyuan Xu, M.D.,[1] and Jason P. Sheehan, M.D., Ph.D.[1]

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Volume staged: patient and treatment charactaristics

Authors & Year	No. of Pts in Study*	No. of Females	No. of Pts Meeting Criteria†	Mean Age (yrs)	Mean AVM Vol (cm^3)	Modality of Treatment	Mean Total Dose (Gy)‡	Isodose Line	No. of Stages	Mean Time Btwn Stages (days)‡	Spetzler-Martin Grade	No. w/ Previous Hemorrhage	No. w/ Previous Embolization
Sirin et al., 2006	37	12/28 (42.9%)	14	37	24.9	GKRS	16	50%	2–3	5	I: 0%; II: 0%; III: 7.1%; IV: 39.3%; V: 53.6%	13/28 (46.4%)	13/28 (46.4%)
Back et al., 2008	23§	8/19 (42%)	19	33	20.2	GKRS	16.5–19.0	NR	2–3	2	NR	8/19 (42%)	0/19 (0%)
	7¶	3/6 (50%)	6	26	22.4	GKRS	17.3	NR	2–3	2	NR	0/6 (0%)	6/6 (100%)
Chung et al., 2008	7	4/6 (66.7%)	6	33	60	GKRS	16–18.6	NR	2	6.9	I: 0%; II: 0%; III: 16.7%; IV: 50%; V: 33.3%	3/6 (50%)	0/6 (0%)
Lee et al., 2009	23	7/23 (30.4%)	5	34	16.8	GKRS	20.8	53%	2	1–7	I: 0%; II: 30.4%; III: 43.5%; IV: 21.7%; V: 4.3%	18/23 (78.3%)	3/23 (13.0%)
Amponsah et al., 2011	5	4/5 (80%)	5	31	37.2	GKRS	18	50%	2 or 4	10	I: 0%; II: 0%; III: 0%; IV: 60%; V: 40%	2/5 (40%)	NR
Kano et al., 2012[25]	47	21/47 (44.7%)	47	33	22	GKRS	16	NR	2 (some re-treated)	4.9	I: 0%; II: 0%; III: 10.6%; IV: 59.6%; V: 29.8%	18/47 (38.3%)	21/47 (44.7%)
Huang et al., 2012	18	10/18 (55.6%)	18	35	22.9	GKRS	15–18	50%	2–4 (some re-treated)	3–9	I: 0%; II: 0%; III: 11.1%; IV: 55.6%; V: 33.3%	10/18 (55.6%)	8/18 (44.4%)
total	167	69/152 (45.4%)	120									72/152 (47.4%)	51/147 (34.7%)

Volume staged: Results

Authors & Year	Mean Follow-Up Duration (mos)	Mean Time to Complete Obliteration (mos)	Complete Obliteration Rate	Partial Obliteration Rate*	RIC Rate	Hemorrhage Rate	Mortality Rate
Sirin et al., 2006	50	NR	7/14 (50%)	7/7 (100%) [unspecified]	7/28 (25%)	4/28 (14.3%)	2/28 (7.1%)
Back et al., 2008	>36	NR	18/25 (72%)	NR	3/25 (12.0%)	4/25 (16.0%)	0/25 (0%)
Chung et al., 2008	28	53	2/6 (33.3%)	4/4 (100%) [unspecified]	0/6 (0%)	1/6 (16.7%)	0/6 (0%)
Lee et al., 2009	41.2	NR	2/5 (40%)	3/3 (100%) [unspecified]	0/23 (0%)	2/23 (8.7%)	2/23 (8.7%)
Amponsah et al., 2011	76.5	NR	2/5 (40%)	3/3 (100%) [unspecified]	2/5 (40%)	1/5 (20%)	0/5 (0%)
Kano et al., 2012[25]	87	NR	17/47 (36.2%)	5/30 (16.7%) [>75%]	6/47 (12.8%)	10/47 (21%)	5/47 (10.6%)
Huang et al., 2012	>36	NR	11/18 (61.1%)	NR	1/18 (5.6%)	5/18 (27.8%)	1/18 (5.6%)
total			59/120 (49.2%)	22/47 (46.8%)	19/152 (12.5%)	27/152 (17.8%)	10/152 (6.6%)
mean (95% CI)			47.5% (34.3–60.8%)	83.3% (37.1–100%)	13.6% (0.20–27.1%)	17.8% (12.3–23.3%)	4.6% (0.37–8.8%)

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Doses staged: patient and treatment charactaristics

Authors & Year	No. of Pts in Study†	No. of Females	No. of Pts Meeting Criteria‡	Mean Age (yrs)	Mean AVM Vol (cm^3)	Modality of Treatment	Mean Total Dose (Gy)§	Isodose Line	No. of Stages	Mean Time Btwn Stages (days)§	Spetzler-Martin Grade	No. w/ Previous Hemorrhage	No. w/ Previous Embolization
Lindqvist et al., 1986	26	14/26 (53.8%)	5	35	43	LINAC	42	NR	12	3.5	NR	14/26 (53.8%)	NR
Lindvall et al., 2003	36	18/29 (62.1%)	10	43	11	LINAC	30–35	90%	5	1–2	I: 31%; II: 31%; III: 34.5%; IV: 3.4%; V: 0%	14/29 (48.3%)	11/29 (37.9%)
Silander et al., 2004	26	12/26 (46.2%)	14	39	24	PBI	20–25	NR	2–4	1	I: 15.4%; II: 23.1%; III: 26.9%; IV: 26.9%; V: 7.7%	NR	NR
Veznedaroglu et al., 2004	7¶	4/7 (57.1%)	6	38	23.8	LINAC	42	89%	6	2	I: 0%; II: 0%; III: 28.6%; IV: 57.1%; V: 14.3%	2/7 (28.6%)	6/7 (85.7%)
	23**	13/18 (72.2%)	18	42	14.5	LINAC	30	80%	6	2	I: 4.3%; II: 0%; III: 43.5%; IV: 43.5%; V: 8.7%	10/23 (43.5%)	13/23 (56.5%)
Karlsson et al., 2005	28	15/28 (53.6%)	24	35	43	NR	41–50	90%	12	3.5	NR	13/28 (46.4%)	NR
Zabel-du Bois et al., 2006	15	9/15 (60%)	15	37	27	LINAC	26	80%	4–5	1	I: 0%; II: 0%; III: 33%; IV: 40%; V: 26.7%	8/15 (53.3%)	4/15 (26.7%)
Xiao et al., 2010	24	13/20 (65%)	20	34	46.84	LINAC	25–30	90%	5–6	1	I: 0%; II: 0%; III: 0%; IV: 35%; V: 65%	11/20 (55%)	10/20 (50%)
Blamek et al., 2013	49	25/49 (51%)	49	36	25.07	LINAC	20	NR	2–4	≥7	I: 0%; II: 30.6%; III: 36.7%; IV: 24.5%; V: 8.2%	18/49 (36.7%)	28/49 (57%)
total	234	123/218 (56.4%)	161									90/197 (45.7%)	72/143 (50.3%)
Park et al. 2016.	45			29	20	GK	13/17Gy		2	39m.	III 38% IV 24%	10/45 22%	6/45 (13%)

