

뇌동정맥기형에 대한 감마나이프 방사선수술시 치료성적에 영향을 주는 인자들*

장종희 · 박용구 · 최재영 · 장진우 · 정상섭

= Abstract =

Factors Related to the Success of Gamma Knife Radiosurgery for Arteriovenous Malformations

Jong Hee Chang, M.D., Yong Gou Park, M.D., Jae Young Choi, M.D.,
Jin Woo Chang, M.D., Sang Sup Chung, M.D.

Department of Neurosurgery and Brain Research Institute, Yonsei University College of Medicine, Seoul, Korea

Objective : The goal of this study was to evaluate the effect of Gamma Knife radiosurgery(GKS) on cerebral arteriovenous malformation(AVM) and the factors associated with complete occlusion.

Patients and Methods : A total of 369 radiosurgical procedures for 336 patients with cerebral AVMs were performed between December 1988 and June 2001. Three hundreds and twenty - four cases of 293 patients who were treated with GKS procedures from May 1992 to December 2000 were analyzed. Various clinical and radiologic parameters were evaluated.

Results : The total obliteration rate for the cases with satisfactory radiological follow - up(more than 2 years) after GKS was 79.3%. In multivariate analysis, maximal diameter, angiographic form of AVM nidus, and number of draining veins significantly influenced the result of radiosurgery. In addition, marginal radiation dose, Spetzler - Martin grade, and flow pattern of AVM nidi also partly influenced the radiosurgical outcome.

Conclusion : GKS on cerebral AVM is considered as an effective treatment modality. The risk of hemorrhage seems to decrease within the latency interval between GKS and complete occlusion of nidus. Along with the size, topography, or radiosurgical parameters of AVMs, it is necessary to consider the angioarchitectural and hemodynamic aspects to select proper candidates for radiosurgery.

KEY WORDS : Gamma Knife · Radiosurgery · Arteriovenous malformation · Complete occlusion · Embolization.

서론
가 (nidus)
2 (hemodyna
(complete obliteration) mic)
60 85% 3)5)19)23)27) 1)22)
(angioarchitecture)

대상 및 방법

1. 대상환자

1988년 12월 2001년 6월 336명
 23명, 1992년 5월 369명
 313명, 346명 (nidi) 30.6%
 1992년 5월 2000년 12월 6명
 293명, 324명 27명
 2명, 2명 3명
 15명, (staged radiosurgery)
 14명, 2명
 29.7% (2.8~68.1)
 170명, 123명
 0.2명, 341.7명 34명
 25.1명 (6.3~90.2)
 145명 (44.8%),
 134명 (41.3%),
 45명 (13.9%)
 117명 (36.1%),
 28명 (8.7%)
 6명
 8명 (2.5%), 120명
 (37.0%)

2. 치료방법

324명 (58.6%) 190명
 77명 (23.8%)가

가 7명

18명 (5.6%)

가 가

11명

39명 (12.0%) 2명

가

가 4명 가

가 4명

3. 방사선수술시 치료계획

1999년 9월 KULA (version 5.4, Elekta, Sweden) GammaPlan (version 5.30, Elekta, Sweden) KULA
 가 270명, GammaPlan 가

54명

31.5Gy

(20~60Gy)

51.6%(30~90%)

16.2Gy (8.4~30Gy)

(isodose center)

1명 14명 5명

12.3cc(0.15~109.5cc)

4. 분석 요인

1) 증상발현(Presenting symptom)

324명 209명 (64.5%)가 71명 (21.9%)
 가 23명
 (steal phenomenon) 7명
 3명, 2명 가
 9명 3명

2) 혈관색전술(Embolization)

77명 (23.8%)

3) 해부학적 위치(Anatomical location)

MRI 가
 6명 가 182명 (56.2%),

(lentiform nucleus), (caudate nucleus), 240 (85.4%), 41
 (internal capsule) 58 (17.9%), (14.6%)
 20 (6.2%), 가 27 (8.3%), 14 (4.3%),
 (cistern)가 23 (7.1%)

(enlargement) (stenosis), (ectasia), (kinking), (folding), (venous collateral)

4) 횡단면 위치(Cross sectional location)

(34, 10.5%), (140, 43.2%),
 (72, 22.2%), (23, 7.1%)

(Fig. 2)¹⁾

9) 유출정맥의 수(Number of draining veins)

