

Transpacific Aeromedical Evacuation for a Ruptured Brain Arteriovenous Malformation During the COVID-19 Pandemic

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ABSTRACT The COVID-19 pandemic has altered preexisting patient treatment algorithms and referral patterns, which has affected neurosurgical care worldwide. Brain arteriovenous malformations are complex vascular lesions that frequently present with intracerebral hemorrhage. Care for these patients is best performed at large medical centers by specialists with high volumes. The authors describe the care of a patient who presented *in extremis* to a resource-limited, community-sized military treatment facility (MTF) in Southeast Asia. In the MTF, the patient underwent emergent neurosurgical therapy. However, given newly implemented restrictions enacted to mitigate COVID-19 spread, local transfer for definitive care to a tertiary care facility was not possible. In order to attain definitive care for the patient, a transpacific aeromedical evacuation augmented with a critical care air transport team was utilized for transfer to a tertiary care, teaching hospital. This case demonstrates the safe treatment of a patient with hemorrhagic arteriovenous malformations and postoperative management under limited conditions in an MTF outside the CONUS. Given the unique circumstances and challenges the pandemic presented, the authors feel that this patient's outcome was only possible by leveraging all the capability military medicine has to offer.

INTRODUCTION

At the time of submission, greater than 52 million people have tested positive for COVID-19, and the disease has been implicated in more than 1,290,000 deaths worldwide.¹ Without any proven preventative medical treatment, such as vaccination, many countries and regions of the world have instituted mitigation strategies designed to minimize human interaction and, thus, transmission.

Several reports have suggested that these strategies have resulted in a degradation of contemporary medical care in various cardiac, neurological, and surgical conditions.^{2–5} Diminished elective services and patient reluctance to seek medical care are postulated as causes for decreased emergency visits related to non-COVID-19 diseases as well as greater severity of illness at the time of presentation.⁶ The COVID-19 pandemic has also affected the typical access to regional hospitals

and altered the ability for physicians to transfer patients to the tertiary care centers they previously used to augment care.⁷

Brain arteriovenous malformations (AVMs) are congenital lesions in 0.02% of the adult population. They commonly present with intracranial hemorrhage, seizure, or headache and have an annual hemorrhage rate of approximately 2% to 4%. Although the decision to treat unruptured AVMs may be nuanced secondary to somewhat controversial results of the randomized trial of unruptured brain AVMs,⁸ there is a general agreement that ruptured AVMs require treatment when lesions and patients are amenable.⁹ Treatment strategies require a multidisciplinary approach often including microsurgical resection, endovascular embolization, stereotactic radiosurgery, critical care medicine, and, most commonly, a combination of these services. Outcome and cost data demonstrate that these lesions are best treated at large-volume hospitals by specialists.¹⁰

With the concept of aeromedical transportation born in the days of World War I, the military has developed the highly sophisticated, critical care air transport team (CCATT) to perform complex medical care while patients are moved via aeromedical evacuation (AEROVAC) to support the modern warfighter.¹¹ This staple service of military medical transport ensures improved patient outcomes and rapid transport of patients with severe traumatic brain injuries in austere, far forward military treatment facilities (MTFs) to definitive, tertiary care centers.^{12,13} Military surgeons in forward deployed, less-resourced MTFs must often consider alternative, “next-best” therapy for their patients.^{14,15}

This case report describes the multiple obstacles our patients must overcome to obtain medical care and what our physicians must do to deliver it in the setting of the COVID-19