Los tratamientos por volume-staged en AVM grandes tiene mejores tasas de oclusión y toxicidad similar a doses-staged.
El manejo en AVM sin ruptura es controversial.

Dosis total de 30Gy/5F es superior a 25Gy/5F en respuesta a la obliteración o reducción de volumen, con baja toxicidad.

HSRT puede ser usada en MAV grandes para reducción de volumen o manejo adyuvante con otras modalidades (microcirugía, embolización, SRS dosis única)

Doses staged: Results

Authors & Year	Mean Follow-Up Duration (mos)	Mean Time to Complete Obliteration (mos)	Complete Obliteration Rate	Partial Obliteration Rate*	RIC Rate	Hemorrhage Rate	Mortality Rate
Lindqvist et al., 1986	>60	NR	1/5 (20%)	3/4 (75%) [>10%]	3/26 (11.5%)	4/26 (15.4%)	2/26 (7.7%)
Lindvall et al., 2003	38	39	7/10 (70%)	NR	4/29 (13.8%)	2/29 (6.9%)	0/29 (0%)
Silander et al., 2004	40	NR	2/14 (14.3%)	4/12 (33.3%) [>50%]	5/26 (19.2%)	0/26 (0%)	0/26 (0%)
Veznedaroglu et al., 2004	102/82†	27/48†	9/24 (37.5%)	NR	6/30 (20%)	0/30 (0%)	0/30 (0%)
Karlsson et al., 2005	>36	NR	2/24 (8.3%)	5/22 (22.7%) [>50%]	NR	13/28 (46.4%)	5/28 (17.9%)
Zabel-du Bois et al., 2006	31	29	3/15 (20%)	10/12 (83.3%) [>50%]	2/15 (13.3%)	3/15 (20%)	0/15 (0%)
Xiao et al., 2010	32	NR	0/20 (0%)	8/20 (40%) [>50%]	1/20 (5%)	1/20 (5%)	0/20 (0%)
Blamek et al., 2013	29	16	6/49 (12.2%)	13/43 (30.2%) [unspecified]	0/49 (0%)	2/49 (4.1%)	0/49 (0%)
overall			30/161 (18.6%)	43/117 (36.8%)	21/195 (10.8%)	25/223 (11.2%)	7/223 (3.1%)
mean (95% CI)		31.8	22.8% (4.4 to 41.1%)	47.4% (20.8 to 74.0%)	13.5% (6.7 to 20.3%)	12.3% (−0.74 to 25.2%)	3.2% (−2.3 to 8.7%)
Park et al. 2016.			29/45 (64%)				

Neurosur focus. Vol 37. September 2013.
Hiro Sparks, et al. World neurosurgery . 2019.

Repeated linac-based radiosurgery in high-grade cerebral arteriovenous-malformations (AVM) Spetzler–Martin grade III to IV previously treated with radiosurgery

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ABSTRACT

Background: Aim was to access outcome and toxicity of repeated linac-based radiosurgery in incompletely obliterated cerebral AVM.

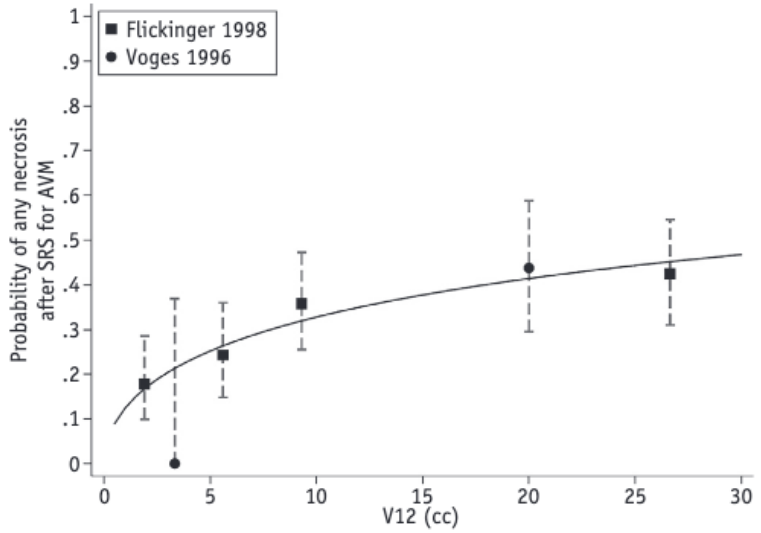
Patients and methods: Between 1998 and 2008, 11 patients were treated with repeated radiosurgery. The median dose to the 80%-isodose was 15 Gy (range, 12–18 Gy). During initial radiosurgery the median dose was 18 Gy (range, 9–22 Gy).

