Article published online: 2024-09-19

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Case Report

Successful Microsurgical Clipping under Extracorporeal Membrane Oxygenation Treatment for a Poor-Grade Subarachnoid Hemorrhage Patient with Severe Pulmonary Neurogenic Lung

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Asian J Neurosurg

Abstract

Hemorrhagic strokes are considered as contraindications of extracorporeal membrane oxygenation (ECMO) therapy because of anticoagulant administration and ECMO-associated coagulopathy. We present a rare case of successful microsurgical clipping under ECMO for a poor-grade subarachnoid hemorrhage (SAH) patient with severe neurogenic pulmonary edema (NPE). A 50-year-old man presenting with the sudden loss of consciousness was diagnosed with poor-grade SAH with severe NPE, and was intubated. Because of severe hypoxemia refractory to conventional treatment, veno-venous ECMO was used 6 hours after admission. To avoid thrombosis inside the ECMO circuit despite no anticoagulants, a heparin-bonded ECMO was maintained at a comparatively high blood flow rate. Subsequently, the patient underwent a microsurgical clipping under ECMO. Intraoperatively we had difficulty in bleeding control, and therefore the multiple transfusions were necessary to correct anemia and ECMO-associated coagulopathy. The aneurysmal clipping was accomplished without hemorrhagic intracranial complications. After 2 years from onset, his activities of daily life were independent. To our knowledge, this is the first report of successful microsurgical clipping for poor-grade SAH under ECMO without any anticoagulants. The use of a heparin-bonded ECMO tubing, maintenance of a slightly higher ECMO pump speed, and multiple transfusions to correct ECMO-associated coagulopathy could make the micro-neurosurgical procedures under ECMO possible. This report demonstrated the possibility to extend the range of application of microsurgical clipping for poor-grade SAH patients requiring ECMO treatment.

Keywords

- ECMO-associated coagulopathy
- extracorporeal membrane oxygenation
- heparin-free ECMO
- microsurgical aneurysmal clipping
- pulmonary neurogenic lung
- subarachnoid hemorrhage

DOI https://doi.org/10.1055/s-0044-1791189.
ISSN 2248-9614.

Thieme Medical and Scientific Publishers Pvt. Ltd., A-12, 2nd Floor, Sector 2, Noida-201301 UP, India

Introduction

In the acute neurocritical care region, extracorporeal membrane oxygenation (ECMO) has been thought to be of limited use due to the concomitant need for anticoagulation.[1–3] Thus, the accumulation of clinical evidence about ECMO management in the neurosurgical intervention is essential. Here, we present a successful case of microsurgical aneurysmal clipping during venovenous ECMO for World Federation of Neurological Societies (WFNS) grade V subarachnoid hemorrhage (SAH) with severe neurogenic pulmonary edema (NPE).

Case Presentation

A 50-year-old man was admitted to our hospital due to sudden loss of consciousness. His vital signs were as follows: blood pressure 80/58 mm Hg, heart rate 65 beats/min, and oxygen saturation 85% under 10 L/min oxygen in a reservoir mask. A chest computed tomography (CT; ►**Fig. 1a**) and an echocardiography revealed an NPE and a stress-induced cardiomyopathy, and the patient was intubated. Head CT and CT angiography (►**Fig. 1b, c**) showed SAH with multiple aneurysms. Because of poor clinical course at admission, this patient was diagnosed as WFNS grade V SAH. Owing to the aneurysmal size, shape, and location, microsurgical clipping was considered to be preferable to endovascular treatment, which is the preferred treatment in serious systemic conditions. Repeated arterial blood gas analyses showed severe hypoxemia refractory to conventional treatment. Therefore, we initiated venovenous ECMO (►**Fig. 2**). To avoid thrombosis inside the ECMO circuit despite no anticoagulants, a heparin-bonded ECMO was maintained at a comparatively high flow rate (4.2 L/min). Gradually, low blood pressure improved without vasopressor administration. On day 3, we decided to perform a microsurgical clipping on ECMO. Intraoperatively we had difficulty in bleeding control because of low platelet count, and a very bloody surgical field led to poor vision of the microscope (►**Fig. 3a**). After the transfusion of 6 units red blood cells and 20 units platelets to correct anemia and coagulopathy, we managed to apply clips for all the aneurysms (►**Fig. 3b**). Intraoperative blood loss was approximately 640 mL. Postoperatively ECMO weaning was successful. The patient was doing well except for lenticulostriate artery (LSA) infarction (►**Fig. 3c**). After 2 years from onset, his neurological examination showed only a slight hemiparesis. His activities of daily life were independent (modified ranking scale 1).