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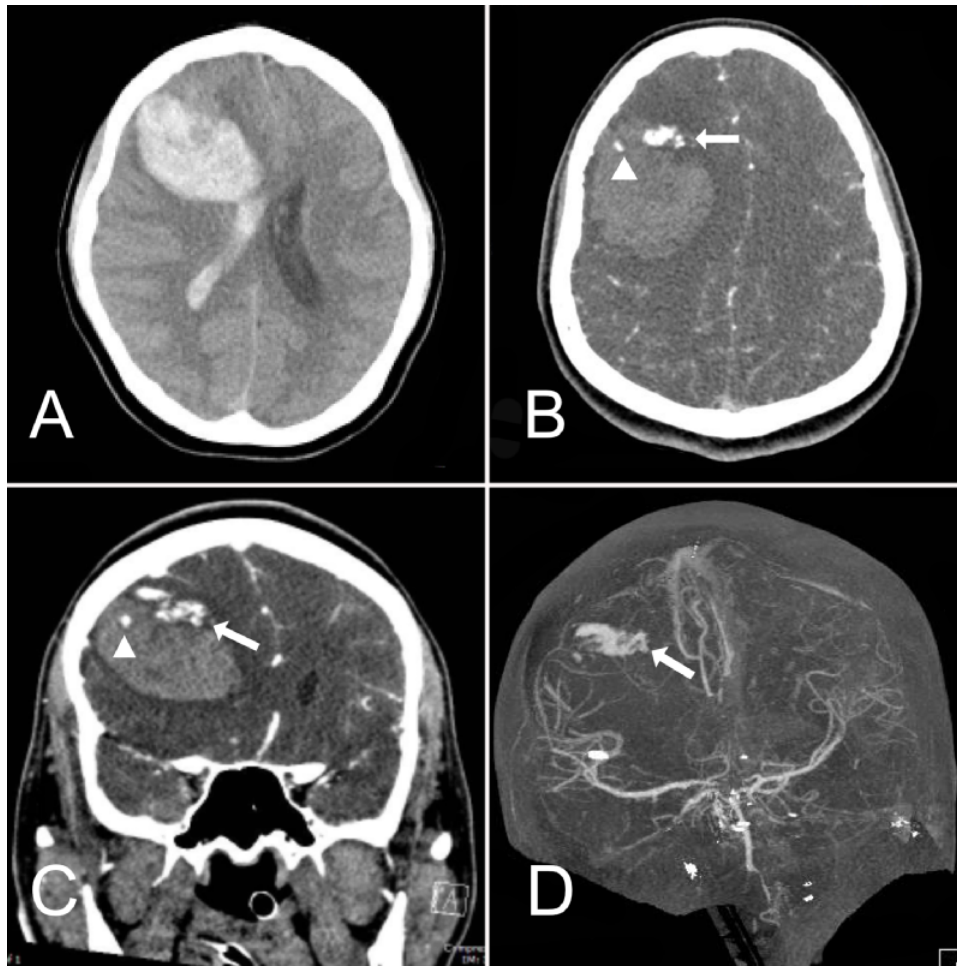


FIGURE 1. Preoperative imaging. A noncontrast head CT (A) demonstrates a large right frontal hematoma with extension into the right lateral ventricle. CTA axial (B), coronal (C), and 3D (D) reconstructions demonstrate the expanding hematoma, a radiographic “spot sign” (white arrowheads), and brain AVM nidus (white arrows). AVM, arteriovenous malformation; CTA, computed tomography angiography.

pandemic. Additionally, it demonstrates the inimitable agility of the military medical system, which is capable of performing staged, yet superlative care in a vast array of medical environments.

CASE REPORT

History and Physical Examination

A 27-year-old previously healthy female presented to a community-sized MTF in the Southeast Pacific with altered mental status after collapsing in front of her husband. She experienced a new onset “sinus headache” for 6 days before the abrupt decline. Computed tomography of the head demonstrated a 45-mL intracerebral hemorrhage (ICH; Fig. 1A). Thirty minutes later, a computed tomography angiography (CTA) demonstrated that the ICH had expanded to 83 mL, with an associated radiographic “spot sign,” and a Spetzler-Martin Grade II AVM as the source of hemorrhage (Fig. 1B, 1C, and 1D). The patient was found *in extremis* nonverbal, with equal

pupils, and only withdrawing to pain in the right upper and lower extremities.

Emergent Surgical Treatment

The patient was taken emergently to the operating room where she underwent a right fronto-temporo-parietal craniotomy, evacuation of the hematoma, microsurgical resection of the AVM, and placement of an external ventricular drain (EVD; Fig. 2A and 2B). Owing to the lack of endovascular capability at the MTF, a CTA was performed immediately after surgery, which demonstrated no residual AVM nidus (Fig. 2C and 2D). The patient remained neurologically stable, but continued to require critical care support.

Postoperative Course

While a common practice before the COVID-19 pandemic, a local transfer to the host-nation tertiary care hospital was unable to be performed secondary to mitigation strategies preventing lateral patient transfers. On hospital day 3, the