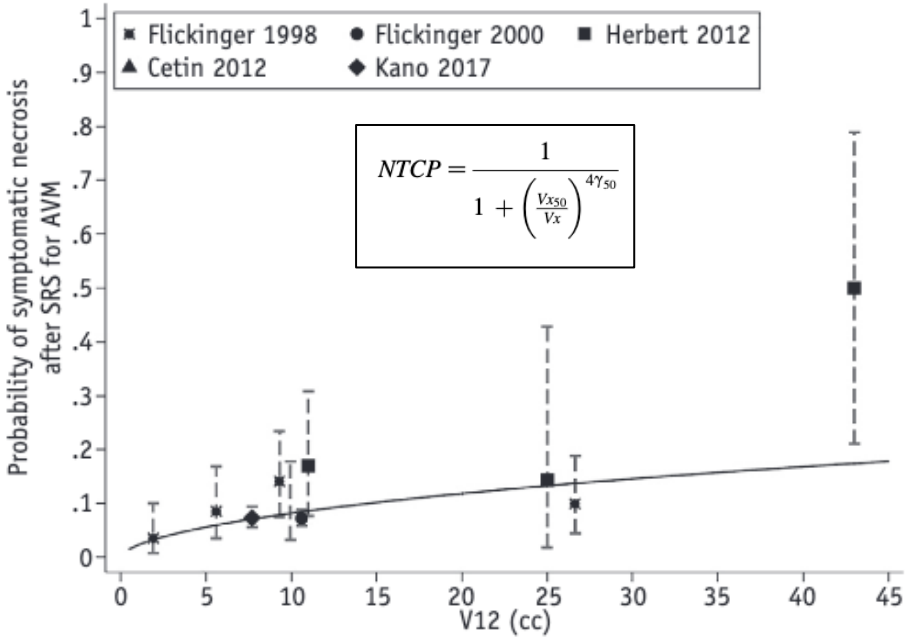
Results: The median time interval between initial radiosurgery and re-treatment was 9 years (range, 4–16 years). The median follow-up was 26 months (range, 2–115 months). Treatment response was seen in 8 patients (89%). Complete (partial) obliteration was achieved in 5 (3) patients (56%, 33%, respectively).The median time to complete obliteration was 26 months (range, 5–45 months). Pre-existing neurological symptoms improved in 2 patients (18%), were stable in 7 patients (64%) and worsened in 2 patients (18%). Prevalence of intracranial hemorrhage was 9% (1/11). Post-re-treatment intracranial hemorrhage rate was 2.7% (1/38 years at risk). During follow-up, no secondary malignancies or toxicity > grade III were observed.

Conclusion: Repeated linac-based radiosurgery in incompletely obliterated cerebral AVM is an effective treatment option with a high rate of treatment response and an acceptable risk for side effects. Marginal doses above 15 Gy might further improve the rate of complete obliterations.

 Radiotherapy and Oncology 98 (2011) 217–222

Dosis de tolerancia para tejido cerebral



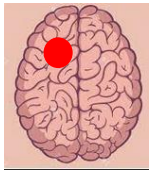
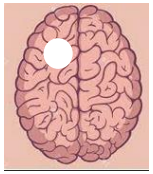


- Volume staged: los estudios publicados incluyen un número bajo de pacientes y no se han centrado en los efectos dosis-volumen y riesgo de necrosis.
- HSRT: los estudios publicados están para metástasis cerebrales.

Int J Radiation Oncol Biol Phys, Vol. 110, No. 1, pp. 68e86, 2021

Dosis de tolerancia para tejido cerebral

Se requiren restricciones más estrictas en áreas elocuentes

QUANTEC Lawrence et al. IJROBP 2010	V12 podría ser < 10 cc	 Variación entre los reportes en parametros de tratamiento y resultados en los diferentes centros
UK consortium: Stereot ablative body radiation (SABR) 2019	V12 cerebro excluyendo GTV podría ser < 10cc	 Riesgo de cualquier grado de radionecrosis

Description	Constraint	1 fraction		3 fractions		5 fractions		8 fractions		Source	End point (and magnitude of risk if previously quantified)
		Optimal (Gy)	Mandatory (Gy)	Optimal (Gy)	Mandatory (Gy)	Optimal (Gy)	Mandatory (Gy)	Optimal (Gy)	Mandatory (Gy)		
Normal brain (whole brain – gross tumour volume)	D10 cm^3	<12	–	–	–	–	–	–	–	Group consensus	Radiation necrosis
	D50%	<5	–	–	–	–	–	–	–	Group consensus	Cognitive deterioration

Factors Predictive of Symptomatic Radiation Injury After Linear Accelerator-Based Stereotactic Radiosurgery for Intracerebral Arteriovenous Malformations

Christopher Herbert, F.R.C.R.,* Vitali Moiseenko, Ph.D.,† Michael McKenzie, F.R.C.P.C.,* Gary Redekop, F.R.C.S.C.,‡ Fred Hsu, F.R.C.P.C.,§ Ermias Gete, Ph.D.,† Brad Gill, M.Sc.,† Richard Lee, Ph.D.,† Kurt Luchka, M.Sc.,† Charles Haw, F.R.C.S.C.,‡ Andrew Lee, F.R.C.S.C.,‖ Brian Toyota, F.R.C.S.C.,‡ and Montgomery Martin, F.R.C.P.C.¶