305 가 1
 가 144 (47.2%), 2 가 161 (52.8%)

5) MRI에서의 병소의 확인(Visibility on MRI)

(feeding artery)

MRI 가 18

(5.6%)가

10) 정맥유출의 종류(Type of venous drainage)

305 가
 125 (41.0%), 180 (59.0%)

6) 병소의 최대 직경(Maximum diameter of nidus)

305 가
 32.7 ± 16.6mm(5~90mm) . Yasargil³⁰⁾
 5 (micro)
 (5~10mm)가 13 (4.3%), 10~20mm 가 58
 (19.0%), 20~40mm 가 145 (47.5%),
 40~60mm 가 63 (20.7%), 60mm
 (giant) 가 26 (8.5%)

7) 병소의 형태(Form of nidus)

280 가
 (compact) 가
 (diffuse)
 가
 (Fig. 1)³⁰⁾.
 가 231 (82.5%), 가 49 (17.5%)

8) 병소의 혈류 양상(Flow pattern of nidus)

281 (high flow)
 (low flow)

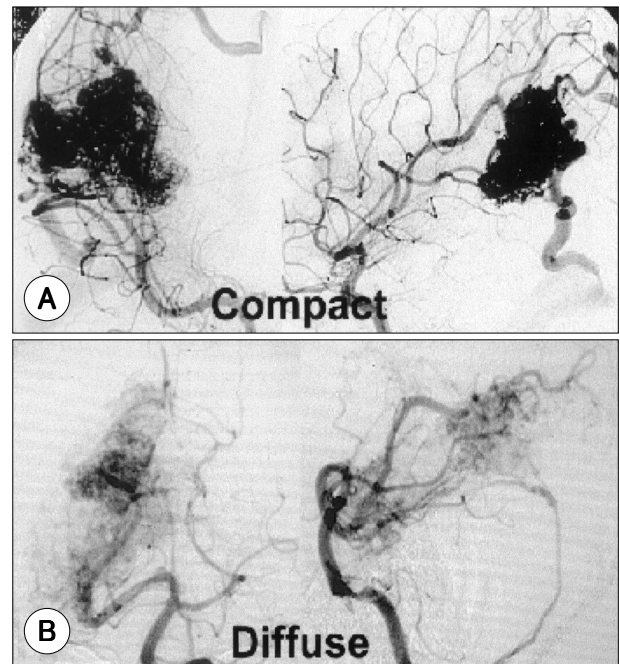


Fig. 1. Form of AVM nidus on angiogram. A : Compact type AVM with well-demarcated margin. B : Diffuse type AVM scattered throughout surrounding normal brain tissue.

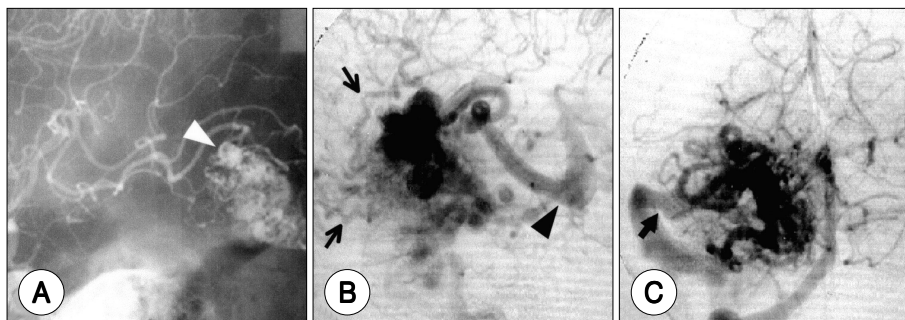


Fig. 2. Some angiographic characteristics of high flow AVM. A : Intranidal aneurysm(white arrowhead). B : Ectasia of draining vein (black arrowhead) and collateral draining veins(thin arrows). C : Stenosis of draining vein(arrow).