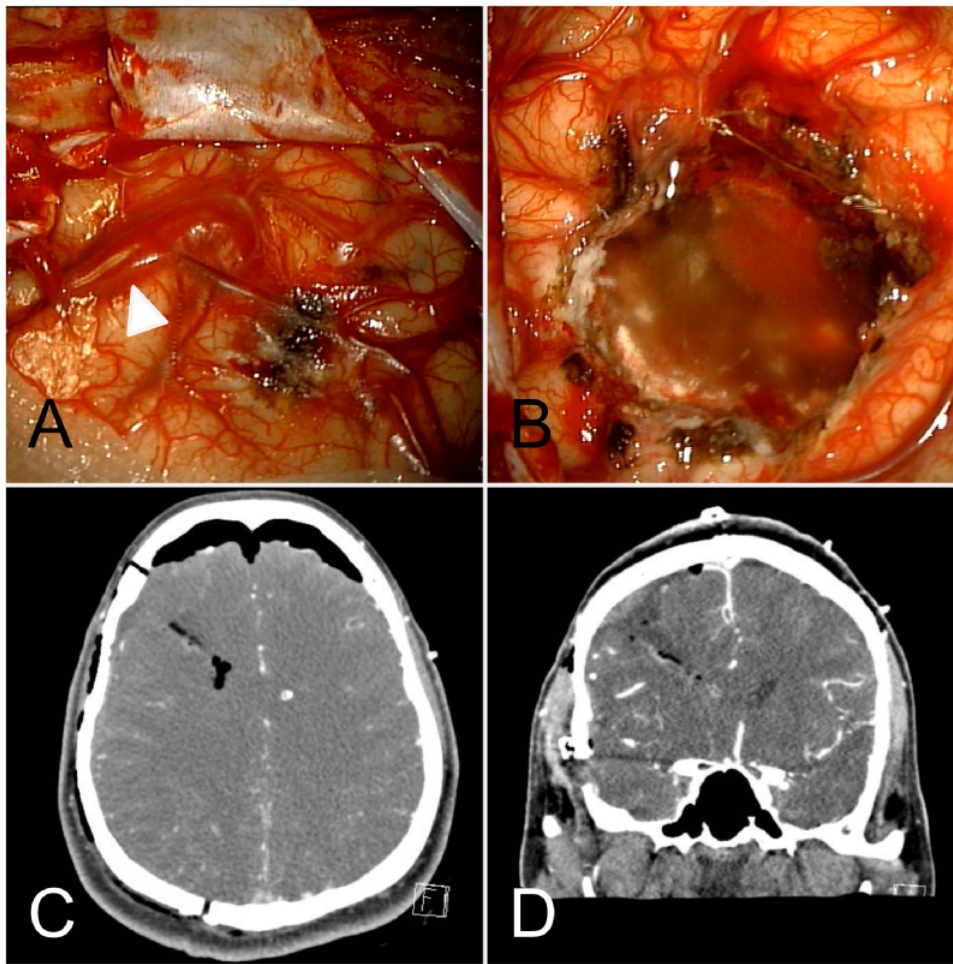


FIGURE 2. Intraoperative and postoperative imaging. Intraoperative images demonstrate the AVM (A) with an arterIALIZED draining vein (white arrowhead) and successful resection with the cavity filled with saline (B). Postoperative CTa axial (C) and coronal (D) reconstructions demonstrate no residual AVM or complicating features of surgery. AVM, arteriovenous malformation; CTa, computed tomography angiography.

patient was stable without any evidence of progressive cerebral edema or recurrent hemorrhage. The CCATT was mobilized, and the patient was transported in a government aircraft via a transpacific AEROVAC to a CONUS tertiary care MTF 3 days after surgery. The transfer required 16 hours of flight time. The CCATT team treated fluctuating intracranial pressure with CSF drainage from the previously placed EVD and optimized her ventilatory status *en route*.

Upon arrival to the receiving MTF, a catheter-based digital subtraction angiogram (DSA) was performed confirming no residual AVM nidus (Fig. 3). Her EVD was removed on hospital day 7 and was transferred out of the ICU for further rehabilitation. At 2 months after surgery, the patient was living independently with her family and demonstrated a near-full neurological recovery.

DISCUSSION

Contemporary neurosurgery has never faced the obstacles that the COVID-19 pandemic presents to our patients and surgeons. There has been a dramatic reduction in elective surgical

services and in some regions of the world a realignment of hospital services where specialty care is not performed to centralize patients with or suspected of having COVID-19.^{7,16} Additionally, many have suggested “collateral damage” of the COVID-19 pandemic, where mitigation strategies, decreased patient movement, and delayed presentation to the hospital have resulted in a decrement of patient care and worse outcomes for unrelated medical conditions.^{3–5,17}

This case illustrates several challenges to medical care during this time. Initially, it may represent a delay in seeking medical care because of conscious or latent trepidation that was driven by COVID-19.³ Before her decline, our patient voiced concerns about pursuing hospital care for the new onset headache, because of perceived limitations in treating patients other than those with COVID-19. In general, AVMs do not typically have high risk of recurrent hemorrhage in a short period¹⁸; however, she developed new hemorrhage from the 30-minute interval of presentation to the time of CTa. Given the right frontal location of this AVM and ICH, it is possible that she had an ictus of a smaller, neurologically “silent”