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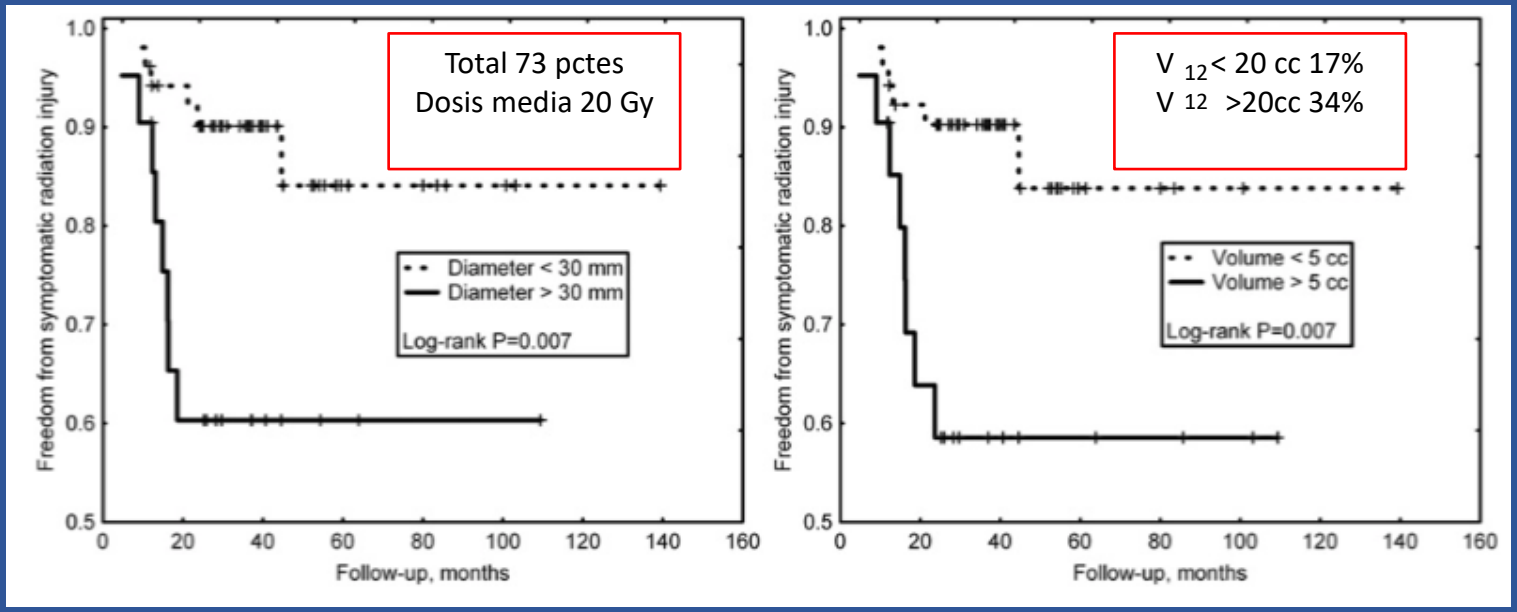


- Riesgo de lesión por radiación sintomática después de radiocirugía con LINAC estuvo relacionado al diámetro , volumen de la lesión y al volumen del tejido irradiado.

Int J Radiation Oncol Biol Phys, Vol. 83, No. 3, pp. 872e877, 2012

Patterns of Failure After Linear Accelerator Radiosurgery for Cerebral Arteriovenous Malformations

Youssef El Ouadih[1,5], Jean Jacques Lemaire[1,5], Bénédicte Vigier[2], Jean Gabrillargues[2], Aurélien Mulliez[3], Véronique Dedieu[4], Guillaume Dupic[4], Pierre Verrelle[4,6], Julian Biau[4,7], Toufic Khalil[1]

288 ptes
(44 ptes falla terapeutica)

Definición no clara del nido

- No se identifico bordes del nido
- No se identifico vena de drenaje
- Nido dividido por embolización previa
- Nido parcialmente tapado embolización previa

