Interdisciplinary Neurosurgery: Advanced Techniques and Case Management 2 (2015) 98–102

Contents lists available at ScienceDirect

Interdisciplinary Neurosurgery: Advanced Techniques and Case Management

journal homepage: www.inat-journal.com

Case Reports & Case Series (CRP)

Utility of intraoperative diagnostic C-arm angiography for management of high grade subarachnoid hemorrhage ☆

Zhikui Wei [a], Tomas Garzon-Muvdi [a], Wuyang Yang [a], Justin M. Caplan [a], Martin G. Radvany [b], Geoffrey P. Colby [a], Alexander L. Coon [a], Rafael J. Tamargo [a], Judy Huang [a,*]

[a] Department of Neurosurgery, Johns Hopkins University School of Medicine, Baltimore, MD 21205, USA
[b] Division of Interventional Neuroradiology, Johns Hopkins University School of Medicine, Baltimore, MD 21205, USA

ARTICLE INFO

Article history:
Received 11 December 2014
Revised 19 February 2015
Accepted 7 March 2015

Keywords:
Subarachnoid hemorrhage
C-arm angiography
Digital subtraction angiography
Computed tomography angiogram
Cerebrovascular imaging

ABSTRACT

The accurate and efficient localization of underlying vascular lesions is crucial for prompt and definitive treatment of subarachnoid hemorrhage (SAH). To demonstrate the utility and feasibility of intraoperative C-arm angiography in cerebrovascular emergencies, we report five cases of high grade SAH and/or intracerebral hemorrhage (ICH) where intraoperative diagnostic C-arm angiography was safely and effectively utilized. Initial evaluations of all patients included a non-contrast head CT scan, which was followed by urgent decompressive hemicraniectomy as a life-saving measure in the presence of markedly elevated intracranial pressure. Further diagnostic evaluations were performed intraoperatively using a multi-purpose C-arm angiography system. The C-arm angiography findings greatly aided the intraoperative planning and led to definitive treatments in four cases of SAH by elucidating the underlying neurovascular lesions. With this treatment strategy, two of the patients made moderately good recoveries from their SAH and/or ICH with a Glasgow outcome score (GOS) of 4. Three of the patients expired despite maximal therapy mostly due to unfavorable presenting grade. These results suggest that C-arm angiography is a reasonable diagnostic and surgical planning tool for selected patients with high grade diffuse SAH who require immediate decompression.

Introduction

Subarachnoid hemorrhage (SAH) is an acute cerebrovascular event with an overall incidence of 8–11 per 100,000 person-years and a mortality of ~33% among in-hospital patients in the US [1].

Accurate and efficient localization of underlying vascular lesions is crucial for prompt treatment of SAH. Digital subtraction angiography (DSA) is the gold standard in the diagnosis of vascular lesions in SAH. However, DSA may be limited by time constraints during the acute management of critically ill patients with high grade SAH. Recently the use of computed tomography angiography (CTA) in the management of SAH patients has been reported [2]. Although CTA has a shorter acquisition time, it has less sensitivity in the detection of small aneurysms (<5 mm) or aneurysms at certain locations [3].

Here we report the utility of intraoperative C-arm angiography in the urgent management of five critically ill patients with high grade SAH. These cases suggest that C-arm angiography is useful in identifying vascular pathology intraoperatively in acutely unstable SAH patients.

Clinical presentation

Case 1

A 42-year old woman with hypertension was found unresponsive after a fall. Generalized tonic-clonic seizures were noted in the emergency room (ER) with a dilated left pupil and extensor posturing. A head CT showed diffuse SAH and a left temporal intracerebral hemorrhage (ICH) with intraventricular hemorrhage (IVH) (Fig. 1A). The patient received an emergent left-sided decompressive hemicraniectomy. Following the decompression, an intraoperative C-arm angiogram (ARCADIS Varic system, manufactured by Siemens Medical Solutions USA, Malvern, PA, USA) was performed through the right femoral artery puncture and catheterization of left and right common carotid and vertebral arteries. This demonstrated a bilobed left MCA bifurcation aneurysm measuring 3 mm (Fig. 1B). Subsequently, two small aneurysms, 3 mm each, were identified at the MCA bifurcation and were clipped. After confirming the patency of the MCA branches with indocyanine green (ICG) videoangiography [4], a dural substitute onlay graft was placed without the bone flap due to severe cerebral edema. A complete DSA angiogram confirmed obliteration of the MCA

☆ Source of support: No funding, financial interests or potential conflict of interest is involved in this study.

