

Radiation-Induced Changes After StereotacticRadiosurgery for Brain ArteriovenousMalformations: A Systematic Review andMeta-Analysis

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Learning Objectives

By the conclusion of this session, participants should be able to:

1. Define radiologic, symptomatic, and permanent RIC and quote the approximate rates of their formation following AVM SRS.

2. Identify risk factors for the formation of RIC following SRS for AVMs.

3. Describe management strategies for the treatment of RIC.

4. Provide a pathophysiologic explanation for RIC.

Introduction

Radiation-induced changes (RICs) are the most common complication of stereotactic radiosurgery (SRS) for brain arteriovenous malformations (AVMs), and they appear as perinidal T2-weighted hyperintensities on magnetic resonance imaging, with or without associated neurological symptoms. The aim of this systematic review and meta-analysis is to determine the rates of RIC after AVM SRS and identify risk factors.

Methods

A literature review was performed using PubMed and MEDLINE to identify studies reporting RIC in Based on pooled data from 51 studies, the overall rates of radiologic, symptomatic, and permanent RIC after AVM SRS were 35.5% (1143/3222 patients, 32 studies), 9.2% (499/5447 patients, 46 studies), and 3.8% (202/5272 patients, 39 studies), respectively. Radiologic RIC was significantly associated with lack of prior AVM rupture (odds ratio [OR] = 0.57; 95% confidence interval [CI]: 0.47-0.69; P < .001) and treatment with repeat SRS (OR = 6.19; 95% CI: 2.42-15.85; P < .001). Symptomatic RIC was significantly associated with deep AVM location (OR = 0.38; 95%) CI: 0.21-0.67; P < .001).

Conclusions

Results

Approximately 1 in 3 patients with AVMs treated with SRS develop radiologically evident RIC, and of those with radiologic RIC, 1 in 4 develop neurological symptoms. Lack of prior AVM hemorrhage and repeat SRS are risk factors for radiologic RIC, and deep nidus location is a risk factor for symptomatic RIC.



No. Studies	Radiologi	c RIC Rate	Meta	Meta-Analysis OR (95% CI)				OR	Avalue	Heterogeneity	
	A	в	6.01	0.1	1.0	2	120	(95% CI)	, -value -	p	xa
7 (1,607 pts)	Male Sex	Female Sex			н		_	1.03	0.79	0%	4.75 (p=0.5
5 (72 pts)	Spetzler-Martin G	irade (continuous)			H			0.97	0.92	0%	2.9 (p=0.5
8 (1,934 pts)	Nēdus Volum	a (continuous)			н			1.16	0.14	74%	26.3 (p+0.03
6 (220 pts)	Age (co	กถึงขอบร)			•			1.02	0.41	0%	3.8
6 (1,732 pts)	No Prior Embolization	Prior Embolization			н			1.10 (0.87-1.38)	0.43	0%	3.4 (p=0)
8 (1,927 pts)	Unupfured	Ruptured			н			0.57 (0.47-0.69)	<0.0001	0%	2.3 (p=0.1
6 (174 pts)	Deep Location	Superficial Location			H-H			0.78 (0.35-1.72)	0.54	0%	2.6 (p=0.7
8 (1,764 pts)	Margin Dose	(continuous)			•			0.98 (0.93-1.03)	0.33	0%	7.4 (p=0.)
4 (181 pts)	SS-RS	Repeat SRS			E	• 1		6.19 (2.42-15.85)	0.0001	0%	0.6 (p=0.
7 (184 pts)	Non-Obliterated	Obliterated			H+H			1.30 (0.64-2.64)	0.45	0%	2.0. (p=0.1
	A	8	0.01	1	1	10	100	(80 % Cil)		ρ	×
	Α	8	0.01	11	1	10	100	(96% Cit)		ρ	x
(2,612 pts)	Nidus Volum	a (continuous)						(0.97-1.19)	0.20	70%	(p=0.0
6 (1,000 pts)	Age (co	ntinuous)			+			0.99 (0.94-1.06)	0.87	46%	9.2 (p=0
7 (2,280 pts)	No Prior Embolization	Prior Embolization			н			0.77 (0.57-1.05)	0.10	32%	8.8 (p+0)
9 (2,526 pts)	Unruptured	Ruptured			-			0.55 (0.29-1.03)	0.06	57%	18 (p+0.
7 (1,270 pts)	Deep Location	Superficial Location		H	-1			0.38 (0.21-0.67)	0.0009	11%	6.7 (p+0.
6 (2,406 pts)	Margin Dose	(continuous)			H			0.94 (0.83-1.07)	0.35	58%	11.) (p+0.
4 (324 pts)	SS-SRS	Repeat SRS			+-	1		1.73 (0.73-4.14)	0.21	0%	1.9 (p=0.
4	Non-Obliterated	Obliterated			•	1		1.19 (0.28-5.01)	0.81	0%	0.8 (p=0
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(01 (08)											
No. Studies	Permaner	nt RIC Rate	Net	a-Anały	rsis OR	(95% C	0	OR		Hete	rogeneil
No. Studies	Permanen	nt RIC Rate	Me5	a-Analy	nsis OR	(95% C	0	OR (96% CI)	P-value	Hete P	rogeneit X ⁱ
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5 (1,186 pts) 4 (1,171 pts)	A Nidas Volum Age (co	nt RIC Rate B 2 (continuous) mitruous)	11e5	a-Analy	10 10	(96% C	0 ,30	OR (96% CI) 1.02 (0.96-1.09) 1.01 (0.98-1.04)	P-value -	Hete P 58% 6%	rogeneit X ⁴ 9.4 (p=0 3.2 (p=0
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Figure 3: Summary of the meta-analysis for the association of various factors with development of (A) radiologic, (B) symptomatic, and (C) permanent RICs.



Figure 2: Bar graph of incidence of various symptoms in patients with symptomatic (white) and permanent RICs (black). One patient each in the former cohort presented with short term memory loss and dysphagia. Two patients in the latter cohort presented with aphasia while one patient presented with altered mental status.