Recanalización

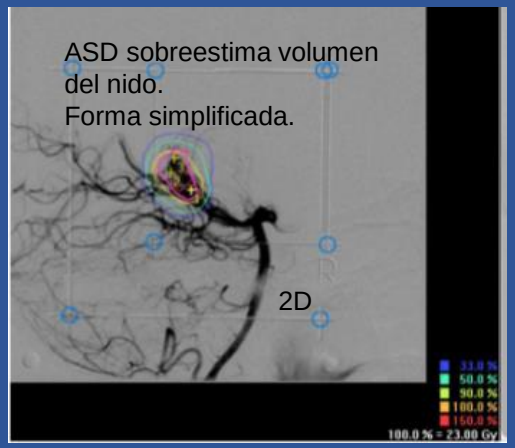
Embolización previa 77%

Dosis marginal < 18Gy

- Cercanía área elocuente
- Volumenes grandes

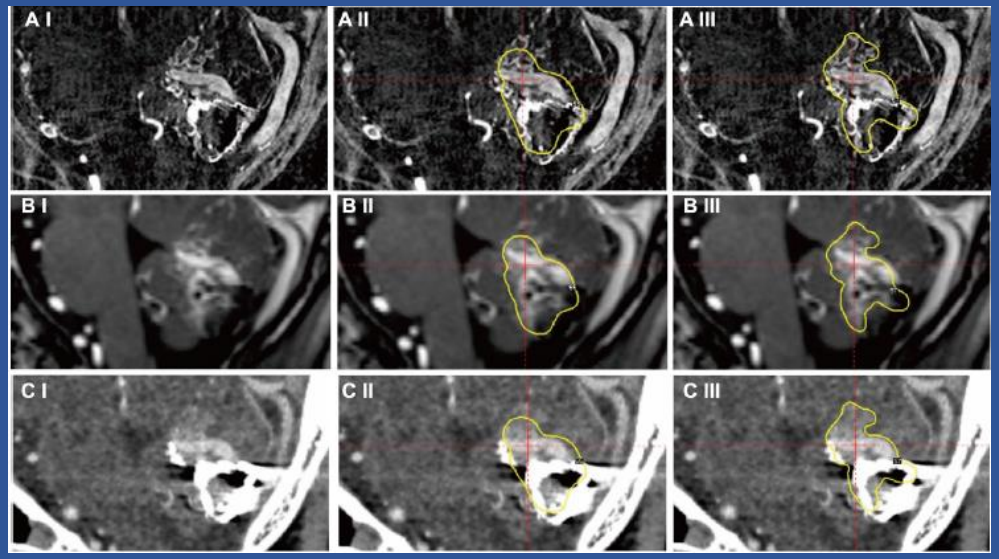
No se identifico causa

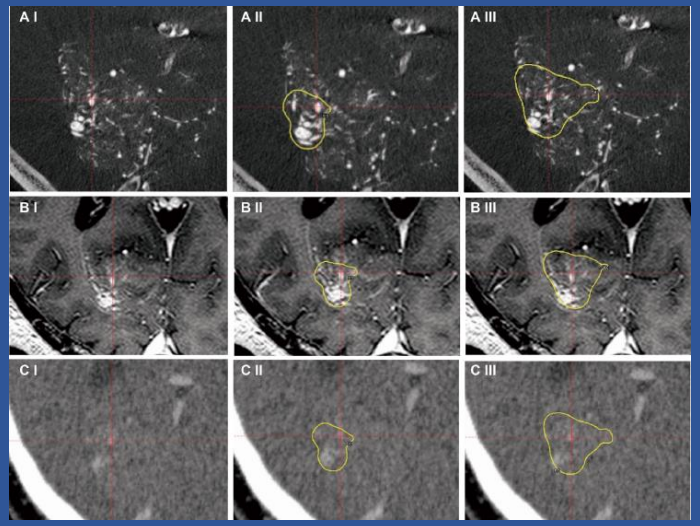
- Radioresistencia
- Hipoxia crónica por embolización
- Efecto meseta >25Gy



World Neurosurgery 136: e141-e148, April 2020

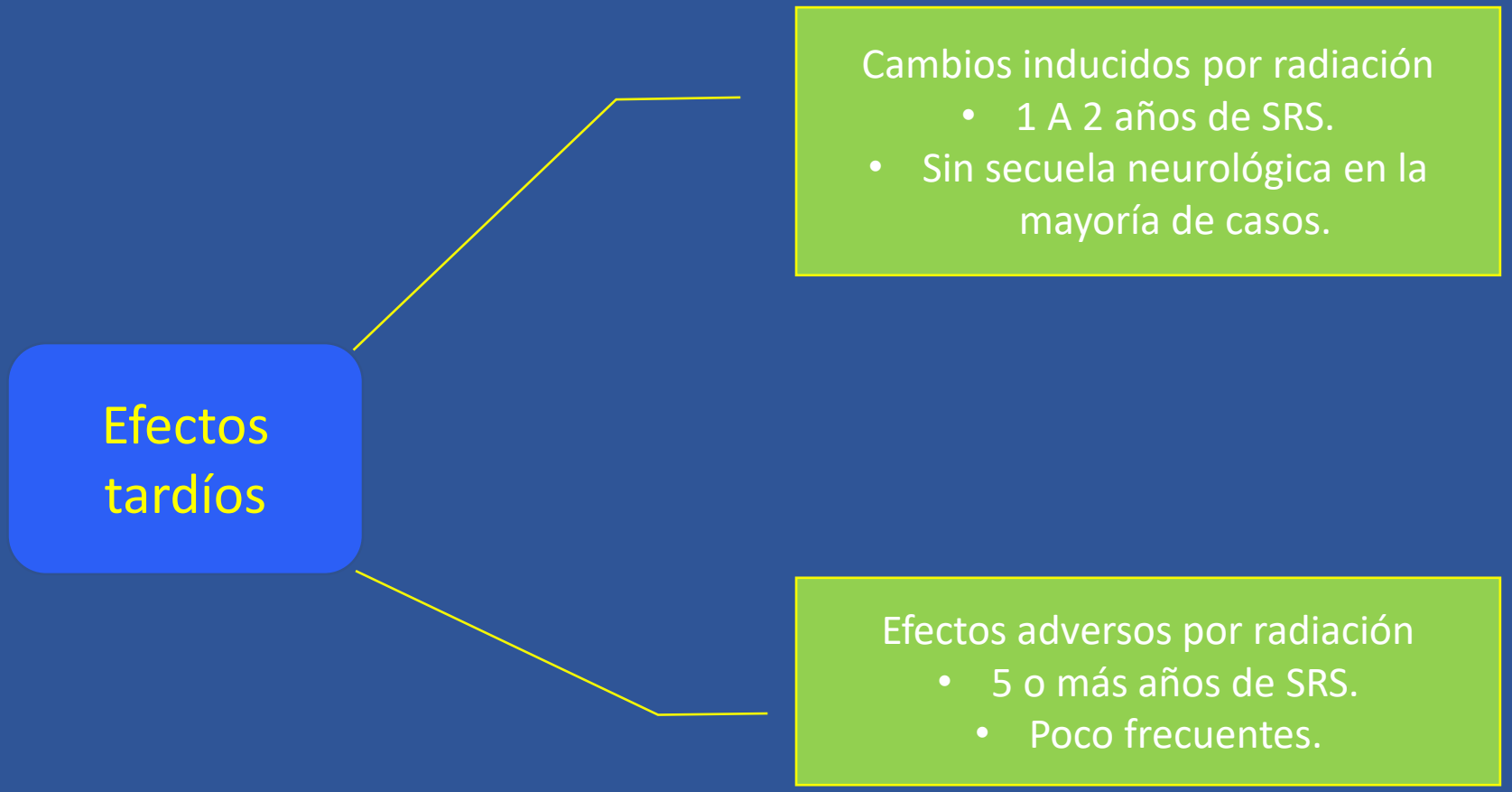
Rotational Angiography-Based Gamma Knife Radiosurgery for Brain Arteriovenous Malformations: Preliminary Therapeutic Outcomes of the Novel Method





Mejor definición del nido, mayor posibilidad de obliteración de forma más temprana.