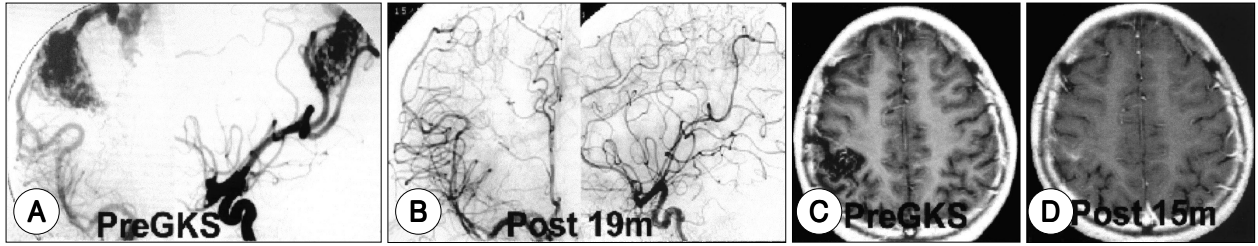


Fig. 3. Angiogram and MRI of 38 year-old male patient who presented with seizure. A : Pre-Gamma Knife surgery(GKS) angiogram showing an AVM nidus fed by middle cerebral artery. B : Follow-up angiogram at 19 months after GKS showing completely disappeared AVM nidus. C : Pre-GKS MRI showing a signal voiding lesion at postcentral gyrus. D : Follow-up MRI at 15 months after GKS showing small enhanced portion which reflects completely thrombosed nidus. There is no signal voiding lesion on postcentral gyrus.

11) Spetzler-Martin 등급

1 43 (14.1%), 2 102 (33.4%), 3 98 (32.1%), 4 58 (19.0%), 5 4 (1.3%)

12) 동맥류의 동반(Associated aneurysm)

74 (26.4%)
60 (81.1%)가
14 (18.9%)
22 (36.7%)
38 (63.3%)

13) 동정맥 션트 및 석회화의 동반(Associated arteriovenous shunting or calcification)

37 (13.2%) 14 (5.0%)

14) 혈종 유무(Presence of hematoma)

33 (11.8%)

15) 방사선수술적 요인들

5. 통계분석

Cox proportional hazard model

Cox

(months) . p

0.05 가

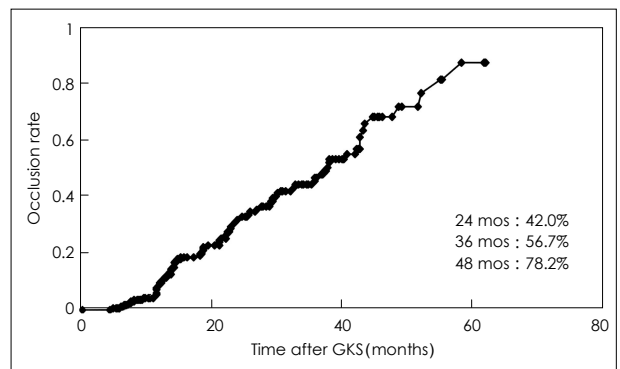


Fig. 4. Cumulative complete occlusion rate curve after GKS by Kaplan-Meier analysis. The actuarial cumulative complete occlusion rate was 42.0%, 56.7% and 78.2% at 24 months, 36 months and 48 months after GKS, respectively. GKS : Gamma Knife surgery, Occlusion rate : cumulative complete occlusion rate.

6. 연간 출혈율(Annual hemorrhagic rate)

가 (loss of follow-up) 가 (presumed annual hemorrhagic rate, pAHR)

B, O, 가, R, N

$$pAHR(\%) = \frac{B}{\{R+N \times R/(O+R)\}} \times 100$$

결 과

1. 방사선수술의 치료성적

2 가 150

(Fig. 3). , , , Spetzler - Martin ,

2
79.3% . 24
44.5%, 36 62.5%, 48 75.0%
(Fig. 4).

2. 방사선수술 후 동정맥기형의 완전 폐색과 관련된 요인들

Cox proportional hazard model

($p=0.097$). (multi-variate analysis)

, MRI 가 , (Table 1).

, Spetzler - Martin , ,
(univariate analysis)

3. 합병증

(perilesional imaging change)가 가 40
(12.3%) . 15

가 9 , 가
가 5 , 1

가 , 22 (6.8%)

, 1 (0.3%)

22 Table 2
. 6 가 7 , 3

4 38 , 49
, 49 , 72 . 2

(0.7%)

고찰

가

2

60~85%
5)19)23)27)29)