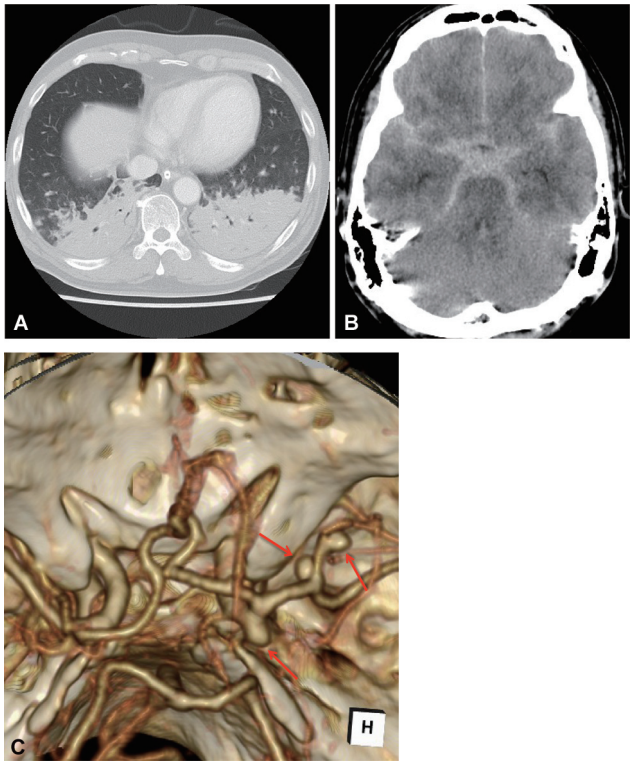

Fig. 1 (**A**) Chest computed tomography (CT) on admission shows neurogenic pulmonary edema in both lungs. (**B**) Head CT and (**C**) CT angiography on admission show diffuse subarachnoid hemorrhage and an anterior choroidal artery aneurysm and two middle cerebral artery aneurysms (*red arrows*).

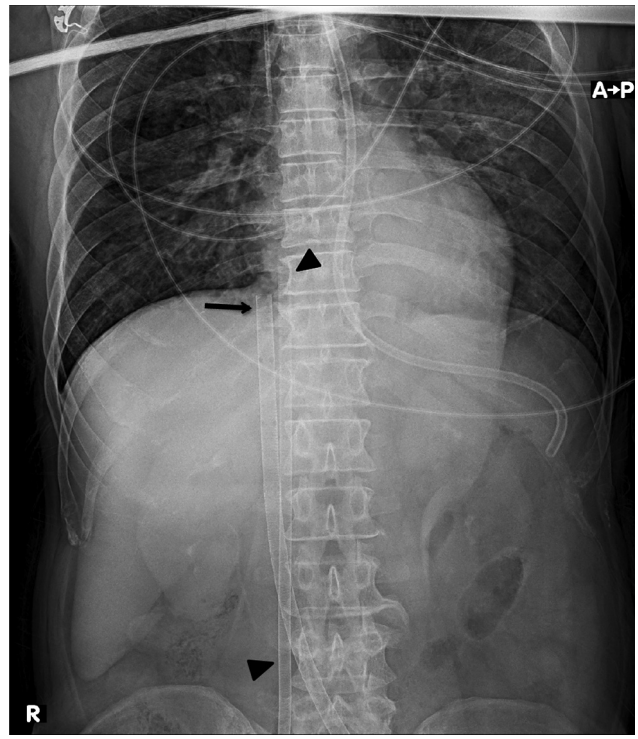

Fig. 2 Chest X-ray after the extracorporeal membrane oxygenation cannulation shows two single lumen cannulas, draining from the inferior vena cava (IVC) and reinfusing into the IVC/right atrium. The *black arrow* shows the tip of the draining venous cannula, and the *two black arrowheads* show the reinfusion cannula.

Discussion

Although ECMO can be a last-resort treatment for patients with severe acute respiratory failure, neurosurgical interventions are generally considered contraindications for ECMO therapy because ECMO may increase additional neurological injuries such as intracranial hemorrhage and ischemic stroke.[4–6] In particular, the use of systemic

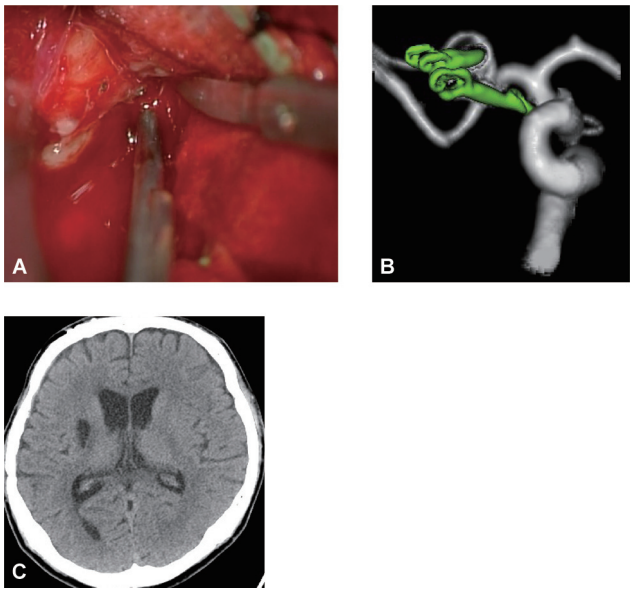

Fig. 3 (**A**) An intraoperative photograph during the dissection of sylvian fissure shows very bloody surgical field and poor vision of the microscope. (**B**) The anteroposterior view of postoperative computed tomography angiography shows complete neck clipping. (**C**) A head computed tomography performed 1 month after the operation shows a right lenticulostriate artery infarction.

anticoagulation and impaired hemostasis due to platelet consumption and its dysfunction during ECMO can increase intracranial hemorrhagic complication. Thus, avoiding systemic anticoagulation and considering platelet transfusion are desirable when neurosurgical interventions are performed for intracranial hemorrhagic patients on ECMO.