Efectos tardíos por radiocirugía en AVM

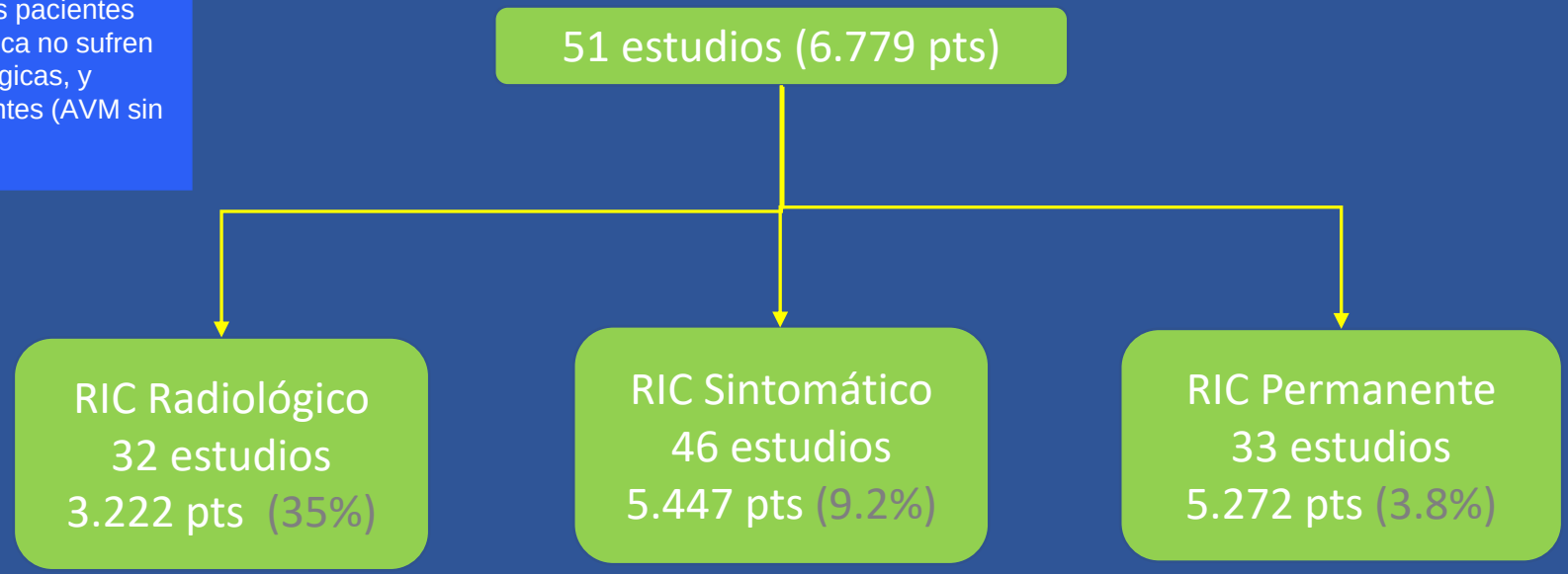


B. Pollock et al. Neurosurgery. 0:1-7.2017.

Radiation-Induced Changes After Stereotactic Radiosurgery for Brain Arteriovenous Malformations: A Systematic Review and Meta-Analysis

A. Ilyas et al.

La mayoría de los pacientes con RIC radiológica no sufren secuelas neurológicas, y déficits permanentes (AVM sin ruptura / RIC)

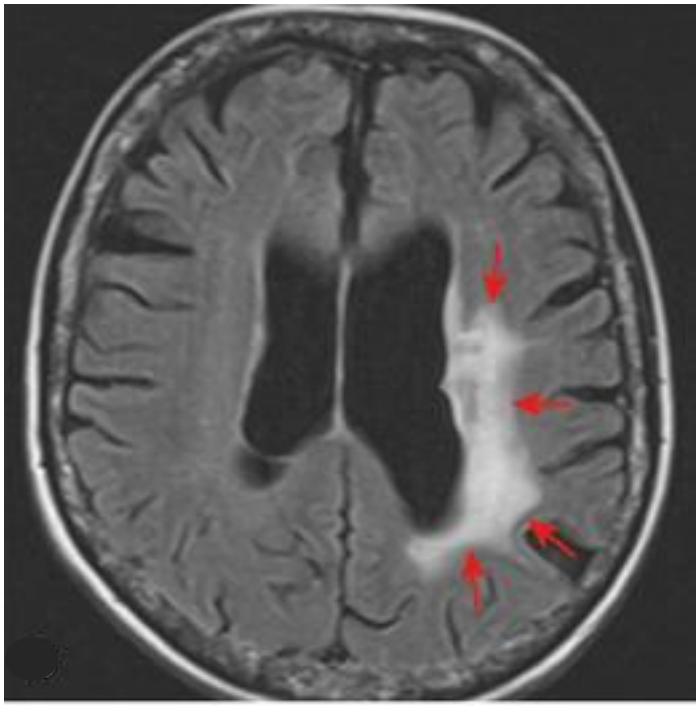


- 24/51 estudios LINAC

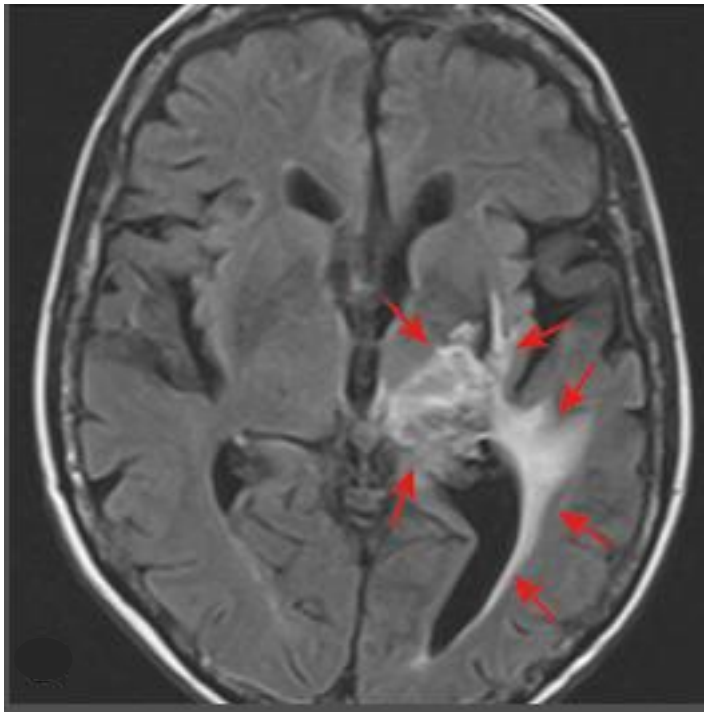
Las AVM profundas mayor riesgo de desarrollar RIC sintomático.

