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Clinical commentary

# Awake craniotomy for excision of arteriovenous malformations? A qualitative comparison study with stereotactic radiosurgery

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ABSTRACT

Treatment of arteriovenous malformations (AVM) located at the eloquent area has been a challenge. Awake brain mapping allows identification of a non-eloquent gyrus for intervention and can potentially facilitate resection with preservation of functions. An alternative treatment option is stereotactic radiosurgery (SRS). The objective of this study was to perform a qualitative comparison of the treatment outcome of awake AVM excision versus SRS. We conducted a 13-year retrospective review of AVM excision under awake craniotomy performed at Prince of Wales Hospital, Hong Kong, from 2003 to 2016. Patients' presentation, Spetzler-Martin (SM) grading, rate of obliteration and complication were reviewed and analyzed with the modified radiosurgery-based AVM score (RS score). Six patients had excision of AVM under awake mapping during this period of time. Two were SM Grade II and four were SM Grade III. Five located at the peri-rolandic region while one at the temporal language area. None had failed mapping. Five out of six achieved complete obliteration (83.3%). Qualitative comparative analysis had revealed better treatment outcome with awake AVM excision as compared to SRS with the obliteration rate of 100% versus 96% for RS score ≤1.00, 100% versus 78% for RS score 1.01–1.50, and 66% versus 50% for RS score >2.00 respectively. In conclusion, awake mapping and excision of AVMs at the eloquent area is feasible. Qualitative comparative analysis had revealed higher obliteration rate with awake AVM excision as compared to SRS.



## 1. Objectives

Treatment of high-grade arteriovenous malformations (AVMs) located at an eloquent area has been a challenge. Awake brain mapping allows identification of a non-eloquent gyrus for intervention and can potentially facilitate resection with preservation of functions. An alternative treatment option is stereotactic radiosurgery (SRS). The objective of this study was to perform a qualitative comparison of the treatment outcome of awake AVM excision with SRS.

## 2. Methods

We conducted a 13-year retrospective review of AVM excision under awake craniotomy performed at Prince of Wales Hospital, Hong Kong, from 2003 to 2016. Inclusion criteria included 1) microsurgical excision of AVM with craniotomy and 2) awake speech or motor cortical mapping. The anaesthetic technique performed was the "asleep-awake-asleep" procedure. The patient was first placed under general anaesthesia (asleep) with a laryngeal mask. Scalp block was performed with local anaesthetic (0.25% xylocaine with 1: 800,000 adrenaline) by the anaesthetists. It was followed by the application of Mayfield clamp. The head was turned 45 degrees to the contralateral side. Monitors with slides for testing of language were set up. Myocutaneous flap was elevated and craniotomy was performed. Dura was infiltrated with local anaesthesia. Sedation was stopped at this point and laryngeal mask was removed when the patient was conscious (awake). Intraoperative ultrasonography and doppler were used for localization of the AVM. A large dural opening was created for an adequate

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exposure of both the AVM and the potential gyrus for mapping. Cortical mapping was performed with Ojemann cortical stimulator and Cadwell stimulator. Naming, comprehension, calculation and motor functions were mapped (if applicable) with threshold up to 6 mA. After the mapping, the patient was then put back to general anaesthesia (asleep). Excision of AVM was then performed till draining vein turned blue and aiming at complete obliteration with ultrasound doppler showing no AVM. Patients' presentation, Spetzler-Martin (SM) grading, rate of obliteration and complication were reviewed. These were analyzed and compared with the modified radiosurgery-based AVM score (RS score), or the Pollock-Flickinger AVM score [1].

## 3. Results

In total 232 cases of AVM were treated at Prince of Wales Hospital, Hong Kong, during the study period from 2003 to 2016. Six patients had excision of AVM under awake mapping during this period of time, which accounted for 2.59% (6/232) of the AVM treated in the study centre. The average age at the time of operation was 31 years old (16–49 years old). Five presented with intracranial haemorrhage while one presented with seizures (Table 1). Two were SM Grade II and four were SM Grade III. Five were located at the peri-rolandic region while one located at the temporal language area. None had failed mapping. There was no intraoperative seizure. Two SM Grade II (100%) had complete excision of AVMs with no new neurological deficit (Fig. 1). Three SM Grade III (75%) had complete excision of AVMs (Fig. 2). One had postoperative haemorrhage with new neurological deficit (Fig. 3). One SM Grade III had subtotal excision. There was no mortality. Five had improvement in functional outcome (83.3%) in terms of modified Rankin Scale. Qualitative comparative analysis had revealed better treatment outcome with awake AVM excision as compared to SRS with the obliteration rate of 100% versus 96% for RS score $\leq$1.00, 100% versus 78% for RS score 1.01–1.50, and 66% versus 50% for RS score >2.00 respectively (Table 2). None had rebleed or new neurological deficit during a mean follow-up period of 45 months.