* Corresponding author at: Department of Neurosurgery, Johns Hopkins Hospital, Zayed Tower, Suite 6115F, 1800 Orleans Street, Baltimore, MD 21287, USA. Tel.: +1 410 502 5767; fax: +1 443 287 0683.
E-mail address: jhuang24@jhmi.edu (J. Huang).

http://dx.doi.org/10.1016/j.inat.2015.03.002
2214-7519/

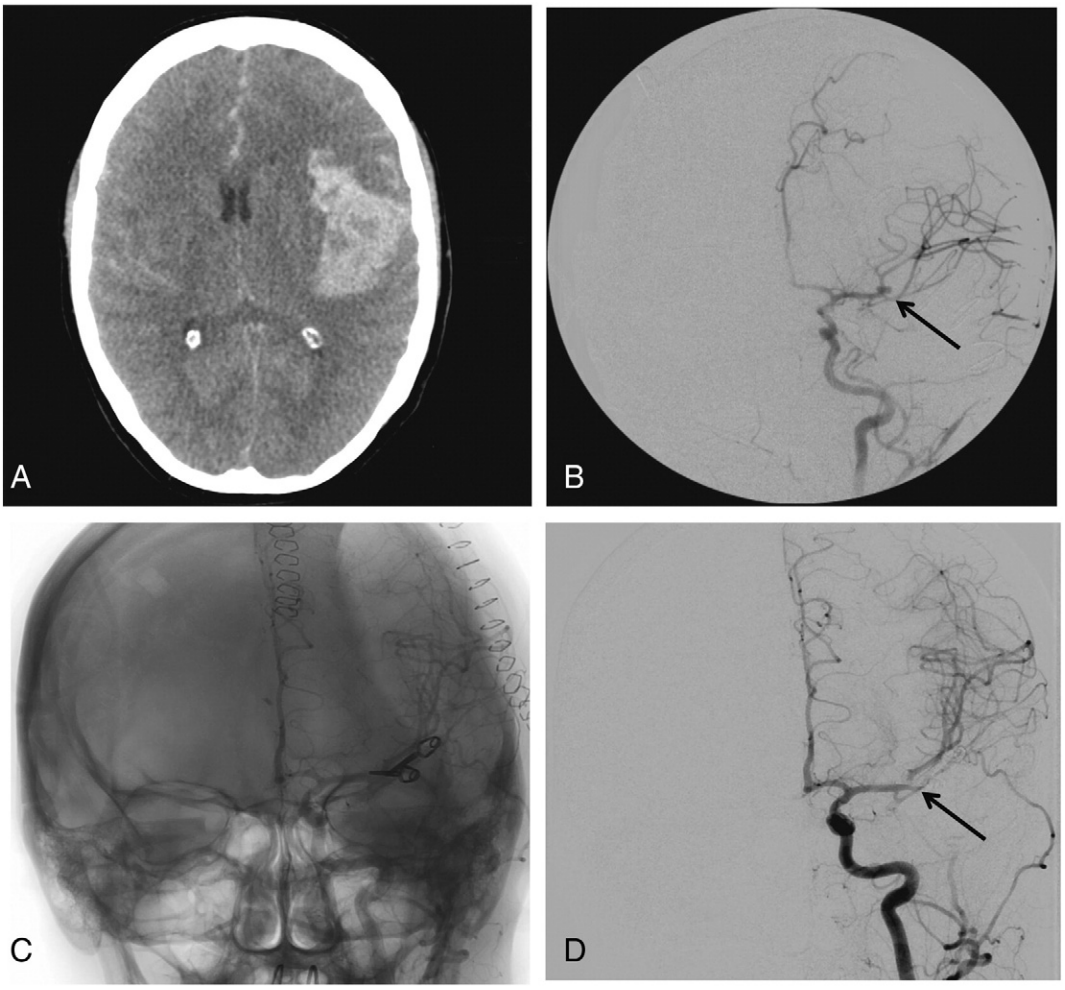

Fig. 1. Imaging studies for case 1. (A) The initial computed tomography (CT) scan showing a left temporal intracerebral hemorrhage (ICH) in coronal view, diffuse subarachnoid hemorrhage (SAH), and intraventricular hemorrhage (IVH). (B) The intraoperative diagnostic C-arm angiography demonstrating a bilobed aneurysm at the left middle cerebral artery (MCA) bifurcation, as indicated by the arrow in left anteroposterior view. (C) The post-operative digital subtraction angiography (DSA) (obtained with biplanar angiography 1 day postoperatively) showing the two aneurysm clips in anteroposterior view. (D) The subtracted view of post-operative catheter angiography (1 day postoperative) demonstrating no filling of the aneurysm, as indicated by the arrow in anteroposterior view.

aneurysm on postoperative day 1 (Fig. 1C and D). At one year, the patient has a right hemiparesis but requires minimal assistance with activities of daily living (Table 1).