The recent improvements in ECMO devices may make the use of heparin-free ECMO possible.[1,6,7] Arlt et al[8] reported that heparin-free ECMO could be a safe alternate rescue treatment in patients with severe trauma and hemorrhagic shock. Faulkner et al[1] also reported the successful utilization of venovenous ECMO for severe respiratory failure secondary to aneurysmal SAH after endovascular coiling. To reduce the risk of clot formation in the oxygenator and venous thromboembolism even without any anticoagulants, they used short lengths of heparin-bonded venovenous ECMO tubing and maintained the venovenous ECMO pump speed at a slightly higher-than-normal speed for increased flow throughout the ECMO circuit.[1] However, most of such successful reports about the utilization of ECMO in the acute neurocritical care region were dominantly limited to macro-neurosurgical interventions and postmicrosurgical management.[1,9,10] There was an extremely rare report of a successful microsurgical intervention under ECMO.

According to our literature review, Hwang et al[11] were the first to report successful aneurysmal clipping under ECMO by using nafamostat mesylate alternatively as a regional anticoagulant for an SAH patient with NPE. To our knowledge, the present case is the first report of successful microsurgical clipping for SAH during ECMO without any anticoagulants.

Preoperative management should begin with a critical evaluation of whether the patient can be weaned from ECMO prior to the cerebral aneurysm surgery. If weaning from ECMO is possible, careful attention to ECMO-associated coagulopathy is not needed and, therefore, surgery can be performed under standard general anesthesia management for cerebral aneurysmal clipping surgery. The next step is to determine the feasibility of endovascular treatment. If ECMO weaning is not possible and the ruptured cerebral aneurysm can be fully treatable with the endovascular treatment, this approach is preferable to the direct surgery. In the cases where direct surgery is unavoidable, it is crucial to plan a preoperative simulation so that the surgical procedures can be conducted minimally invasively in the shortest possible time.

According to the Extracorporeal Life Support Organization (ELSO) guidelines,[12] relevant literature,[13] and our experience with this case, intraoperative management by anesthesiologists should include red blood cell transfusion to maintain hemoglobin levels between 7 and 9 g/dL. Platelet transfusions should be administered based on the extent of intraoperative bleeding; however, it is essential to maintain a platelet count above 100,000/μL to avoid a bloody surgical field, especially during microscopic procedures. Fresh frozen plasma transfusion is recommended to maintain fibrinogen levels between 250 and 300 mg/dL. For neurosurgeons, the primary focus during surgery must be on meticulous bleeding control. In the direct surgery for ruptured middle cerebral artery aneurysms like the present case, a distal sylvian approach should be selected whenever possible, because the extent of microsurgical dissection is minimally required. In addition, proximal control should be achieved with minimal exposure of the M1 segment for the application of a temporary clip. If the surgical field becomes bloody, timely replacement of platelets and coagulation factors is essential, along with precise bipolar coagulation and the use of suitable hemostatic agents. In the present case, the bipolar coagulation in a bloody surgical field during M1 exposure may have contributed to LSA infarction. Among hemostatic agents, a topical gelatin-thrombin hemostatic matrix such as FLOSEAL appears to be particularly effective. Literature[14] supports FLOSEAL's efficacy in achieving hemostasis, especially in cases of diffuse bleeding or when bleeding points are difficult to identify. FLOSEAL's effectiveness has been demonstrated even in patients under heparinization.[15] Such a hemostatic agent is likely well suited for use in microsurgical procedures for patients with bleeding tendencies on ECMO.

Conclusion

The use of a heparin-bonded ECMO tubing, maintenance of a slightly higher ECMO pump speed, and preparation of enough platelet transfusion to correct coagulopathy are essential to perform a safe and precise microsurgical procedure for SAH patients on ECMO without any anticoagulants. This report demonstrated the possibility to extend the range of application of microsurgical clipping for poor-grade SAH patients requiring ECMO treatment.

Authors' Contributions

K.S. was responsible for conceptualization, formal analysis, project administration, visualization, writing the original draft, writing, review, and editing of manuscript. Data curation was done by K.S. and S.I. Methodology was developed by K.S., T.M., K.M., J.I., and M.N.

Funding

None.

Conflict of Interest

None declared.

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