Table 1. Statistical analysis of various factors related to complete occlusion*

| Possible factors | Univariate | Multivariate | Favorable group |
|---------------------------|------------|--------------|-----------------|
| Diameter of nidus | 0.0001 | 0.0402 | Smaller size |
| Number of veins | 0.00003 | 0.0368 | Single vein |
| Form of nidus | 0.0072 | 0.0396 | Compact type |
| Spetzler-Martin grade | 0.0252 | 0.3289 | Lower grade |
| Marginal dose | 0.0081 | 0.0642 | Higher dose |
| Flow pattern | 0.0997 | 0.3745 | Low flow |
| Prior embolization | 0.2195 | | |
| Location of nidus | 0.9423 | | |
| Cross-sectional location | 0.5181 | | |
| Visibility on MRI | 0.2920 | | |
| Maximum dose | 0.0682 | | |
| Type of presentation | 0.1435 | | |
| Type of venous drainage | 0.8800 | | |
| Associated aneurysm | 0.8366 | | |
| Associated AV shunting | 0.1063 | | |
| Presence of calcification | 0.9002 | | |
| Presence of hematoma | 0.6640 | | |

* : Probability value is based on the proportional hazards model of Cox
Abbreviations : AV : arteriovenous

Table 2. Presumed annual hemorrhagic rates of AVM after Gamma Knife surgery*

| F/U(year) | No. of nidus with bleeding | No. of cumm. occluded nidus | No. of remained nidus | No. of no F/U | Presumed annual hemorr. rate(%) |
|-----------|----------------------------|-----------------------------|-----------------------|---------------|---------------------------------|
| 1 | 12 | 21 | 212 | 91 | 4.07 |
| 2 | 4 | 67 | 135 | 122 | 1.85 |
| 3 | 2 | 94 | 76 | 155 | 1.38 |
| >3 | 4 | | | | |

* : no F/U include cases that can not be followed and are not followed yet
Abbreviations : cumm. : cummulative, hemorr. : hemorrhagic

ler - Martin 가 , Spetz- 가 95 (29.3%) 가

가 가 77 (23.8%)

($p=0.2195$). 2

8)10)23)26)

가

(Fig. 5).

(recanalization rate)

7~20%

3)7)

3)19)23)

가 1~2

1. 방사선수술 전 혈관색전술

2. 병소의 위치

18)19)23)

2)19)28) Meder 19)

가

가

가

가

가

가

가

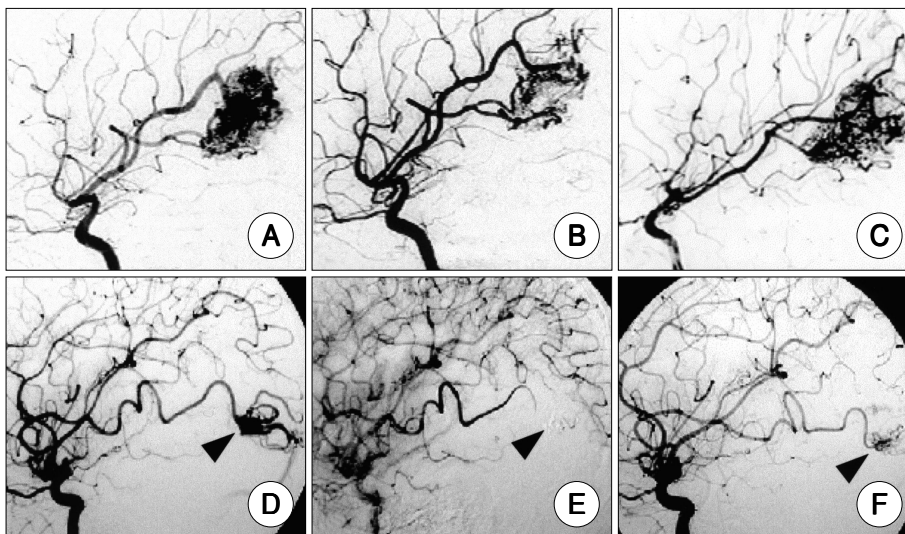


Fig. 5. Upper : Angiogram of 16 year-old male patient who presented with seizure (A-C). A : Initial angiogram showing an AVM nidus fed by middle cerebral artery. B : Postembolization angiogram showing decreased filling of AVM nidus. C : Angiogram at the day of Gamma Knife surgery, 1 month after embolization, showing refilling of previously embolized portion. Lower : Angiogram of 31 year-old male patient who presented with headache (D-F). D : Initial angiogram showing an AVM nidus fed by middle cerebral artery. E : Post-embolization angiogram showing complete occlusion of AVM nidus. F : Follow-up angiogram at 20 months after embolization showing recanalized nidus.