Case 2

A 23-year old woman with a history of prescription drug abuse experienced a syncopal event. She was found to have a Glasgow Coma Score (GCS) of 3, pinpoint pupils, and decorticate posturing in ER. A head CT showed diffuse SAH with extensive right sylvian fissure ICH, IVH in the fourth ventricle, and diffuse cerebral edema. She then received an emergent decompressive hemicraniectomy. An intraoperative C-arm angiogram was performed, and a small, Spetzler Martin grade I AVM nidus fed by MCA branches was visualized in the insular region with drainage into the vein of Labbe (Fig. 2A). ICH evacuation then proceeded in the temporal lobe and a temporal lobectomy was performed. Dura-Guard was then placed as an onlay graft and the skin closed. Postoperatively, the patient's neurological exam remained poor. She expired after a 2-month hospital stay.

Case 3

A 23-year old male awoke in the morning with diaphoresis and several episodes of vomiting followed by a fall and loss of consciousness. In the ER, SAH with a large temporal ICH was identified on a head CT. The patient underwent an emergent left decompressive hemicraniectomy and ICH evacuation. The intraoperative C-arm angiography failed to demonstrate any aneurysms, AVMs, or fistulas (Fig. 2B). A repeat angiogram 3 days later revealed a partially thrombosed left giant fusiform MCA aneurysm, and the patient underwent surgical trapping of the aneurysm. Postoperatively, his condition improved significantly. At 1 month after the surgery, his neurological exam was mostly benign except left sided ptosis and blurry vision.

Case 4

A 47-year old woman with a history of cigarette smoking and heavy alcohol use was found unresponsive. On exam, she had GCS 3 T, dilated nonreactive pupils, and minimal cough and gag reflexes. A head CT demonstrated massive left hemispheric subdural hematoma (SDH)

Table 1
Summary of patient cases 1–5[a].

Patient	Age, gender	Initial presentation	CT findings	Suspected diagnosis for SAH	Intraoperative C-arm angiogram findings	Surgical procedures	Outcome	GOS[b]
1	42, F	Seizure, extensor posturing, dilated left pupil; H&H grade V SAH	Diffuse SAH, left temporal ICH with IVH and hydrocephalus	Left MCA aneurysm	3 mm bilobed left MCA bifurcation aneurysm	Left decompressive hemicraniectomy, left MCA aneurysm clipping	Requires minimal assistance, with right-sided hemiparesis and non-fluent aphasia 12-months after surgery	4
2	23, F	GCS 3 with pin point pupils, decorticate posturing; H&H grade V SAH	Diffuse SAH, extensive sylvian fissure ICH, IVH in the 4th ventricle, diffuse cerebral edema	Right MCA aneurysm	Right insular AVM nidus (Spetzler Martin grade I)	Right decompressive hemicraniectomy, ICH evacuation, AVM resection	Comatose, bacterial endocarditis from previous drug abuse, respiratory failure. Died after a 2-month hospital stay	1
3	23, M	Diaphoresis, vomiting, loss of consciousness; H&H grade IV SAH	Large right frontotemporal ICH	Left MCA aneurysm	No aneurysm, AVM, or fistula noted	Left decompressive hemicraniectomy, left frontal ICH evacuation; left craniotomy and distal MCA aneurysmal clipping 3 days post-initial surgery	Oriented and attentive, blurry vision and ptosis on the left side. Right hemiparesis 1 month after surgery	4
4	47, F	GCS 3 T with agonal breathing, unreactive dilated pupils, minimal cough and gag reflexes; H&H grade V SAH	Massive left subdural hematoma, a 4 cm left temporal ICH and associated IVH	left MCA bifurcation aneurysm	7 mm bilobed left MCA bifurcation aneurysm	Left decompressive hemicraniectomy, left MCA bifurcation aneurysm clipping, partial frontal and temporal lobectomy	Comatose with cough reflex, minimal movement in extremities 1 day after surgery. Died on the same day	1
5	43, F	GCS 3 T with dilated pupils and minimal brainstem reflexes; H&H grade V SAH	Large left frontotemporal ICH, extensive SAH and IVH	Left MCA bifurcation aneurysm	6 mm oblong left MCA bifurcation aneurysm	Left decompressive hemicraniectomy, temporal ICH evacuation, left MCA aneurysm clipping	Poor neurological response with cardiopulmonary failure. Died 2 weeks after surgery	1