## 4. Discussion

Treatment of arteriovenous malformations (AVMs) has been a challenge. Spetzler et al. had developed a grading scale for "resectability" AVMs [2,3]. AVMs with Spetzler-Martin (SM) Grade I or II have been considered safe for surgical resection [4,5]. However, treatment of AVMs with high grading or locating at an eloquent area remained controversial [6]. Burchiel et al. first reported the technique of awake mapping for AVM excision in 1989 [7]. The technique of awake motor examination was also used in treatment of other vascular condition such as intracranial

**Table 1**
Background demographic of the patients and characteristics of the artery venous malformations (AVMs) which were treated with awake excision in this study. Patients' age, gender and presentation were included. Radiosurgery score of the AVMs were calculated based on the nidus size, age of the patient and the location of the AVM.

| Age | Sex | Presentation | Location | Nidus Size | Arterial feeder | Venous drainage | SM Grade | Radiosurgery Score* |
|---|---|---|---|---|---|---|---|---|
| 16 | M | ICH. R hemiplegia. Good recovery limb power 4/5 | L parietal | 0.9 cm × 2 cm | L MCA | SSS | II | 0.41 |
| 21 | F | ICH. Dysphasic with recovery. | L temporal | 5 mm × 8 mm | Left MCA | Transverse sinus through the vein of Labbe | II | 0.44 |
| 49 | M | ICH. Slurring of speech. Full power. | R posterior frontal | 6.51 mm × 7.29 mm × 6.51 mm | R MCA | Internal cerebral vein and straight sinus | III | 1.13 |
| 45 | F | ICH IVH. L hemiplegia. Good recovery limb power 4/5. | R frontal-parietal | 3.5 cm × 1.6 cm × 4.1 cm | R ACA and R MCA | SSS | III | 2.06 |
| 17 | M | Complex Partial Seizure since 11-year-old (09/2004). | L frontal | 3.2 cm × 4 cm × 3.5 cm | L MCA | Middle cerebral vein, veins of Labbe and Trolard | III | 2.58 |
| 39 | F | IVH with SAH | L parietal | 4 cm × 4 cm | L MCA | SSS | III | 3.98 |

M: Male. F: Female. ICH: Intracerebral haemorrhage. IVH: Intraventricular haemorrhage. SAH: Subarachnoid haemorrhage. R: Right. L: Left. ACA: Anterior cerebral artery. MCA: Middle cerebral artery. SSS: Superior sagittal sinus. cm: centimetre. mm: millimetre.

* Modified AVM Radiosurgery score (RS Score) or Pollock–Flickinger AVM score = (0.1 × volume [$cm^3$]) + (0.02 × age [years]) + (0.5 × location).

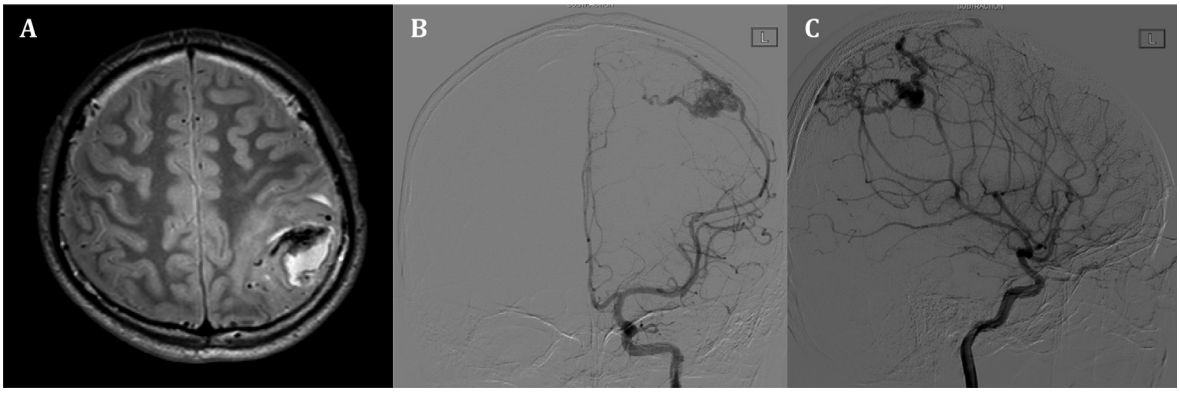


**Fig. 1.** Illustration of a Spetzler-Martin (SM) Grade II AVM in close proximity to an eloquent gyrus. A 16-year-old boy presented with sudden onset of right sided hemiplegia with limb power 0/5. (A) Magnetic resonance imaging (MRI) showing left fronto-parietal intracranial haemorrhage with flow void. He had a good recovery and was able to walk independently with one stick. Right sided power improved to 4/5. Digital subtraction angiogram (DSA) PA view (B) and lateral view (C) showing a left fronto-parietal 0.9 cm × 2 cm AVM with arterial supply from the left middle cerebral artery and venous drainage into the superior sagittal sinus (SM Grade II). Functional MRI was also performed (not shown) showing adjacent gyrus activation with motor (finger movement), speech and calculation function. In view of the good neurological status, he underwent AVM excision with awake mapping and complete obliteration was achieved with intact function and no new neurological deficit.

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