3. 병소의 크기

3)5)6)19)23) Lunsford¹⁶⁾ 가 2 가
 가 1ml 가 가 가 가
 100%, 1~4ml 85%, 4~10ml 58% 가 가
 Colombo²³⁾ 가
 15mm 가
 96.5%, 15~20mm 73.9% 가
 25mm 33.3% 가
 Ellis³⁾ 10ml가 가 가
 가 가
 (p=0.0402). 가 Pollock²⁴⁾ 10 가
 가 6 가
 , Maesawa¹⁷⁾ 2 가
 가 41
 가 15)29) 가
 가 가
 2 가 , 2

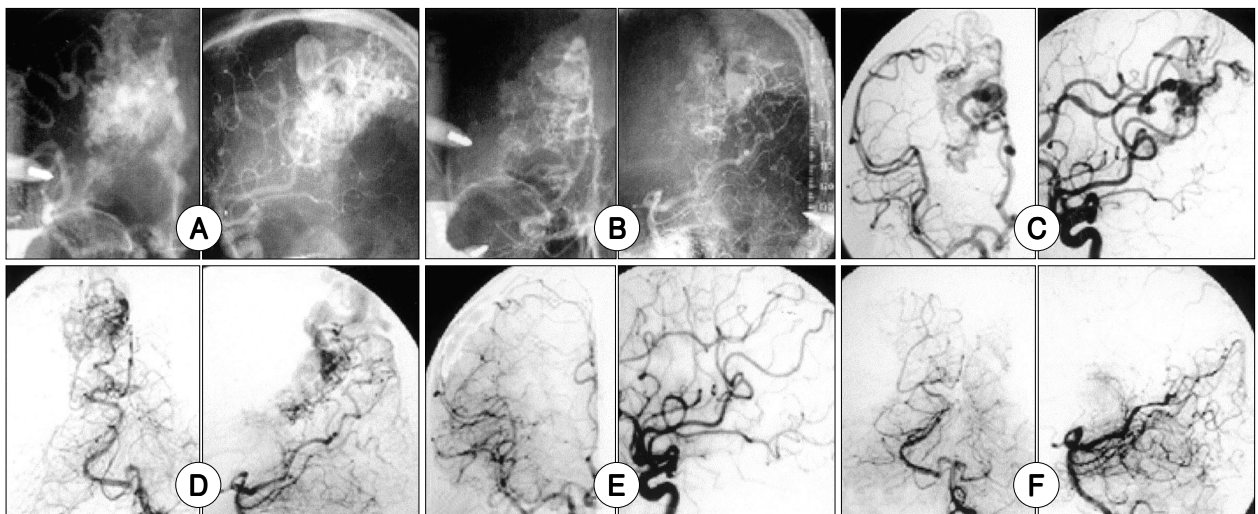


Fig. 6. Upper : Angiogram of 43 year-old male patient who presented with hemorrhage. Right internal carotid(A) and vertebral angiogram(B) at the day of the first Gamma Knife surgery(GKS) showing large AVM nidus fed by both anterior and posterior circulation. Middle : Follow-up angiogram at 23 months after the first GKS showing decreased but remained AVM nidus which was still fed by both anterior(C) and posterior circulation(D). We performed the second GKS for residual nidus. Lower : Follow-up angiogram at 37 months and 14 months after the first and the second GKS, respectively showing completely disappeared AVM nidus(E & F).

6. 혈종의 동반

Ellis³⁾ 가 1
 Karlsson¹²⁾ 가
 (subendothelial cell) 가
 (organized) (resolved) 가

7. 방사선수술적 요인

Karlsson¹⁴⁾ 15Gy 50% 20Gy 70%
 Ellis³⁾ 15Gy 15Gy 20Gy 25Gy 56.5% 66.7% 87.5% 79.3%
 (p=0.0081), (p=0.0642).
 Spetzler - Martin 가

결론

8. 방사선수술 후 출혈위험

2~6% 가¹²⁾¹³⁾
 가⁴⁾¹²⁾ 가
 22 1/3 6
 1 4.07%
 2, 3 1.85%, 1.38%

- : 2001 8 13
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 - :
- 120 - 752 134
- : 02) 361 - 5625, : 02) 393 - 9979
- E - mail : ygpark@yumc.yonsei.ac.kr

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