[a] F, female; M, male; AVM, arteriovenous malformation; H&H, Hunt and Hess; ICH, intracerebral hemorrhage; IVH, intraventricular hemorrhage; MCA, middle cerebral artery; SAH, subarachnoid hemorrhage.
[b] Glasgow Outcome Scale (GOS): 1, death; 2, persistent vegetative state; 3, severe disability; 4, moderate disability; 5, low disability, assessed at the time of last follow-up.

with a 4 cm left temporal ICH and IVH. She received an emergent decompressive hemicraniectomy and evacuation of the SDH. An intraoperative C-arm angiogram demonstrated a left 7 mm MCA bifurcation aneurysm (Fig. 2C). Evacuation of the temporal hematoma and partial anterior temporal lobectomy were performed to prepare for the sylvian fissure dissection with subsequent aneurysm clipping. Patency of the distal MCA branches was demonstrated on intraoperative angiogram. Unfortunately, on post-operative day 1, she demonstrated trace brainstem reflexes and developed coagulopathy. She expired soon after.

Case 5

A 43-year old woman with a history of hypertension, IV drug use, and cigarette smoking experienced a sudden onset of headache. She then had a seizure and became unresponsive. On arrival to our institution, she had dilated pupils with minimal brainstem reflexes and a GCS of 3 T. A head CT demonstrated a large left frontotemporal ICH, extensive SAH, and IVH. She underwent an emergent decompressive hemicraniectomy. An intraoperative C-arm angiogram demonstrated a 6 mm left laterally projecting MCA bifurcation aneurysm (Fig. 2D). A corticectomy was performed in the anterior superior temporal gyrus to evacuate the ICH. The aneurysm was clipped utilizing temporary arterial occlusion of the distal M1. Patency of the distal MCA branches with aneurysm obliteration was demonstrated on a second intraoperative angiogram. Postoperatively, the patient continued to have a poor neurological examination with cardiopulmonary failure despite maximal medical therapy. She expired two weeks postoperatively.

Discussion

Fast and accurate localization of underlying vascular abnormalities is paramount in the preoperative workup for SAH patients. While DSA is the gold standard for aneurysm detection, a number of studies have documented the role of CTA as an adjunct or alternative method to DSA in the acute management of SAH patients [2]. In a recent meta-analysis, Menke et al. [2] concluded that CTA had an overall sensitivity of 97.2% and specificity of 97.9% in aneurysm detection. Further, the application of multisection CT scanner such as 64-section scanner has enabled 3D reconstruction with further shortened acquisition time [5]. Such findings have led to the practice where only CTA was used for pre-surgical planning in SAH cases [6].

However, replacing DSA with CTA in preoperative workup of SAH has not been straightforward. While the multisection CTA has excellent efficacy in identifying perimesencephalic bleed of SAH, it has higher false negative rate for diffuse aneurysmal SAH [7]. Also, aneurysms near the skull base, Pcom aneurysms, and small aneurysms are still more likely to be associated diagnostic errors with CTA, and these errors are operator rather than scanner-dependent [3]. Finally, the accuracy of CTA may be lower than previously reported [8].

In light of the challenges in the management of high grade SAH patients, our experience suggests that intraoperative C-arm angiography may provide a valuable strategy for the diagnostic workup of critically ill SAH patients with diffuse aneurysmal SAH. The use of intraoperative C-arm angiography in patients with high grade SAH decreased the time interval between the diagnostic imaging and urgent decompressive hemicraniectomy. It also facilitated intraoperative planning without a delayed standard biplane DSA.