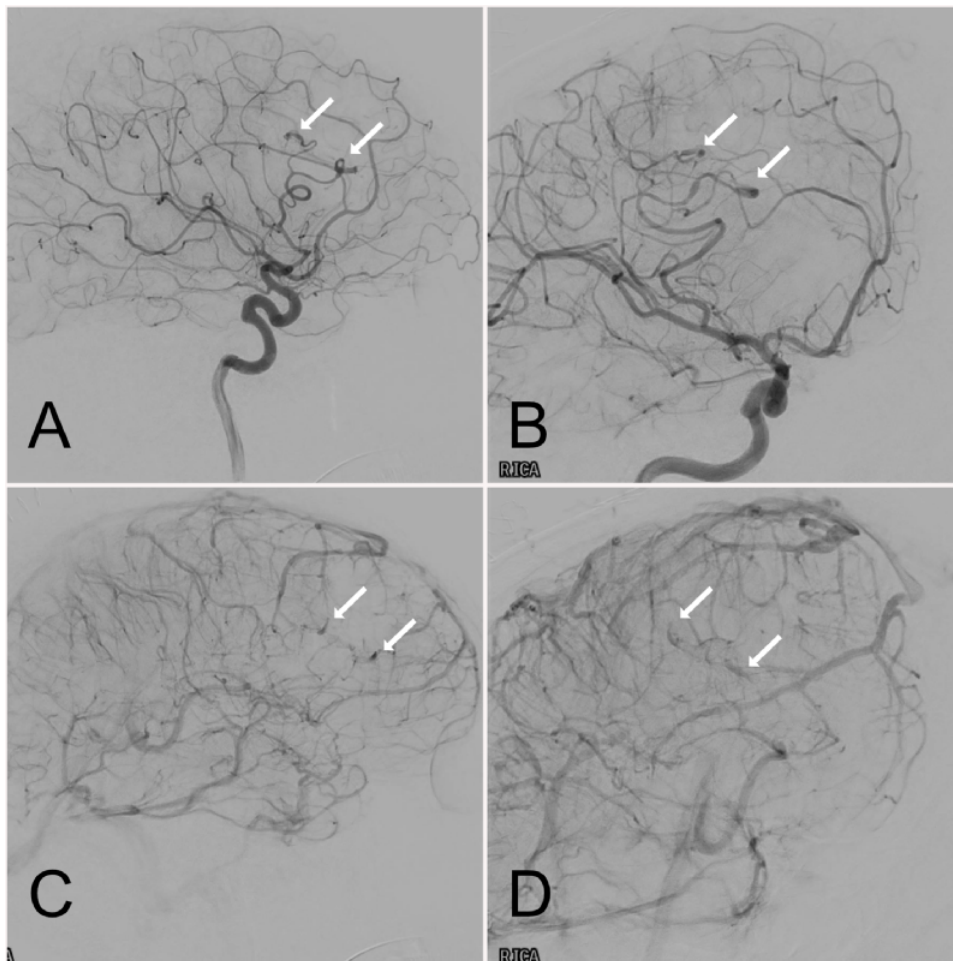


FIGURE 3. Cerebral DSA. Postoperative DSA performed 5 days after surgery. AP (A) and oblique (B) mid-arterial and early-venous (C and D) imaging demonstrates no evidence of early draining vein or AVM nidus with stagnant flow in two large arterial feeding vessels (white arrows). AVM, arteriovenous malformation; DSA, digital subtraction angiography.

ICH not large enough to cause altered mental status until re-hemorrhage occurred.

Although successful emergent surgical treatment was performed at a community-sized MTF, ordinarily this patient would have been transferred to a host-nation tertiary care, university hospital with cogent cerebrovascular and critical care services. At the time of presentation, our host-nation colleagues were unable to accept such patients as a hospital mandate to decline in an effort to mitigate the virus spread. Also, DSA is the gold standard for postoperative assessment for inspection of residual AVM after microsurgery.^{9,19} Secondary to restrictions in patient movement and lack of DSA at our MTF, postoperative decision-making was based on a helical CTa.

Predicting a long recovery and the need for ongoing critical care services, it was clear that the patient would require transfer to a tertiary care hospital for definitive treatment. Uniquely capable to leverage patient transport with CCATT, we arranged a transpacific AEROVAC to such a facility in the CONUS. While CCATT has a long history in AEROVAC

for injuries sustained in the battlefield,¹¹⁻¹³ these incredibly skilled teams are capable of treating many critical conditions. This case demonstrates that superlative outcomes can be achieved for complex surgical problems across continents by utilizing CCATT capabilities, which were previously limited to combatant casualty injuries.

CONCLUSION

This case represents a modification and adaptability of military resources as a result of the COVID-19 pandemic. Although a positive outcome in this case, we hope this demonstration remains unique and does not represent a commonplace practice, where patients are subjected to such extraordinary measures. However, if restrictions persist or similar limitations resurface, this case will serve as a template for success in suboptimal conditions.

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CONFLICT OF INTEREST STATEMENT

None declared.

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