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Acute Spinal Cord Ischemia: Treatment with Intravenous and Intra-Arterial Thrombolysis, Hyperbaric Oxygen and Hypothermia

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A 58-year-old man with a medical history of hypertension and hepatocellular carcinoma status after liver transplantation 2 years previously developed head and neck pain. Computed tomography (CT) revealed a contrast enhancing C₂ vertebral body metastasis. The highly vascular lesion was embolized prior to surgical resection to minimize surgical complications. The diagnostic angiogram revealed a hypervascular lesion fed by the artery of C₁, C₂ and C₃ of the nondominant right vertebral artery (VA; fig. 1). The artery of cervical enlargement feeding the anterior spinal artery was identified at the level of C₅. Prior to the VA take-down, a balloon test occlusion was performed without any adverse events. Coil embolization from C₁ to C₂, followed by xylocaine testing and mannitol/polyvinyl alcohol 250–350 µm embolization of the hypervascular lesion at C₂ was done. Subsequently, coil embolization for VA take-down was performed to the level of C₃.

The procedure was completed uneventfully, and the patient returned to the neurological intensive-care unit for monitoring. Lovenox 40 mg as subcutaneous injections twice daily was started. Approximately 6 h after the procedure, he developed left-sided numbness and right-sided severe weakness (0 out of 5 on the motor deficit score). Sensory examination revealed decreased pinprick and temperature sensation on the left side of his body with a new sensory level around the C_{4–5} area. A noncontrast CT scan of the head and cervical spine was negative for bleeding. The patient received thrombolysis with 25 mg (2/3 of total 0.9 mg/kg body weight) of intravenous tissue plasminogen activator (tPA) within 90 min of the symptom onset. Emergent angiography revealed near total occlusion of the right VA at the level just proximal to the artery of cervical enlargement, which was the area of prior guide-catheter-induced vasospasm (fig. 2A). Successful clot lysis was achieved with 10 mg intra-arterial tPA within 150 min of the onset of symptoms (fig. 2B). After the procedure, MRI of the head and neck was performed (fig. 3, 4). The patient had minimal improvement of the right arm, but the right leg was still densely paretic. Hyperbaric oxygen (HBO) treatment was given for 90 min within 6 h of the onset of symptoms (monoplace chamber without face mask, FiO₂ = 1.0, chamber pressure = 2 atm). Immediately after HBO treatment, the patient demonstrated a sig-

nificant improvement in motor function (3 out of 5 on the motor deficit score on the right upper extremity and 2 out of 5 on the right lower extremity). MRI with diffusion-weighted image showed a restricted diffusion in the right-sided anterolateral spinal cord (fig. 5). Because of the immediate clinical improvement after the first treatment, the patient received the second HBO treatment in 12 h but did not have further improvement after the second treatment. Starting 24 h after the onset of symptoms, the patient then received induced hypothermia for 24 h using a surface-cooling device (Arctic Sun, Medivance Inc.). The target temperature was set at 33°C. Shivering was treated with intravenous dexmedetomidine, magnesium and propofol sedation. Passive re-warming was performed at a rate of 0.2°C/h after 24 h of hypothermia. After cooling, the patient was noted to have a significant neurological improvement in strength on the right side as well as his sensory deficit on the left side of his body. His motor scale improved to 4 out of 5 on both right upper and lower extremities. The sensory deficit completely disappeared, and he was able to feel both pinprick and temperature sensations. Three weeks later, he was able to walk without assistance and regained all of his strength in his right arm with minimal residual weakness in his right leg. There was no sensory deficit to any sensory modalities on either side of his body.

Discussion

Acute ischemic injuries to the spinal cord often lead to devastating outcomes [1, 2]. The etiology of the injuries remains heterogeneous including but not confined to thromboembolic events, aortic dissection, mechanical injury and trauma. Intravenous tPA remains to be the only proven therapy to improve the long-term outcome of acute ischemic stroke if administered within 3 h after symptom onset [3]. A recent randomized controlled trial revealed that the positive effect of improving the long-term outcome may be seen even up to 4.5 h [4]. In the Prolyse in Acute Cerebral Thromboembolism trial, intra-arterial pro-urokinase infusion therapy has shown promising results in terms of enhanced recanalization rates [5]. In both animal and human models, HBO therapy has sporadically demonstrated a decrease in the size of infarcts [6]. The positive effect was not consistent, and a recent randomized trial showed disappointing results with no improved outcome after the use of HBO in acute ischemic stroke [7]. Animal data suggest that the benefit conferred by HBO treatment was lost after 4 h since the time of artery occlusion [8]. The current literature provides limited information, however, as the studies were done with relatively small sample sizes and variable times from symptom onset to treatment. Hypothermia has been shown to improve outcomes after cardiac arrest and the neuroprotective effect in animal models after acute ischemic injuries [9, 10]. The exact mechanism of how hypothermia may provide a neuroprotective effect is not clear. From the animal models, it has been suggested that hypothermia may suppress excitatory synaptic transmission and reduce neuronal injury [11, 12].

Fig. 1. **A** Right vertebral angiography showing brisk contrast filling into the hypervascular tumor fed by the vertebral artery at C₂ and C₃ (white arrows). **B** Artery of cervical enlargement (white arrow) at C₅ level feeding anterior spinal artery (dark arrows). **C** Partial coil embolization with guide catheter in place for xylocaine testing and polyvinyl alcohol/mannitol embolization (white arrow). **D** Successful coil embolization of right VA (white arrowheads) with catheter-induced vasospasm (dark arrows).

Our patient underwent an extensive coil embolization and take-down of the right VA to minimize local tumor vasculature prior to resection. Despite anticoagulation, he experienced acute thrombus formation at the proximal site of the coil mass followed by cord ischemia. Given the poor natural history of this lesion, the decision was made to treat the patient aggressively using multiple treatment modalities. This included intravenous and intra-arterial thrombolysis, repeated HBO treatment and induced therapeutic hypothermia for 24 h. The patient showed clinical improvement after each of these treatments. Therefore, it is not clear which of these interventions was responsible for the final positive

outcome. It is possible that the effect of thrombolysis was sustained without any unwanted reperfusion injury due to the neuroprotective effect provided synergistically by both HBO and hypothermia. Although gradual improvement occurred after each intervention, it is possible that our patient could have improved without any of these interventions. Given the historically poor outcomes associated with spinal cord infarction, a multimodality approach based on intravenous and intra-arterial thrombolysis, HBO therapy and hypothermia appears to be feasible and deserves further investigations.

Fig. 2. A Right vertebral angiography reveals occlusion (arrowheads) of the VA from C₆ and beyond including the area of the take-off of the artery of cervical enlargement. **B** Successful recanalization (arrowheads) of right VA with intra-arterial rtPA.

Fig. 3. Diffusion-weighted image of the cervical spinal cord at C₂. There is an increased signal on the right side of the spinal cord.

Fig. 4. Apparent diffusion coefficient of the cervical spinal cord at C₂. There is an abnormally low signal on the right side corresponding to the lesion seen by abnormal diffusion-weighted imaging.

Fig. 5. MRI with diffusion-weighted imaging after hyperbaric chamber treatment. The diffusion-weighted signal abnormality is now mildly decreased in size and intensity.

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