A. Ilyas et al. Neurosurgery. 0. 2017.

Cambios inducidos por Radiación



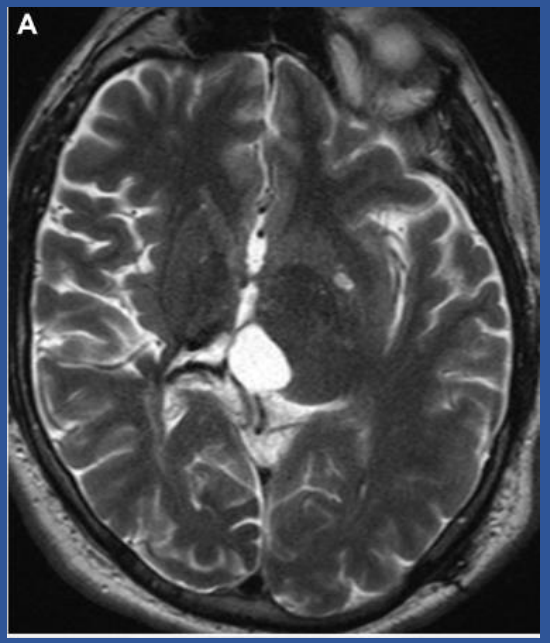
RIC sintomático 8 meses después



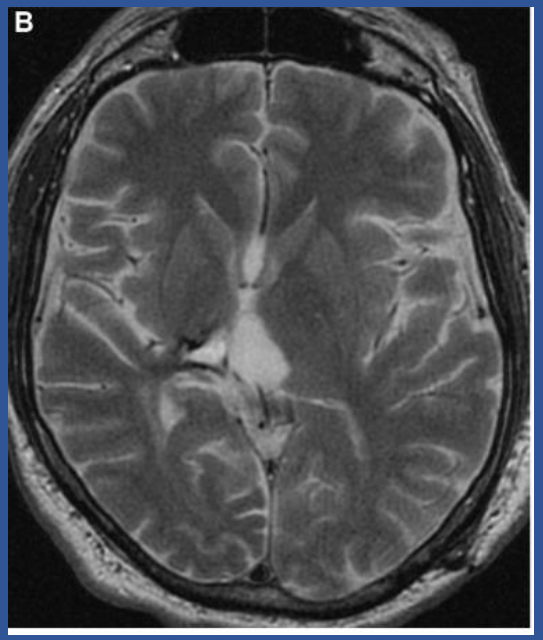
AVM talamica izq.