Fig. 2. Intraoperative C-arm angiography for cases 2–5. (A) Intraoperative C-arm angiography for case 2 demonstrating a Spetzler Martin grade I arteriovenous malformation (AVM) nidus fed by middle cerebral artery (MCA) branches, as indicated by the arrow in right anterior oblique view. (B) The absence of aneurysm, arteriovenous malformation (AVM), or fistula in the intraoperative C-arm angiography for case 3 in left anteroposterior view. (C) Intraoperative C-arm angiography of case 4 demonstrating a left middle cerebral artery (MCA) bifurcation aneurysm, as indicated by the arrow in left anteroposterior view. (D) Intraoperative C-arm angiography of case 5 demonstrating an oblong left middle cerebral artery (MCA) bifurcation aneurysm projecting laterally, as indicated by the arrow in left posterior oblique view.

The diagnostic power of the intraoperative C-arm angiography is greatest when the laterality of the lesion is clearly demonstrated on the preoperative CT scan, as in case 1, where a left temporal hematoma was first visualized on the non-contrasted CT scan (Fig. 1A). However, in cases where the laterality of the lesion is ambiguous from the initial scan, the diagnostic and imaging quality of the intraoperative C-arm angiography can be compromised. This could be due to relatively restricted imaging angle, reduced resolution, and single plane imaging mode of the C-arm angiography compared to a standard biplane DSA. These factors may have contributed to the negative intraoperative diagnostic findings in case 3. If the patient were sufficiently stable, a repeat standard DSA would be utilized to delineate the anatomy of the underlying pathology and facilitate surgical planning and treatments.

Of note, Ayuzawa et al. [9] previously reported using intraoperative portable DSA in an emergent aneurysm surgery without preoperative angiography. Our study extended the applicability of such a strategy to critically ill patients with space-occupying hematomas caused by different cerebrovascular lesions such as aneurysms and AVMs. Further, this strategy of C-arm angiography is valuable and practicable especially considering the limited availability of hybrid operating rooms with both endovascular and microsurgical capabilities.

Conclusion

C-arm angiography is valuable in identifying vascular lesions intraoperatively to allow expedited decompressive procedures for high grade SAH. C-arm angiography combines the anatomical details attainable with DSA with a shortened acquisition time. These characteristics make it a reasonable alternative to CTA or standard biplane DSA in unstable patients with diffuse SAH when immediate surgical decompression is warranted. Due to the small number of patients in which this management algorithm has been utilized, it remains unclear whether this approach has any impact on the outcome for patients with high grade SAH. Further examination of more selected patients is necessary to elucidate any potential improvements this method may have on patient outcome.

References

[1] Cross III DT, Tirschwell DL, Clark MA, Tuden D, Derdeyn CP, Moran CJ, et al. Mortality rates after subarachnoid hemorrhage: variations according to hospital case volume in 18 states. J Neurosurg 2003;99:810–7.

[2] Menke J, Larsen J, Kallenberg K. Diagnosing cerebral aneurysms by computed tomographic angiography: meta-analysis. Ann Neurol 2011;69:646–54.

[3] Zhang H, Hou C, Zhou Z, Zhang H, Zhou G, Zhang G. Evaluating of small intracranial aneurysms by 64-detector CT angiography: a comparison with 3-dimensional rotation DSA or surgical findings. J Neuroimaging 2014;24:137–43.

[4] Colby GP, Coon AL, Sciubba DM, Bydon A, Gailloud P, Tamargo RJ. Intraoperative indocyanine green angiography for obliteration of a spinal dural arteriovenous fistula: case report. J Neurosurg Spine 2009;11:705–9.

[5] Goddard A, Tan G, Becker J. Computed tomography angiography for the detection and characterization of intra-cranial aneurysms: current status. Clin Radiol 2005;60:1221–36.

[6] Matsumoto M, Sato M, Nakano M, Endo Y, Watanabe Y, Sasaki T, et al. Three-dimensional computerized tomography angiography-guided surgery of acutely ruptured cerebral anuerysms. J Neurosurg 2001;94:718–27.

[7] Agid R, Andersson T, Almqvist H, Willinsky RA, Lee SK, terBrugge KG, et al. Negative CT angiography findings in patients with spontaneous subarachnoid hemorrhage: when is digital subtraction angiography still needed? AJNR Am J Neuroradiol 2010;31:696–705.

[8] Pradilla G, Wicks RT, Hadelsberg U, Gailloud P, Coon AL, Huang J, et al. Accuracy of computed tomography angiography in the diagnosis of intracranial aneurysms. World Neurosurg 2013;80:845–52.

[9] Ayuzawa S, Matsumura A, Nose T. Emergent aneurysmal surgery without preoperative angiography: usefulness of the intraoperative portable digital subtraction angiography. Surg Neurol 1993;40:251–4.