N. Ironside. Operative Neurosurgical Tecniques. Chapter 96, 1125-1133.e4. 2022.

Efectos tardíos por radiocirugía en AVM



Quiste asintomático 9 años después de SRS

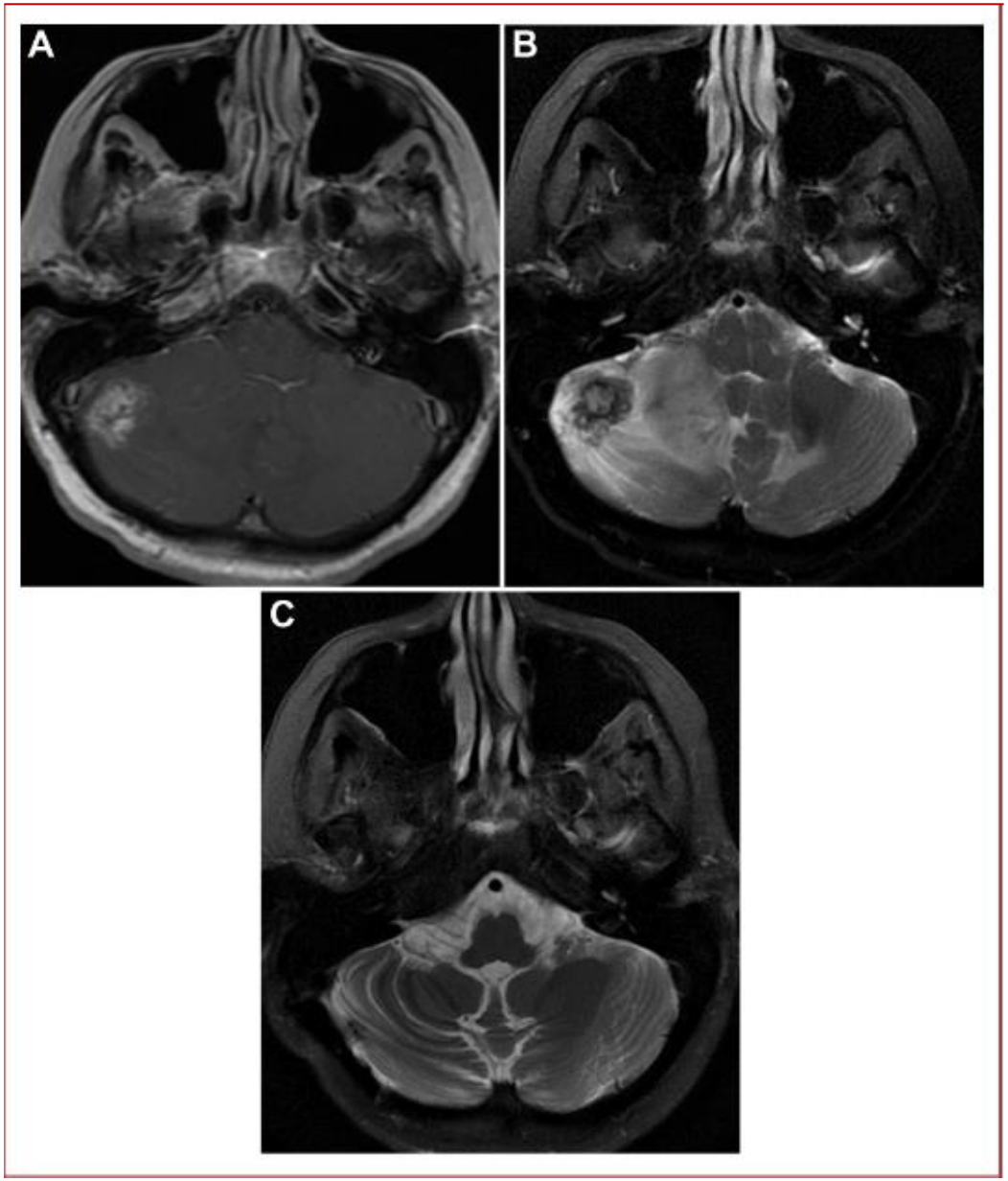


5 años después sin cambios

B. Pollock et al. Neurosurgery. 0:1-7.2017.

Efectos tardíos SRS en AVM

16 años después de SRS (AVM trombosada)



B. Pollock et al. Neurosurgery. 0:1-7.2017.

Cerebral Arteriovenous Malformations Trated with Linear Accelerator Stereotactic Radiosurgery Guided by Magnetic Resonance Imaging and Panangiography: A Latin American Experience

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4 Hospital Universitario San Ignacio, Bogotá, Colombia

INTRODUCTION

Cerebral arteriovenous malformations (AVM) are vascular lesions that include aberrant communication between anterial and venous systems. Treatment for AVM is still under debate. **Surgery, embolization, observation, and radiosurgery** are options for patients. Most data for radiosurgery came from the **Gammaknife** series. However, low middle-income countries have **financial constraints** to establish dedicated intracraneal neurosurgery machines.

AIM

Determine AVM obliteration rate in pattients treated with linear accelerator stereotactic radiosurgery (SRS) guided by magnetic resonance imaging and panangiography fusion with computed tomography simulation at a quaternary care institution in Latin America.

METHOD

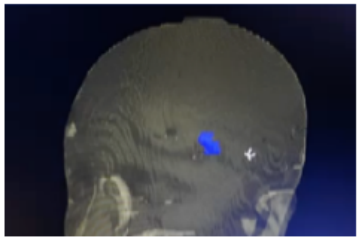
We conducted an **observational** study with pattient trated with SRS at our institution during **2011** and **2017**. Exclusion criteria were age younger than 14 and history of brain cancer. After IRB approval, data were collected retrospectively by reviewing medical records. Patients without available follow-up were contacted to gather missing information.

Primary outcome was **obliteration rate at 3 years**, confirmed by diagnostic imaging (MRI or cerebral panangiography). Secondary outcomes were **intracraneal bleeding, headaches, epilepsy and neurological deficit** at clinical presentaiton and after SRS.

Analysis included **sociodemographic data, AVM characteristics (locarion and Spetzler-Martin grading), and treatment features**. We used descrptive statistics, measures of central tendency and dispersion and proportions,

RESULTS

We included **85** patients. The mean age at treatment was 40,8 (14-73), 49,4% of patients were male, and 50,6% female. The most common location was the **frontal lobe** in 25,9% (n=22) and the parietal lobe in 24,7% (n=21). At diagnosis, 44% of patients had a history of intracranial hemorrhage **49** patients had received previous embolization. The mean dose of radiosurgery was **19,3 Gy** (14-25). The mean isodose was 95,25 (80-98). 35,3% of the patients had an AVM **Spetzler.Martin** grade 2, **40% grade 3**, and 12,9% grade 4. We obtained long-term follow-up data for **42** patients, with a median follow-up of **1366** days. **The overall obliteration rate was 60%**, based primarily on panangiography (59,1%). Symotoms after SRS included **headaches** (n=30) and **seizures** (n=10). 2 patients presented intracranial bleeding. We contacted all missing patients, but no follows-up data available for analysis. Most missing patients lived outside the city.



Video 1 *Planning target volume (PTV) of temporal AVM.*

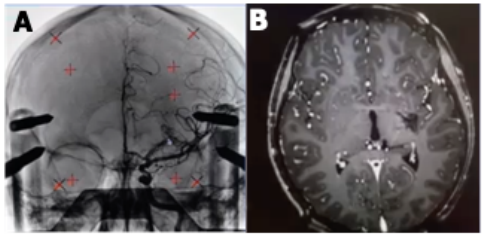


Figure 1. *Temporal Arteriovenous Malformation in cerebral panangiography (A) And magnetic resonance imaging (B).*

CONCLUSIONS

Tri-modality image fusion SRS with linear accelerator for AVM could be a **safe and accessible option in low-middle income ountries.** Health administrator issues, travel distances to access linear accelerators and multidisciplinary teams **hinder timely follow-up and surveillance imaging.** More prospective data are needed to define the role od SRS for AVMs.

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Conclusiones

- Los riesgos del tratamiento deben de ser balanceados en contra de los riesgos asociados con el curso natural de las AVMs.

- La Radiocirugía es el único manejo biológico de AVM, con una respuesta tardía para oclusión completa.

- La Radiocirugía con LINAC tiene resultados similares tanto en oclusión de AVM y complicaciones comparado con otras plataformas de dedicación exclusiva.

GRACIAS